INTEGRATING RIPARIAN ZONES WITH RIGHTOFWAY MANAGEMENT

by

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Abstract

This study tests the applicability of using an Integrated Resource Management (IRM) strategy for more effectively managing riparian zones along electric transmission Rightofways (ROWs). A literature search revealed that while there is an extensive body of information about the importance of riparian zones in creating and maintain aquatic habitat, there has been no research conducted on the effects of transmission powerline vegetation management on riparian zones in British Columbia (BC). Further, an apparent management contradiction exists because electric utilities traditionally manage vegetation on ROWs by cutting all tall trees, whereas in most other situations, tall growing riparian communities are being preserved or restored. In response to this the primary research question for this study is "Is it possible for riparian zone function to be integrated with current vegetation management practices along electric transmission ROWs in BC?"

To investigate the problem 12 separate sites across the BC Hydro transmission facility were studied. Variables were selected as indicators of four separate, but functionally related riparian ecosystem functions; energy flow, stream hydrology, bank stability and habitat complexity. Site data was collected, processed and then each case was described and evaluated independently before trends were compared between sites. Vegetation management practices were investigated by reviewing BC Hydro's documents and by conducting guided interviews with BC Hydro staff. Trends between ecosystem function and vegetation management activities were then compared to the literature to complete analysis.

The key findings of the study are that traditional vegetation maintenance activities appear to have mixed, site sensitive impacts on the riparian ecosystem functions studied. BC Hydro is implementing a management process designed to integrate site specific issues and varied technical information into workplans. As a result, most of the conditions necessary for integrating riparian function with electric transmission ROWs maintenance are present in BC. Recommendations are provided which describe the remaining conditions necessary for a successful IRM approach to this issue. Hence, the project links IRM theory to a case study example and describes a set of parameters necessary to more effectively manage riparian zones along electric transmission corridors.

Table of Contents

List of Tables

List of Figures

List of Photographs

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CHAPTER 1
Introducing the Issues

1.0 Introduction

Natural resource management has traditionally involved extracting raw resources or target populations while minimizing, when possible, impacts to the natural environment. Most often the management goal was applied within a static framework and simply involved maximizing extraction without crippling the natural environment system's ability to keep providing the required resources. With increasing recognition and understanding of the dynamic interdependent linkages within natural systems, resource managers are now being pressured to explicitly manage for all components of a natural system (Mitchell, 1990). This can often include trying to integrate and set appropriate goals for complex, and at times, conflicting issues and scenarios. More research is necessary to aid in establishing processes that help create broader holistic resource management goals, objectives and techniques. New management approaches are needed that help integrate biophysical and anthropogenic issues that often change over both time and space.

This project contributes to the body knowledge by assessing the applicability of using an Integrated Resource Management (IRM) strategy for more effectively managing environmentally sensitive areas that are also critically important to a resource-based industry. In this case, the function of riparian zones along electric transmission Rightofways (ROWs) is examined as the unit of study. Applied research is used to explore the impact of ROW maintenance on the functioning of riparian zones, a topic that has largely been overlooked.

The principal research problem of this project is to determine if it is possible to integrate riparian zone function with current vegetation management practices along electric transmission ROWs in British Columbia (BC). The research goal was accomplished by investigating four secondary questions: What are the current maintenance techniques for riparian zones along electric transmission ROWs and what are their effects on key ecosystem functions? What are the constraints to managing for riparian values along ROWs? What are the opportunities for managing for riparian values along ROWs? What recommendations can be made concerning integrating riparian zone health with ROW vegetation management strategies? The answers to these questions may provide guidance to future management strategies on electric transmission ROWs.

BC Hydro is British Columbia's major electricity provider and generates over 90% of its nameplate capacity at large hydroelectric facilities located far from heavily populated areas. Its transmission system is composed of a mix of high and extra high voltage powerlines ranging from 69kv to 500kv. The extensive transmission powerline and corridor system is approximately 17,000 km long, ranges in width between 15 and 300 m, and traverses some of the most rugged topography found in North America (BC Hydro 1997B).

The corporation has always maintained its large transmission system with a single resource management goal to provide "safe, efficient and reliable delivery of power from generating stations to customers" (BC Hydro, 1997). As a result, management attention has been on methods of guaranteeing vegetation remain a prescribed distance away from the overhead powerlines (BC Hydro, 1997). Existing vegetation control techniques have allowed BC Hydro to maintain a nearly uninterrupted flow of power.

In conjunction with public opinion and regulatory changes, research suggests corporations should shift from maximizing short term financial returns to addressing longer term economic and societal expectations (Alpert, 1995). Similarly, recognition has grown within BC Hydro, and the utility industry as a whole, that resource management practices must change (Breece and Ward, 1996; Yeager, 1996; BC Hydro, 1997). BC Hydro's most recent vegetation management manual (1997) reflects this increased awareness and states its new vegetation management strategy (p.1.1):

> One of BC Hydro's objectives is to ensure the safe, secure and efficient supply of electricity for its customers, while protecting public safety. At the same time, BC Hydro's corporate policy emphasizes minimizing adverse effects on the natural environment and promoting sustainable development to meet the needs of the present, without jeopardizing the ability of future generations to meet their needs.

Riparian zones are one of the natural environments present on BC Hydro's transmission ROWs that are increasingly being recognized as unique and important elements of the landscape. They provide a critical link between terrestrial and aquatic ecosystems, leading to suggestions that their name should be changed to the hydroriparian zone (to better reflect their role)(BC, 1995). Regardless of nomenclature and classification schemes, riparian zones are moist areas adjacent to water that are responsible for supporting terrestrial ecosystems that have high species densities and diversities (BC, 1995). They are responsible for creating and then maintaining several important features of the adjacent aquatic ecosystems. In particular, riparian zones moderate solar energy inputs, stream production, morphology, habitat complexity and flow patterns (Gregory et. al., 1991). When riparian areas are disturbed to the extent that ecosystem function is reduced, adjacent streams often experience conditions less suitable for sustaining aquatic ecosystems, that in turn, may impact fish populations.

BC Hydro's extensive transmission powerline system crosses thousands of streams each bounded by a unique riparian zone. At point of powerline crossing, each riparian zone is influenced by the vegetation maintenance techniques required to keep the vegetation well clear of the powerlines. These techniques can have a wide range of influences, many of which may have adversely impacted riparian ecosystems. However, only a few studies have concerned themselves with these types of impacts (Peterson, 1993; Bunnell et al., 1995). Similarly highways, railways and pipeline corridors have been poorly studied to determine their effects on riparian areas or biodiversity (Bunnell et al., 1995). No research concerning the effects of transmission powerline vegetation management on riparian zones was discovered in the literature, or could be established as having been completed in BC

As a result, there is very little information currently available to either: (1) confirm that current ROW vegetation maintenance strategies are benign (in terms of riparian ecosystem function); or (2) suggest the potential impacts of ROW maintenance on key riparian zone functions. Some of the most recent riparian management strategies for ROWs recommend the preservation of tall growing buffer strips (McLennan, 1996). This management approach originates from the forestry-related research that deals with the impacts of harvest operations on the riparian zones. It is a practice that may be more satisfactory for forestry and other linear projects but cannot work for powerlines because of the necessity to restrict vegetation height. Therefore, there is a need to evaluate the impacts of the vegetation management practices on riparian zones along ROWs and use this information to suggest integrated management techniques.

During the planning stage of this project it was recognized that to meet the research goal, it was critical that this study include information from a variety of sources. In this instance, both quantitative and qualitative data including anecdotal information had to be collected and analyzed to obtain an accurate description of the impact of vegetation management on riparian ecosystem function. Although there are several research design options currently available to handle both qualitative and quantitative information, the case study method was selected as the most powerful design to accommodate this study's research problem (Yin, 1994; Zolman, 1995). Moreover, a multiple case study method was applied using an experimental design that involves each case being described individually but trends compared across case study sites.

Although it is the interaction of several parameters that ultimately defines an ecosystem's state, for this study riparian ecosystem functions were broken into four separate but functionally related categories. The four key functions are: (1) energy flow into a stream; (2) hydrology of the stream; (3) bank stability; and (4) habitat complexity. Observations associated with these four functions were collected at each of the case study sites. Analysis was completed by looking for trends in each of the four key functions across the case study sites. The trends were then compared to vegetation management history to correlate impacts on riparian ecosystem functions. This information was used to develop opportunities and constraints, as well as, conclusions and recommendations about integrating riparian zone function with current vegetation management practices along electric transmission ROWs in British Columbia.

CHAPTER 2
Managing Electric Transmission Righofways And Riparian Zones

2.0 Introduction

Natural resource-based industries are increasingly being challenged to expand their management goals and approaches to encompass many different issues. This section of the thesis considers the now recognized dilemma concerning broadening the management scope for riparian zones located along electric transmission ROWs. The review begins by presenting information about ROW management, including a description of how and why maintenance occurs. Traditional ROW management paradigms are then compared to strategies needed to protect riparian zones including information and examples from other industries. The bodies of knowledge clearly point to an apparent contradiction between management goals for ROWs and riparian zones. Utilities manage ROWs by preventing the growth of tall growing vegetation thereby, ensuring an uninterrupted flow of power. Conversely, in most other situations riparian zones are managed to either restore or preserve tall growing trees and maintain ecosystem function. This apparent conflict leads to a review of IRM, a preferred management approach that has been used elsewhere to help integrate complex and seemingly contradictory issues.

2.1 Managing ROWs

A key component in the integrated electrical system is the transmission facility which links generation of power with the substations and end users. This task is completed by high voltage powerlines which are commonly grouped into three separate levels: high voltage (46-230 kV), extra high voltage (231-765 kV), and extra extra high voltage (above 765 kV)(Randall, 1973). Land based transmission facilities are most often found in one of two arrangements. The first is a buried facility composed of metal powerlines in large insulated and protected bundles below the ground. While this system does have some advantages, mainly associated with aesthetics, it can often be impractical due to cost, geography, public safety and involves significant environmental disturbance. Therefore the second, and most commonly used arrangement, involves high voltage powerlines suspended above the ground on large wooden or metal structures.

As stated, transmission powerlines and their ROWs are maintained to ensure consistent and reliable movement of power, as well as to protect the public from the potentially lethal hazard of contacting high voltage electricity. Maintenance of ROWs is generally broken into two separate categories. Hardware maintenance involves all the tasks associated with ensuring the apparatus directly related to moving power remains in good functioning order (e.g. powerlines, insulators, support structures). The second category, landscape management, involves all the tasks associated with the corridor through which the facility is located. One component of this entails the need to ensure access to the whole line to respond to hardware maintenance and emergencies, and generally involves the task of keeping rough roads along the ROW passable. The significantly larger component of landscape management is the need to continually contend with the tall growing vegetation located along the transmission system corridor.

When a transmission line is built, all vegetation within the construction corridor is usually cut and removed (Nickerson and Thibodeau, 1984; Thibodeau and Nickerson, 1986). Attention quickly turns to ongoing and routine maintenance along the ROW to keep vegetation at safe distances (defined vertical distances) from the power lines (BC Hydro, 1997; Draxler, 1997).

2.1.1 Vegetation Management

Tall growing vegetation can affect powerlines in a variety of ways. Vegetation located adjacent to the ROW poses a significant and ongoing threat to any electrical powerline because of the potential for falling trees, or their branches, to strike the powerline. Most often this results in power outages, fires, and damage to the apparatus. Another more persistent threat is the trees and vegetation located directly under the wires that can grow up into them. Trees, which grow into the wires, can, at the least, impair lines of sight (affecting hardware maintenance) and cause power outages or fires. When trees come into contact with a transmission powerline they can impose a potentially lethal hazard to the public by conducting high voltage electricity. Due to the risks that vegetation poses to the maintenance of transmission systems, the industry standard in North America has been the use of treatments, at the lowest costs available, to interrupt vegetation succession and ensure a condition where vegetation is kept away (Egler, 1975; Luken, 1991). This has involved combining machine grooming, hand cutting, and the application of herbicides (Egler, 1975; Luken, 1991).

Concurrent with public opinion and regulatory changes, recognition has grown within the utility industry as a whole that resource management practices must change (Porteck et al., 1995; Breece and Ward, 1996; Yeager, 1996; BC Hydro, 1997). The modern transmission ROW manager must address a variety of public concerns, including cost of power, environmental quality, other uses along the ROW, and aesthetic values. This introduces the need for increasing complexity into the planning of ROW maintenance (Porteck et al., 1995), which can often eliminate the use of many traditional vegetation control methods. Furthermore, it has been suggested that to remain economically viable within the emerging de-regulated business environment, utilities must maintain consent to operate by meeting public and regulatory demands (Yeager, 1996). Significant environmental impacts, at times acceptable for local economic development, may not be acceptable to consumers who can purchase power from any utility they choose in the emerging deregulated market (Yeager, 1996). Utility managers must adopt broader multiple resource management plans that include integration of pertinent environmental issues (BC Hydro, 1997; Breece and Ward, 1996). However, future viability of the utility also demands that implementation of management techniques is affordable and ensures safe, efficient and reliable power for customers (BC Hydro, 1997). As a result some researchers suggest corporations must move from stressing short-term financial returns to establishing longer-term economic and societal expectations (Alpert, 1995).

One significant aspect of an integrated approach involves developing explicit plans for managing riparian zones along transmission ROWs. Historically, riparian zones were most often managed in an identical manner as the rest of the ROW. It was not common practice to have specific treatment prescriptions designed to help maintain ecosystem function on riparian sections that intersect the ROW. However, there has been increasing awareness that areas located adjacent to water require protection. As a result, some utilities are beginning to manage riparian issues to meet ROW needs and reduce impacts to the affected ecosystem (Breece and Ward, 1996).

2.2 Riparian Zones

Riparian zones are increasingly being recognized as significant elements of the landscape, providing meaningful three-dimensional links between terrestrial and aquatic ecosystems (Gregory et al., 1991; BC, 1995). Moreover, as they are uniquely situated at the boundary between different open systems, riparian zones have dynamic physical properties that vary with climate, fluvial geomorphology and geologic history (Church, 1991; Leopold, 1994; BC, 1995).

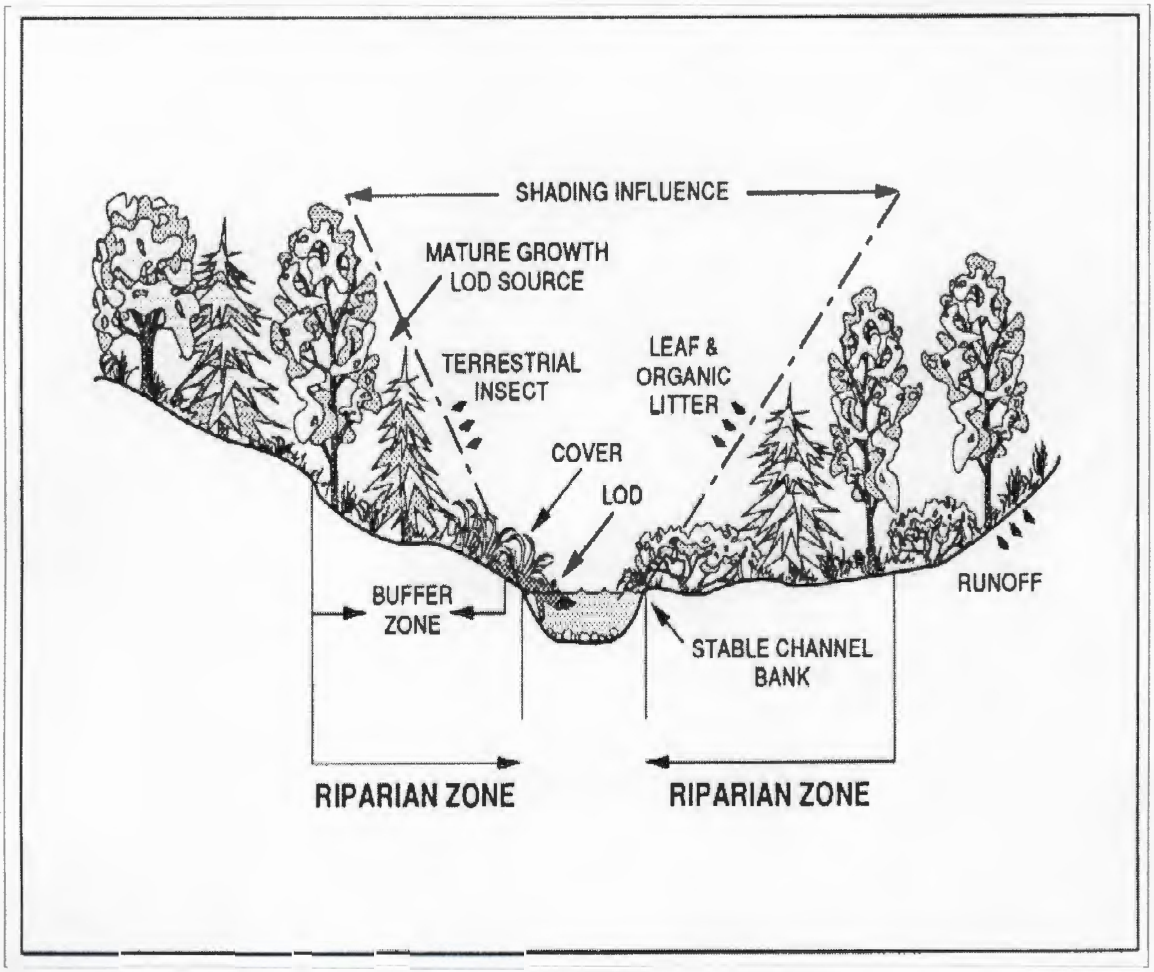
Functionally, these areas create and maintain many key habitat parameters of freshwater stream ecosystems (Gregory et al., 1991). As a result, when riparian zones are disturbed, adjacent river channels often undergo change that is difficult to predict and can lead to less stability and less productivity or in some cases increased productivity (Hicks et al., 1991; Li et al., 1994).

2.2.1 Features of a Riparian Zone

Rivers are dynamic, open transport systems with complex physical properties which vary over time and space (Knighton, 1984). Thus, riparian zones are not static but one of the most dynamic areas of the landscape with properties which change according to fluvial and non-fluvial disturbances (Gregory et al., 1991). Moving downstream from a river's headwaters the morphology and properties of the system and its riparian zone depend on the complex interaction of many factors. A small headwater stream, where the ratio of substrate size (cm) to stream width (m) is greater than 1, lacks the power to determine its own path. Rather, stream morphology (for example cascade-pool, or riffle-pool) and the resulting riparian zone is determined by individual roughness elements, valley gradient, and hydrology (Knighton, 1984; Church, 1991). In medium size streams, where the ratio of substrate size to stream width is between 0.1 and 1, the river system is able to complete more work and modify the landscape. These systems respond morphologically to changes in gradient and hydrology, to maintain competence to move water and sediment. In general, they have less severe gradients, mixed sediment composition, create floodplains and modify the landscape they flow through (Knighton, 1984; Church, 1991). Finally large rivers, where the ratio of substrate size to stream width is usually well below 0.1, usually display large meanders, low gradients and low velocities. Furthermore, they inevitably create large floodplains where large quantities of fine sediments are alternately stored and eroded (Knighton,1984; Church, 1991).

The morphology of the resulting riparian zone is also a function of these same processes. For example, small high gradient streams have riparian areas composed of large and rough sediments, mostly of a non-alluvial origin (Church, 1991). However, further downstream riparian zones are predominantly composed of sediments alternately stored and transported within the alluvial channel (Knighton, 1984; Leopold, 1994). The size and role of the riparian community is determined by the interaction between soils, gradient, climate and hydrologic regime (BC 1995). Species composition, density, diversity and habitat function are unique to each set of parameters. As a result of this variability and the almost limitless combinations in turn confound any simple spatial definition of the terrestrial riparian zone or description of its integration with the aquatic ecosystem by separate criteria (BC 1993).

Regardless of size and function, most riparian zones are composed in a similar manner and have cross-sections based on the amount of time an area is inundated with water (Gregory et al., 1991). Figure 1 is an illustration of a riparian zone. The most upslope community (including the upper portions of the buffer zone in Figure 1) is generally unaffected by the stream other than by increased groundwater availability. Typically it has a relatively stable vegetation community composed of taller mature vegetation species (Gregory et al., 1991). Downslope from this is the floodplain, defined as the valley floor adjacent to a stream (including the lower sections of the buffer zone in Figure 1) that is often inundated only during peak flows (Gordon et al., 1993). The floodplain has increased moisture and regular disturbance resulting in vegetation that is more tolerant of moisture, higher species diversity and is dominated by low growing species (Gregory et al., 1991). Next is the active channel, delineated by the annual high water mark (Gregory et al., 1991). This unit, is completed inundated for periods of each year and as a result does not support terrestrial vegetation (Knighton, 1984, Gregory et al., 1991).



(Figure from DFO and MoELP, Land Development Guidelines, 1992.)

Figure 1: The features and functions of a riparian zone.

2.2.2 Riparian Zones and Aquatic Ecosystems

Riparian zones are unique landscapes where the terrestrial environment helps create and maintain aquatic habitat conditions required to support fish species. All ecosystems are functionally defined by their access to external energy, their ability to capture it and the efficiency by which they move it throughout the biological system (Odum, 1985; Gregory et al., 1991). As a result, riparian zones influence aquatic ecosystems by moderating energy exchange between terrestrial and aquatic environments (BC, 1995). In the winter the riparian vegetation reduces back-radiation, prevents the formation of anchor ice and preserves existing fish assemblages (Platts, 1991). Furthermore, they can directly control the aquatic environment's access to the most important energy source, solar radiation (Gregory et al., 1991)

During the warm summer months the riparian community provides shade and helps maintain acceptable water temperature thereby determining fish presence, variety and density (Barton et al., 1985; Beschta et al., 1987).

As all fish are poiklotherms (unable to regulate internal body temperatures), when the temperature of the external environment moves beyond an acceptable range (either too hot or too cold) the animals must move to other more suitable habitats, or perish (Beschta et al., 1981; Gregory et al., 1991). In the case of salmonids, species specific and stock specific tolerances can vary, but their clear, cool streams must remain absolutely below 24-26 degrees Celsius (Bjornn and Reiser, 1991). As would be expected, the relevance of this temperature control function varies according to season as well as geographical location (Beschta et al., 1987). Accordingly, it is the most critical factor for determining habitat suitability of streams located in warm and dry climates (Platts and Nelson, 1989; Li et al., 1994), but less relevant in cooler and wetter climates (Murphy et al., 1986; Beschta et al., 1987).

Within the absolute realm of habitat suitability (lethal effects), riparian vegetation applies subtle controls on biological processes through control of water temperature. Fish life processes are affected by water temperature regimes. In the case of fall spawning salmon, logging activities can increase the sunlight striking a stream and increase the intergravel water temperatures (Ringler and Hall, 1975). Increased incubation water temperatures can lead to premature emergence and have a negative effect on juvenile survival (Beschta et al., 1987; Hartman et al., 1987). In other situations increased water temperatures can lead to larger alevins and parr and significantly increase their likelihood of success (Scrivener and Anderson, 1984; Beacham and Murray, 1986). The riparian zone helps regulate annual water temperature regimes, thereby affecting juvenile developmental processes and ultimately species survival.

Aside from developmental related sub-lethal impacts, water temperature changes also affect fish behaviors. Research in the Yakima River demonstrated that spawning salmon will actively pursue cool water refuges, associated with pools and ground water sources, during their migration. The benefits to the animal are significant with each difference in 2.5 ^{0}C in water temperature resulting in a 25% change in basal metabolic rate (Berman and Quinn, 1991). Other research has suggested interesting interspecies aspects of water temperature changes. Reeves et al. (1986), investigated the interaction of redside shiner and steelhead trout in a laboratory setting and found that in cooler temperatures the trout dominated habitats and out competed the redside shiners. As temperatures got closer to 19-22^{0}C the shiners enjoyed a larger distribution, trout production decreased and the shiners had the competitive advantage (Reeves et al., 1986). In the field setting, a change in species composition was also noted in high desert streams, as increased water temperatures resulted in significantly lower densities of steelhead trout and sculpins (Tait et al., 1994; Li et al., 1994). Generally non-sport fish are more tolerant of higher water temperatures (Platts, 1991).

Riparian zone vegetation and its associated canopy control primary productivity by providing shade. Autotrophic algae in freshwater streams depend on solar radiation to grow and reproduce (Bilby and Bisson, 1992). As such, riparian vegetation communities help determine aquatic ecosystem biomass and densities. For example, higher amounts of solar radiation entering a stream invariably increase primary productivity, thereby potentially increasing the richness of higher trophic invertebrate and vertebrate communities (Gregory et al., 1991; Bilby and Bisson, 1992). Although increasing primary productivity in cooler, oligotrophic streams, invariably benefit invertebrate and fish populations by creating more feed (Murphy et al., 1986; Hartman et al., 1987; Bilby and Bisson, 1992), in warmer climates this must be tempered by the afore mentioned need to moderate water temperatures (Li et al., 1994).

In conjunction with affecting the amount of sunlight available to drive primary production, the riparian community helps regulate the aquatic community by being a source of allochthonous energy, nutrients and food (Gregory et al., 1991). During the course of a year, vegetation in the riparian zone grows leaves and fruit which over time fall from the plant and land in adjacent streams. This material, most often in the form of leaves, sticks and berries provides nutrients and energy to the invertebrate community, that in turn, fuel higher trophic levels (Gregory et al., 1991). In addition, terrestrial insects often fall from riparian vegetation into the adjacent water and provide a vital food source for many aquatic animals. For example, it has been suggested that in small streams flowing through large mature forests, up to 65% of the salmonid food and organic matter available is of terrestrial origin (Bilby and Bisson, 1992). These inputs vary seasonally.

In addition to water temperature and food availability, another key aquatic habitat parameter largely controlled by riparian vegetation is water quality. As the roots and associated organisms extract nutrients from the ground water to grow, respire and reproduce, they act as a filter mechanism (Lowrance et al., 1984). This helps regulate the quality of the groundwater, which slowly percolates into salmonid streams (Gregory et al., 1991). In some cases it removes significant volumes of nitrates and other chemicals before they enter a stream (Lowrance et al., 1984). In ultraoligotrophic, cool water system the removal of nitrates can lead to reduced productivity. Conversely in areas where water quality has been compromised, often near heavy agricultural development, the filtering removes significant volumes of potentially harmful compounds and ensures good water quality (Lowrance et al., 1984; Osborne and Kovacic, 1993). In summary, the riparian zone often plays a role in ensuring water quality remains within the parameters required to maintain the current aquatic ecosystem (Gregory et al., 1991)

2.2.3 Riparian Zones and Morphological Processes

From a watershed perspective topography, climate and precipitation conditions invariably determine stream networks, morphology, hydrology and water quality (Knighton, 1984; Leopold, 1994). However, from a site or reach specific perspective, riparian vegetation significantly affects morphological processes and as a result also plays a key role in determining the suitability of a water body as aquatic habitat (Gregory et 1991).

The first way riparian zones affect stream properties is by moderating hydrology through attenuation of flow events related to precipitation (rain and snow melt) (Leopold, 1994). In areas without significant vegetation, precipitation strikes the ground, causes rills and runs directly into streams (Leopold, 1994). However, in areas with dense vegetation the precipitation strikes foliage, where its kinetic energy is dissipated allowing it to more slowly flow into streams (Leopold, 1994). Regardless of the climatic region, attenuation of flood events is beneficial to streams because it reduces the likelihood of catastrophic pulse events and subsequent significant damage to aquatic habitat (Leopold, 1994). The latter invariably occurring when a channel erodes and responds morphologically, by either increasing width or gradient, to maintain competency for peak flows (Leopold, 1994).

Interception also moderates hydrology by allowing more water to percolate into the earth and enter the groundwater column (Knighton, 1984). Groundwater flow is more often the consistent stream maintenance flow source, between precipitation events, and is another component of hydrology affected by the structure of the riparian vegetation community. One of the reasons heavily vegetated communities are able to hold more water for longer periods of time is due to increased soil porosity and complexity created by roots and associated organic compounds (Gregory et al., 1991). As a result more vegetation ensures more consistent flows during low flow periods (Leopold, 1994). This is especially important in dry arid regions where removal of vegetated riparian zones, often through grazing, has driven perennial streams to intermittent streams, eliminating them as potential aquatic habitat (Hicks et al., 1991).

Erosion and the subsequent transport of sediment from landscapes are the next significant river process, which to a degree are also regulated by riparian vegetation (Knighton, 1984). Peak flows exert the highest shear forces on bed and bank, complete the greatest amount of work, and ultimately determine a channel's shape and structure (Knighton, 1984). The riparian zone moderates this process by providing roots and other organic compounds which armor the bank and increase its resistance to erosion (Gregory et al., 1991). This armoring works with site roughness elements to reduces shear velocities and lateral erosion at peak flows. The extent of armoring will moderate channel morphological response to changing hydrological variables, as evidenced in vertical processes such as aggradation or degradation (Leopold, 1994).

Stream channels that scour and fill periodically are considered to be at grade. Decreased flows or increased inputs of sediment can result in aggradation (a flow limited situation) (Knighton, 1984, Church 1995). This response improves the flow effectiveness to transport sediment by reducing depth, increasing gradient and thereby reducing the threshold for bed load transport (Lisle, 1982; Gordon et al., 1993). Some of the morphological indicators for these channels are a general widening, large sediment bars, highly eroded banks, and decreased pool volume (Lisle, 1982). If the channel aggrades the water table is raised, providing another mechanism by which to increase groundwater flow (stream maintenance) (Elmore and Beschta, 1987). Increased flows or a reduction in sediment input can lead to narrowing of the channel and degradation of the stream (Church, 1995). Some of the indicators for these channels are a general narrowing, few sediment bars, highly eroded banks and decreased pool volume (BCFPC, 1995). While degradation often involves reduced habitat suitability, in some cases it can create more pools and beneficial instream structures (Smith, 1990).

These physical processes are especially important when considering streams which in order to support fish must exhibit clear, cool water and an array of morphological complexity (Murphy et al., 1986; Bjornn and Reiser, 1991; Fausch and Northcote, 1992). For some species, such as salmonids, spawning and incubation requires riffles and runs composed predominantly of larger sediment, with interstices free of fine sediments (Bjornn and Reiser 1991). Rearing requires deeper runs, a variety of pool types and off-channel areas. These are invariably filled and subsequently eliminated from the stream when excessive fines sediments are deposited into a stream. Without the resistance to lateral erosion many of these morphological forms would disappear, diminishing the stream suitability as aquatic habitat (Heifetz et al., 1986).

In larger river systems morphological complexity is determined by the larger watershed characteristics, including form roughness and large debris jams (Leopold, 1994). However, in smaller streams introduction of large woody debris (LWD) from the riparian zone is largely responsible for creating complexity, and therefore salmonid suitability (Murphy et al., 1986; Robison and Beschta, 1990; Gregory et al., 1991).

As a tree moves from the terrestrial riparian zone into the aquatic environment it becomes a new roughness element of the stream channel that immediately impacts site morphology by reducing and redirecting hydraulic forces (Keller and Swanson, 1979; Lisle, 1982). Because of its large size (relative to small and medium size streams) at lower flows the LWD usually blocks a significant portion of the channel and a backwater pool is formed directly upstream of the obstruction. The new pool then functions as a sediment trap and increases the residence time of organic matter floating downstream (Bilby and Likens,1980; Sedell and Swanson , 1984; Hicks et al., 1991b). At higher flows these areas upstream of the obstruction are scoured and depth is increased. At sites where the LWD creates a small dam, the flowing water is forced to flow over the object and thereby erodes downstream plunge pools.

In other situations where the LWD does not completely block flows water can erode around the object, thereby creating undercut banks. Organic material at a meander bend will reduce velocities and cause creation of a point bar (Knighton, 1984). The LWD may become further embedded in the channel and become relatively stable control structures that can continue to function for centuries (Toews and Moore, 1982; Sedell and Swanson , 1984).

In all streams the important positive effects (to fish habitat) of LWD must be balanced by the potential negative impacts of large debris jams which can destabilize stream banks (Bisson et al., 1982).These negative effects are most often the result of catastrophic events, such as mass wastage or severe wind storms, that introduce large amounts of LWD into a stream and significantly increase erosion and lateral movement (Robison and Beschta, 1990).

A key role of LWD in sustaining a rich aquatic population is creating and maintaining relatively stable, complex microhabitat (Hicks et al., 1991b). Research into the relationship between aquatic life, pools and LWD have found that pool volume is inversely related to stream gradient and directly related to amount of LWD in a stream (Carlson et al., 1990; Hicks et al., 1991b; Bilby and Ward, 1991). Bilby and Likens (1980) found that in first and second order streams, habitats associated with LWD contain between 58-75% of the streams standing organic matter. Pools have more organic matter and result in higher macrobenthos densities, drift and food for foraging fish (Schlosser, 1982; Elliot, 1986).

At higher levels in the trophic structure the interaction between pool and riffle habitat is critical for many fish species to successfully conduct their life history processes (Bisson et al., 1982; Hicks et al., 1991b). Further, it is the diversity of microhabitat that creates conditions necessary to allow the co-existence of multiple species communities (Bisson et al., 1982; Hicks et al., 1991b). The microhabitat caused by LWD contributes to fish survival by providing quality foraging areas, velocity refuges, increased depth and cover from predators (Toews and Moore, 1982; Elliot, 1986; Shirvell, 1990; McMahon and Holtby, 1992; Fausch and Northcote, 1992). For some fish species, such as trout, pools are preferred habitats for conducting most of their life history processes (Dolloff, 1986; Elliot, 1986; Fausch and Northcote,1992). Whereas for some Pacific salmon the volume of pool habitat and cover may only be important for a critical period during one stage of their life history (Heifitz et al., 1986; Shirvell, 1990; Berman and Quinn, 1991).

While the functions of the riparian community can vary over time, depending on climatic conditions, they also vary with space. Again, based upon the paradigm that a biological community within a stream conforms to kinetic energy dissipation patterns of the fluvial system (Vannote et al., 1980), the role of riparian community stretches along a dynamic gradient. This continuum begins at small heterotrophic headwater regimes, then moves through seasonal autotrophic regimes (in the mid-reaches) and finally returns to large river heterotrophic processes (Vannote et al., 1980).

While this size gradient is analogous to the review of stream morphology presented earlier, this paradigm suggests ecosystem function is governed by interaction between stream size and energy availability. Where streams are small and their shape and form depend on the material and gradient, they are often completely enclosed by canopy of the adjacent riparian vegetation (Vannote, 1981; BC, 1993). As a result, habitat complexity, external energy entering the stream (including temperature control and primary productivity), nutrients and feed inputs are directly dependent upon the riparian community (Vannote et al., 1981). As streams become wider and more powerful, they are able to transport more material and modify the adjacent landscapes (Church, 1991). In these wider streams that still have clear water, the riparian community's role changes. Here, the vegetation canopy often covers less than half of the stream area and therefore, instream autotrophic production becomes the mechanism which determines community structure (Vannote et al., 1980). At these sites vegetation takes on an increased role in providing bank form resistance, site specific habitat diversity, and attenuating peak flow pulse events (Leopold, 1994). In larger rivers, water clarity is drastically reduced and correspondingly internal production switches back to a heterotrophic driven ecosystem. In these systems, riparian vegetation helps provide bank resistance, food sources and site specific complexity, but it is less able to affect the quality of the fish habitat provided or stream morphology (Vannote, 1980; Church 1991).

2.3 Managing Riparian Zones

Although the amount of interaction between terrestrial and aquatic ecosystems varies among different riparian zones, disturbances of the terrestrial landscape often reduces stream productivity (Barton et al., 1985; Elmore and Beschta, 1987). As a result landscape management has most often focused on strategies to help protect adequate riparian zones area and thereby preserve stream productivity. More recently, researchers are suggesting that spatial criteria are inadequate to protect ecosystem function. Rather new more integrated management parameters criteria are required (Costanza, 1992). With riparian zones this includes expanding the assessment from what they look like to what are the key functions.

Consistent with the previously described roles of riparian zones in maintaining aquatic habitat, in general, when they are disturbed by land use activities, such as logging and agriculture, there is a corresponding reduction in aquatic ecosystem productivity (Elmore and Beschta, 1987). Because of the variability of riparian zone composition and function, the impacts of terrestrial disturbances can vary with climate, topography and type of activity. For example, in wetter and cooler climates, short term increases in primary productivity often occurs when the canopy is thinned leading to higher juvenile fish populations (Hawkins et al., 1983). But thinning could also result in greater water temperature fluctuations, reduced LWD inputs and reduced habitat complexity leading to decreased fish survival and densities (Heifetz et al., 1986; Riehle and Griffiths, 1993).

Effective riparian zone management involves integrating site and ecosystem specific limiting factors with management strategies. In areas with suitable water temperature regimes and habitat complexity, reducing the vegetation canopy removes a limiting factor and allows a system to become more productive (Smith 1980, Peterson 1993). In fact some (Thedinga et al., 1989) have suggested that cutting vegetation to increase water temperature in streams that are cooler in the summer than optimum, can increase productivity and should be assessed as an enhancement tool. In warmer climates reducing the vegetation cover can lead to increased temperatures, introducing a new limiting factor to stream production (Barton et al., 1985; Li et al., 1994; Tait et al., 1994).

In order to reduce potential impacts of land management activities research has focused on defining empirical criteria which describe the extent and type of riparian zone required to preserve ecosystem function (Taylor and Biette, 1985; Gregory et al., 1991; BC, 1995). This work has generated several discrete criteria (Taylor et al 1985, BC Forest Practices Codes, 1995).

Single key criterion that have been used include measuring the largest trees and assessing either their shading ability or potential for contributing LWD (Brazier and Brown, 1973; Mcdade, 1990). Other terrestrial indicators such as edaphic vegetation have been employed (Gregory et al., 1991; Millar et al., 1996). In still other situations, professional and political judgment has been used to place caveats around streams based on stream width, independent of a documented scientific process of evaluation (Elmore and Beschta, 1987; Castelle, 1994). From a habitat perspective other researchers have used water acidity as indicator criterion (Omerod et al., 1993) or the volume of LWD (Fausch and Northcote, 1992). In addition to habitat suitability, actual fish species and densities have often been used to describe the overall state of an ecosystem (McMahon and Holtby, 1992; Peterson, 1993; Tait, 1994).

The most common management criterion used to identify and subsequently protect the function of riparian zones has been width of pristine terrestrial area (Barton et al., 1985; Castelle, 1994; BC, 1995). Although this has occurred in large part because of the ecologically incomplete perspectives provided by isolated criteria (Gregory et al., 1991), large terrestrial elements, such as protected areas, have many very appealing qualities. The mature forest community: (1) supports the climax community paradigm and represents the preferred structure of a healthy ecosystem (Costanza, 1992); (2) involves a larger and more integrated unit which implicitly provides greater biological diversity and resistance to incursion (Barton et al., 1985; Millar et al., 1996); (3) represents a clearly defined spatial area, which is both quantifiable and easily measured in the field (Platts et al., 1983; Oliver and Hinckley, 1987; Castelle, 1994); (4) is assumed to be a composite indicator of many different parameters within the ecosystem (Costanza, 1992); and (5) its linear properties facilitates relatively uncomplicated management strategies (Castelle, 1994).

However, the consistent focus on the pristine buffer strip as the empirical and spatial unit of assessment has been problematic and has lead to dubious management strategies (Rinne, 1990; Castelle, 1994). The first and most pressing issue is the inability of this relatively simple measure to account for function of the riparian zone within a highly variable natural system. According to Oliver and Hinckley (p.260, 1987),

Riparian zones, particularly in upland regions, are not easily classified, because (1) the riparian vegetation is not distinct from the upland vegetation, because (2) soils are not obviously different nor is there a typical riparian zone soil, and (3) there is not always a topographical depression. Although classification systems are useful in a court of law or for mapping similar units, they may not be appropriate in defining the function of a riparian zone.

In addition, the application of a simple classification and protection scheme can often lead to assessments which neglect the relative state of a site's aquatic habitat, focusing solely on terrestrial areas (Castelle et al., 1984). By establishing finite spatial boundaries instead of functional criteria, the riparian zone is studied in isolation from the surrounding land-use activities (Castelle et al., 1994). This reduces the opportunity for new and more adaptive protection strategies which integrate ecosystem function with change over both time and space (Rinne, 1990; Costanza, 1992; Castelle et al., 1994).

More importantly, this approach often ignores the fact that aquatic ecosystems, including fish species, do not absolutely depend on particular vegetation species or terrestrial landforms. Rather it is the interaction of these that ultimately determines habitat suitability (Wilzbach, 1989; Gregory et al., 1991).

Recognizing the inherent problems with defining ecosystem spatial boundaries other researchers, while not disagreeing with the need for buffer strips, suggest that buffer strip size should be determined by four functional criteria: resource functional value, the intensity of the adjacent land use, buffer characteristics and specific aquatic functions required (i.e. limiting factors)(Castelle et al., 1994). From a more biological perspective, others have suggested that sediment composition, and invertebrate and vertebrate community structure should be used as integrated assessment criteria (Rinne, 1990). In a recent controversial forestry application, integration was fully recognized, resulting in a new title for the area (the hydroriparian zone), recommendations for more qualitative functional criteria, and assessment periods of over 80 years (BC, 1995).

Calls for new and expanded criteria and less static concepts about riparian zone preservation reflects the increasing understanding about the important role these areas play in the landscape and their complex nature; many parameters need to be considered for effective management. The new view of riparian zones have coincided with the redefinition of ecosystem health as an open system that, "maintains its organization and autonomy over time and is resilient to stress" (Costanza et al., 1992). In this paradigm integrated indicators can be used to generate a broader more comprehensive yet adaptable description of a healthy riparian zone (Costanza et al., 1992).

2.3.1 Setting Ecosystem Functions as Criteria for Managing Riparian Zones

As described within this review, isolated empirical assessment parameters cannot accurately describe the health and function of a riparian zone and associated aquatic habitat. Even though spatial preservation frameworks provide a standard and workable way to protect many stream ecosystems, they are inadequate for accurately capturing and describing the functional interactions of these dynamic zones. Notwithstanding, physical and biological features will continue to serve as indicators of current watershed conditions (Rinne 1990). However, as suggested by Rinne (p.375, 1990) to be meaningful they must accurately describe,

> (1) the nature and the variability of stream habitat and biota under natural (pristine) conditions, (2) the patterns of this variability through time, and (3) both the relative information content and interactions of various features.

They must also be communicated into standard, understandable and effective management tools.

In order to accomplish these tasks certain points must be first recognized and then investigated. Rather than using isolated key indicator species (vertebrate, invertebrate or vegetative) composite functional criteria need to be identified. From a functional perspective it is the interaction of several site specific variables, including biological factors, that ultimately defines a stream's productivity. Regardless, the roles of riparian vegetation in affecting aquatic habitat can be grouped into four categories: (1) Energy Flow (the amount of solar energy entering a stream), (2) Habitat Complexity (LWD controlled streams), (3) Stream Hydrology and (4) Bank Stability. Some of the physical criteria which may be used to assess these processes are: water temperature, primary productivity, bank stability, LWD, vegetation density, water flow, rates and timing.

There is a need for research that investigates methods of integrating traditional ecosystem parameters with new more holistic measures, including anthropogenic effects on an ecosystem. Broader ecosystem parameters should be studied from a habitat suitability perspective, allowing for creation of new and more effective and adaptive management strategies; including guidelines for managing different ecosystem habitats.

Riparian zones are extremely dynamic environments with physical and biological characteristics which can change significantly over time and space. These areas are key links between terrestrial and aquatic ecosystems, responsible in large measure for determining the suitability of many aquatic habitats. While recognizing this variability, most research has focused on individual ecosystem functions or key indicator species, in order to define ecosystem health. However, in conjunction with expanded and functional views of ecosystems, has been increased recognition that perspectives based on isolated components are ecologically incomplete. Rather, new more robust and holistic criteria are required to accurately assess riparian zone condition. The literature reviewed suggests that this can best be accomplished by combining many separate but functionally related criteria. Furthermore, it suggests that future research must work within a model that recognizes ecosystem constituents themselves do not ensure species presence. Rather, it is the interaction of these criteria, which creates suitable habitat for both terrestrial and aquatic species of plants and animal.

Given the critical role riparian zones play in maintaining both terrestrial and aquatic ecosystems, it is important that new resource management methods are generated to better integrate riparian zone ecosystem function with anthropogenic activities. For management of riparian zones on ROWs this involves developing management goals, objectives and tools, such as guidelines, that result in maintenance activities that address both utility and resource needs.

2.4 Integrated Resource Management

The two bodies of knowledge explored to this point in the thesis describe the dilemma facing both regulators and the utility industry. The traditional paradigm of using severe physical and chemical methods to achieve a single management goal (maintaining the safe and efficient reliable flow along power ROW) is incompatible with maintaining riparian buffer strips. Equally incompatible is the paradigm of using small and narrow prescribed and static buffer strips to preserve stream function independent of existing and future landscape development, including electric transmission powerlines and their associated ROW. Rather, new management methods are required which better integrate ROW and riparian zone management. The literature suggests that increased interest in managing riparian zones along ROWs is not an isolated issue. Increasing attention reflects the ever increasing societal demand to obtain maximum benefits from limited resources while satisfying concerns over their use (Lang, 1990).

The increasing demand, has in turn, demonstrated the shortcomings of both traditional incremental and rational comprehensive approaches to planning and decision making (Lang, 1990). Current landscape planning approaches rely primarily on punitive regulations and measures defined by acceptable limits of environmental impact (Montgomery, 1995). Some scientists who share this criticism suggest that preserved areas are often insufficient to maintain ecosystem integrity (Lajeunesse et al., 1985; Brown and MacLeod, 1996). Rather, the preferred process should involve identifying the effects of land use disturbances on natural processes in advance, setting common management goals, and tailoring management strategies to attain them (Montgomery, 1995).

It is increasingly being recognized that cross-disciplinary processes are required in order to integrate anthropogenic items into ecosystem description. Other scientists have reviewed management issues associated with controversial terrestrial resource allocation issues. When reviewing the Northern Spotted Owl controversy in California, Roe (1996) proposes that social science is more important than even ecology in making ecosystem management work. She suggests that while several disciplines may be required to make a comprehensive management decision, not all disciplines are equal. In particular, social sciences are offered as a preferred process for reducing several issues as follows: conflicts between groups; inevitable confusion with ecosystem interaction; and the red herring of setting artificial boundaries (arbitrary spatial limits around natural processes). It is also proposed as a preferred method to initiate inside out planning. Inside out planning refers to the planning process where all stakeholders participate at the beginning when goals and objectives are being set. This early and comprehensive participation ensures that all concerns are addressed in the resulting management strategies, thereby reducing the likelihood of implementing management process which conflict with key expectations. For example, with the Northern Spotted Owl example, inside out planning did not occur, and as a result management strategies to preserve owl habitat appeared to clash with local economic objectives concerning employment and economic prosperity.

While the desire for broader approaches to environmental management are not new and can be traced through several fields of research (Mitchell, 1990; Burroughs and Clark, 1995; Margerum, 1997), they increasingly emphasize IRM as the preferred process (Lang, 1990). The literature includes significant debate concerning methods of moving from a linear single resource focus (often easily quantified) to a non-linear multiple resource use paradigm (Born and Sonzogi, 1995). This shift must account for the different needs of resource regulator, resource manager and the general public. IRM must work within a framework which minimizes the impacts within the broader context of societal objectives defined for a landscape (Montgomery, 1995).

Whereas the concept of integration is generally agreed upon, considerable debate still surrounds the definition and preferred process of IRM. In their review of the Hunter Valley Conservation Trust, Mitchell and Pigram (p.210,1989) state that, "there is no single method of implementing IRM....Rather there are a number of complimentary leverage points". To account for its inherent complexity other researchers have suggested that the process must be coordinated, aim at specific societal objectives and incorporate an inclusive strategic component (Born and Sonzogi, 1995). More specifically an IRM process should be functionally defined by four essential components as follows: comprehensive; interconnective; interactive/coordinative; and strategic (Born and Sonzogi, 1995).

While the four essential components provide a conceptual framework for an IRM process, each planning process is unique and will develop a unique set of methods to realize its goals. Comprehensive refers to the need to include all the significant present and potential uses and objectives for the system, as well as all the groups, that affect or can be affected by management of a system. Interconnective refers to the dimension of IRM which involves addressing interrelationships and linkages, including conflicting uses. The strategic dimension of the IRM process is like a filtering process and involves focusing on key aspects of a problem and selectively targeting those which are critical. Interactive/Coordinative indicate more of how IRM should occur as a planning and decision making process. Specifically that an IRM approach must be interactive and involve dispersal of information and shared decision making (Born and Sonzogi, 1995). In this case the goal is to determine if it is possible to apply these elements and integrate vegetation management along electric transmission ROWs with key riparian ecosystem functions and as result progressively integrate the health of landscape and ecosystem with societal and ecological factors (Samson and Knopf, 1996).

The actual application of these concepts has proved to be challenging as more failures than preliminary successes have been reported (Walther, 1987; Born and Sonzogi, 1995). Hilborn (1987) summarized weaknesses in IRM in dealing with three types of uncertainty: noise (ongoing flux), uncertain state of nature (dynamic equilibrium), and surprise (catastrophic change). However, he further states knowledge and reactability are required in management, undeniably demonstrating the support to continue refining the IRM process (Burroughs and Clark, 1995).

As discussed previously, one implicit assumption with the current riparian zone management paradigm is that any land disturbance within the riparian zone will compromise function. An opportunity for shifting to an integrated management along ROWs lies in the fact that other researchers do not support this assumption. Smith (1980) advises afforestation and subsequent meadow creation in Scotland has significantly improved trout habitat in streams less than two meters wide. Furthermore, Peterson (1993) proposes that ROW construction and subsequent maintenance has increased habitat suitability and fish densities in the state of New York. These studies indicate that, in some cases, limited disturbance and the introduction different physical forms and energy types into an ecosystem may in fact increase stream's productive capability.

Another opportunity for shifting to IRM stems from changes in ecosystem theory. The traditional climax community paradigm of ecosystem progression has been challenged. Instead, this normative view of community condition is being contested by the notion that disturbance is an essential feature of the ecosystem process (Crossley, 1995). Moreover, it has been asserted that an ecosystems condition should be judged functionally in terms of activity and a system's ability to maintain community organization, autonomy and resistance to stress (Costanza 1992). A distressed ecosystem can display several symptoms, which can either increase or decrease productivity, as follows (Crossley 1995):

1) changes in nutrient cycling;

2) changes in size of dominant species;
3) changes in species diversity; or
4) a shift in species dominance to shorter lived forms.

As result, management structures should also be able to differentiate between natural and anthropogenic changes and be adaptable enough to respond when any of these changes are observed. Further short-term changes may occur naturally and different ecosystem end states may result from an environmental shift (Crossley, 1995).

The fundamental shift proposed by IRM is echoed in suggestions concerning setting ecosystem based goals and objectives for the landscape management process (Slocombe, 1998). To date, management has been conducted to maximize the volume of an item extracted, while still maintaining a sustainable ecosystem. Ecosystem management proposes replacing this single resource focus by maintaining the complete natural system (Alpert, 1995; Slocombe, 1998). The emerging ecosystem services model supports and suggests that in order to ensure ongoing delivery of the myriad of services and products we require from the natural environment, we must maintain complete and functioning natural systems (Daily, 1997). Therefore, management goals must shift from managing single resources and maximizing extraction to sustaining complete ecosystems, including anthropogenic components. Some researchers suggest this can be accomplished by setting explicit goals, objectives and targets defined to keep impacts within acceptable bounds (Alpert, 1995; Slocombe, 1998).

Applying IRM within an ecosystem management framework provides a flexible structure where scientific knowledge and complex sociopolitical concepts can be integrated towards a general goal of protecting ecosystem integrity over the long term (Alpert, 1995). From an ecosystem perspective it promotes more autonomous scientific bodies and a continuous process of improvement and pursuit of understanding. In addition, it provides a process by which social values and expectations are integrated with resource management decision making. This lends support for its potential use for managing the increasing complex relationships involved in ROW vegetation management

2.5 Summary

In summary the literature which has been reviewed for this research clearly points to the problem which requires attention. Government and the utility industry perceive the potential need to change traditional work practices in riparian zones. However it is unclear whether vegetation and management can be integrated with riparian zone functions. In order to answer this question information is required which helps determine the effect traditional ROW vegetation maintenance techniques have had on riparian zone ecosystem functions. In addition, this information can then be used to help identify key strategic issue and variables for developing more holistic management goals, strategies and techniques.

CHAPTER 3
The Methods Used In This Study

3.0 Introduction

The previous chapter considered the gap in information currently exists about whether it is possible to integrate vegetation management along ROWs with maintaining key riparian zone functions. To help correct this situation and thereby increase the body of knowledge concerning IRM this research project involved collecting, documenting and analyzing both quantitative and qualitative data. This chapter describes the research design selected to accommodate the objectives of this study. It then provides a detailed account of the research protocol used collect the information presented later in the results chapter of the thesis.

In order for the project to reflect the diverse climate and topographies found in BC, sites were located in a variety of different biogeoclimatic zones around the province. Recognizing time and monetary constraints, a total of 12 separate case studies were selected across 5 separate major biogeoclimatic zones throughout BC (Figure 2) and studied during summer and fall, 1998. Four were located on Vancouver Island within Coastal Douglas Fir zones, three were located in the Fraser Valley within coastal Western Hemlock zones, and five were located in the central interior of the province within the Sub-Boreal Spruce zone, Interior Douglas Fir zone and Boreal White and Black Spruce Zone (BC, 1991).

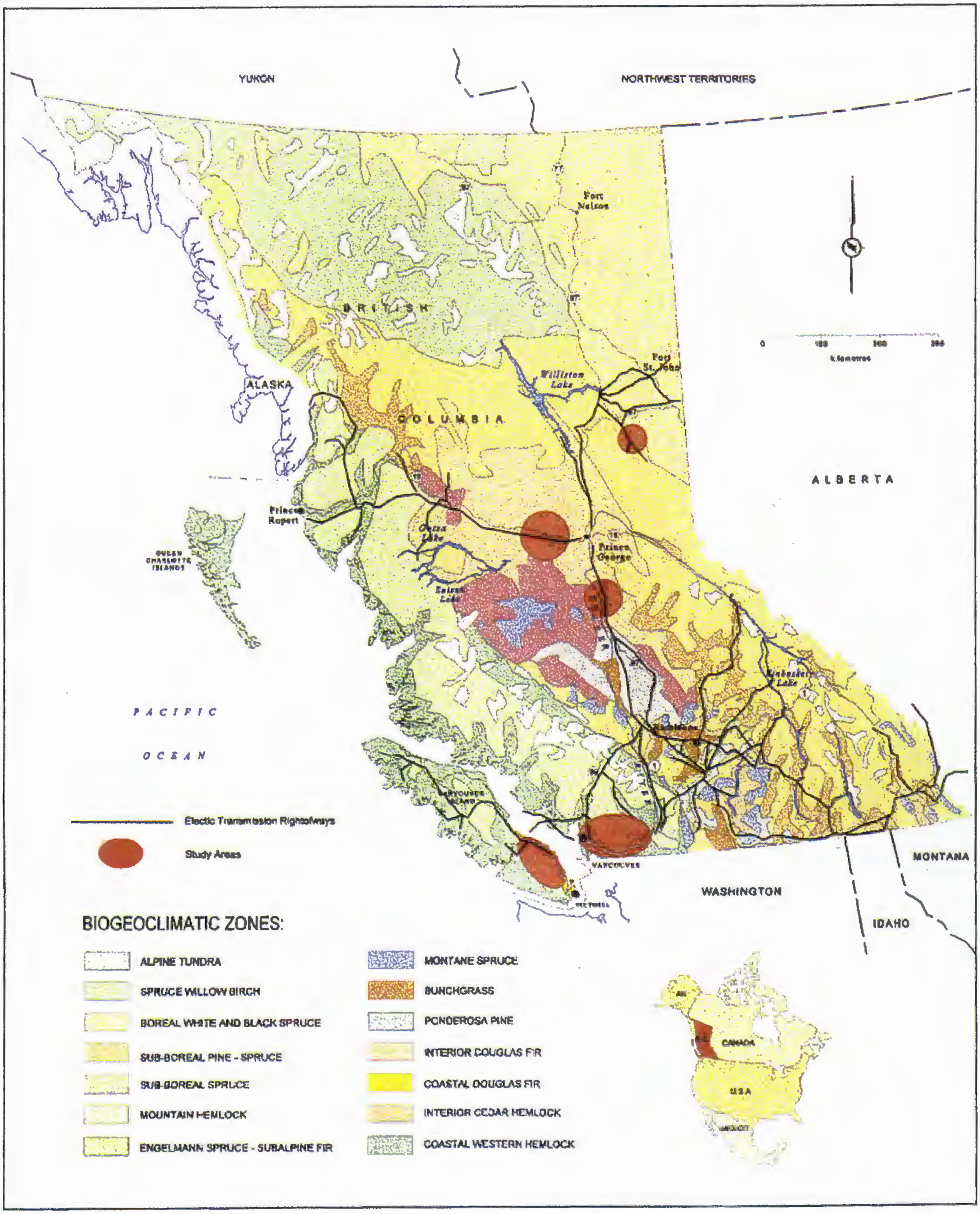


Figure 2: The Case Studies

3.1 Research Design

The scientific process is the systematic collection of accurate observations to increase the body of knowledge about a particular phenomenon (Babbie, 1995). The classic approach to this procedure has involved the use of experimental or quasi-experimental research designs, appropriate whenever the independent, dependent and confounding variables can be identified and then controlled or explained (Babbie, 1995). These designs generally use a process of falsification, through inferential analysis of larger samples of quantitative data, to help suggest attributes about a population. However, many phenomena exist in terms of variables that cannot be controlled or identified, and as such, require qualitative research designs (Zolman, 1993). In these types of designs, emphasis is placed on gaining a better understanding of complex relationships rather than on control and explanation (Zolman, 1993). Moreover, they are often termed non-experimental by empiricists (Zolman, 1993), insinuating a hierarchical order of investigative power (Yin, 1984). However, qualitative researchers continue to develop more rigorous methods to ensure the validity and reliability of their work (Yin, 1994), thereby increasing the investigative power of their research designs and progressively eliminating any hierarchical comparisons. In addition, qualitative methods of research are increasingly being recognized for the benefits inherent in their ability to study complex topics in great detail (Babbie, 1995; Stake, 1995).

The research goal for this study was best met with the case study, a qualitative research approach to examine the stated research questions. This approach maximizes internal validity, external validity, reliability and power, when dealing with studies which involve: (1) contemporary phenomena, (2) important contextual components (management direction), (3) confounding variables (site interactions) which cannot be controlled, and (4) both quantitative and qualitative information (Yin, 1994).

Within a broader case study strategy, this research was conducted with a multiple case study method and applied using an experimental logic. This involved analyses of several individual cases which were described and evaluated independently. Analyses were completed, within each case by comparing empirical and qualitative site observations between a treatment and upstream control site. Pattern matching was then conducted between sites and cross case comparisons were compared to the current body of literature to answer the research questions.

Application of the case study method most often involves collecting a variety of data and observations from different sources. This information is then analyzed to identify convergences, divergences and trends. As a result, triangulation, of information form diverse sources is critical to the validity of the research. The general protocol used to answer the main and secondary research questions involved a three-part process. As presented in Figure 3, this first involved using a multiple case method to determine the effects of current vegetation maintenance on riparian zone function. The results of this case study were used, in conjunction with a literature review to inform questions two and three. Finally all three answers and information were used to inform question four and the primary research question (Figure 3).

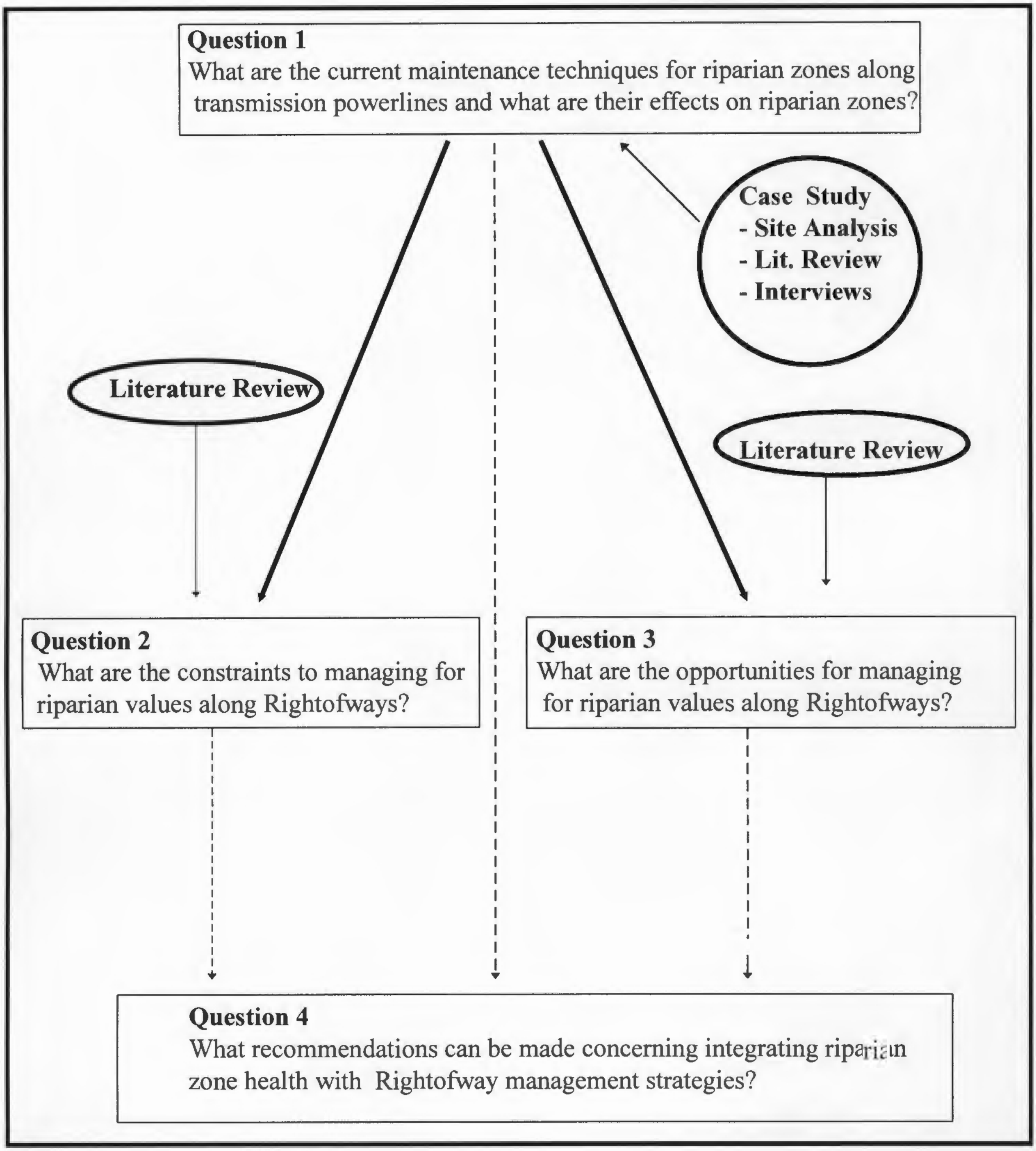


Figure 3: Mode of Triangulation and Analysis

3.2 Research Protocol

3.2.1 Criteria Used to Select Case Sites

In addition to triangulation of information from different sources, documentation and consistent application of a procedure is another means of increasing the power of the case study method. The most significant threat identified, to both the validity and repeatability of this research, was confounding variables potentially introduced from different watersheds located throughout the province of BC In response to this potential problem sites were selected systematically based on specific criteria which were chosen to ensure that a consistent type of stream (morphology) and crossing were used in this study.

Although it was important that all study sites for this project were located along electric transmission ROWs where vegetation management had occurred, it was also important that all sites met parameters designed to ensure consistency of layout. Each study site was composed of:

(1) an upstream control segment (immediately upstream of the ROW);

(2) the ROW study segment; and

(3) a downstream assessment segment (immediately downstream of the ROW).

Furthermore, in order to ensure an adequate upstream control each site was to have a mature, undisturbed control forested site (stretching at least one ROW width) immediately upstream of the ROW. In addition, sites were only selected where streams cross the ROW within one span (the distance between two support structures of an electric powerline), thereby focusing observations on the effect of vegetation management applied within that ROW span.

This project focused on collecting information on medium size (as described in the literature review) LWD controlled, gravel and cobble streams, with a D/d ratio between 0.1 and 1.0 (B.C.E. 1996, Church, 1992, Knighton, 1984). Within this context, research sites were to be selected partially on the basis of mean stream widths (bank to bank) between one to ten meters, mean gradients less than less than 10%, and gravel or cobble topologies (B.C.E., 1995). To eliminate any potentially significant confounding morphological variables like introduction of sediment, sites were to be rejected if they have bridges or other road crossing built upstream of the ROW test site. Hydrology, including, intermittent versus continuously flowing water was not used a decision criterion.

As a precautionary item against uncontrolled anthrpogenic influences preference was given to sites where minimal land use activity is present in the watershed upstream of the ROW. Moreover potential sites were rejected if there was current activity immediately upstream of the proposed site.

3.2.2 Selecting the Case Sites

Locating sites that met the stated criteria proved to be one of most challenging aspects of this research project, consuming significant time and energy. The first step in this process involved obtaining all available ROW mapping including BC Hydro access maps, as well as1:10,000 scale and 1:20,000 scale topographical maps. In addition, where digital mapping existed, BC Hydro's LapMap (a GIS type mapping and data tool) was also used. These sources identified where transmission powerlines crossed streams. Preliminary investigations with available information of site layout, fish presence, and morphological conditions were made to obtain a better description of the potential sites and select good candidates. These were listed and local

BC Hydro staff were questioned about the potential sites. Finally, each site was visited and assessed according to the stated criteria as to their suitability for this project.

The lengthy process described above involved an initial screening of approximately 1000 streams, subsequent visits to over 250 crossings throughout the province (often along very difficult access roads in remote locations) and final selection of 12 final case study sites which best fit the selection criteria. It should be noted that the original study proposal suggested using 16 case study sites. However, given the finite resources available and the difficulty in finding sites which met the criteria, 12 sites were deemed adequate for this project.

In the urban and developed areas of Vancouver Island and the Fraser Valley the most common reasons for rejecting potential sites was the lack of forested upstream controls, access roads upstream of a potential site, upstream logging and development, and stream widths in excess of those desired for the study. The latter was, provided the stream had a mean gradient of less than 10% and cobble or gravel topology, the variable for which maximum tolerance was given.

In less developed and rural areas, the most common reasons for rejecting streams was excessive stream width, access roads upstream of the site, and significant site modifications. In numerous cases, good potential sites had been recently converted to swamps, sloughs or fens, by beavers and their dam construction activities. In addition, sites were selected if they met all appropriate criteria except for possessing a downstream study section. In many cases, roads were located at the downstream edge of the ROW, and as such introduced confounding variable which rendered the downstream area invalid for comparison to the upstream control and the ROW sections.

As a result, the sites used in this study involve high and extra high voltage lines, ranging from 69 kV to 500 kV in a variety of configurations, including both wood and steel support structures. There was diversity in the size of the corridor and transmission line arrangements from single transmission powerline corridors 80 m wide, to triple system corridors (with mix of voltages) up to 300 meters wide. In addition, all case study sites have been managed since construction of the ROW. All the ROWs were built within the last 25 to 40 years.

3.2.3 Relevant Site Information

As discussed in the literature review, significant research has been completed to increase the body of knowledge concerning measuring riparian zone function. The ecosystem functions of riparian zones described by Gregory et al. (1991) can be grouped into four broader more descriptive categories: (1) energy flow (the amount of solar energy entering a stream), (2) stream hydrology, (3) bank stability and (4) habitat complexity. A variety of data collection techniques were used at each site to collect integrated information that informed each of these categories. Furthermore, this also involved collecting both empirical and nonempirical information to suggest the effect of current riparian management techniques on key riparian ecosystem functions. The information was then amalgamated and compared to more general ecosystem criteria and information from the literature to suggest the relative state of function of the riparian zone at each ROW. Each of the parameters will be further discussed according to the methods employed in measuring ecosystem function.

Energy Flow

The first riparian zone function studied, energy flow, was investigated by using variables that indicate the amount of solar energy striking the stream at each of the three segments of a case study site. The first variable measured to represent this function was water temperature. Data was collected using ONSET T-45 continuous temperature measurement and collection devices. All units were deployed using a trigger start (on site) that recorded data in degrees Celsius at 15-minute intervals, 24 hours a day. These data were then mathematically averaged to 4-hour intervals, filtered and graphed in an X-Y scatter plot using MSExcel software to display the five continuous warmest days of the data set. The data from the hottest day within that 5-day period was then plotted and graphed using the original 15-minute increment data recordings. Trends were suggested from both sets of graphs. In addition, trends results were compared to pertinent corresponding air temperature information.

Solar energy input was also assessed by measuring Photosythentic Photonic Flux Density (PPFD). As described by Messier and Puttonen (1995), instantaneous light measurements were taken across each site by two researchers moving sequentially and in tandem upstream through a site. The instantaneous readings were then pooled to calculate mean and range of the PPFD for each of the three segments of the study site. Light was measured in flux density (micromolm-2 s-1), using hand held digital read out Apogee Instruments Model QMSW quantum light meters. The majority of data collection occurred in the summer, during the dry and hot time of the year. However to be valid the light measurements as described, must be taken during dusk, dawn or overcast conditions to ensure more consistent and diffuse photons of light (Messier and Puttonen, 1995). As a result light measurements were taken at each site in the autumn when the water temperature meters were retrieved.

Stream Hydrology

The second riparian zone function studied was the effect of vegetation management on stream hydrology. This was investigated by measuring and describing three highly related variables. Erosion was estimated by the presence or absence of rills in each segment of the case study site.

The density of tall growing tree species across each segment was also determined choosing one stem as the center axis and measuring the distance from the center tree to the three closest tall trees by (Wells, 1998, pers. com.). In addition, the number of stems is documented for each tree, including the center tree. Using a standard calculation sheet the number of stems/hectare is calculated for the study area. It is critical that as many measurement plots are established as required to be representative of the site. Lastly, dominant vegetation species were identified and abundance estimates were made for each segment. The presence or absence of rills, vegetation density and community description variables were used as surrogates for the ability of the existing vegetation in intercepting precipitation and modifying hydrologic processes.

Bank Stability

The third riparian zone function studied was the effect of vegetation maintenance on stream bank stability. The effect of reduced bank stability can be either aggradation or degradation of the adjacent stream channel.

To assess the relative trends in the ability of the riparian zone across the segments of the case study site to maintain bank stability the BC Channel Assessment Procedure (BCCAP) and associated field handbook, including pertinent diagrams and charts, was employed (B.C.E., 1996B). This procedure involves a two-part process and calculates the relative level of disturbance longitudinally along a stream. First, the researcher establishes five transects across each stream segment and measures stream gradient between transects, using a hand held clinometer. The preferred location for the transects is at the downstream edge of pools, where thalweg depth is recorded In addition five representative sediment items are selected at each transect. The sediment items selected are those which the stream moves only at very high bank maintenance flows and are recognized by features such as being the largest in the area without moss and other organic matter growing on them. These are measured across the b-axis, averaged and compared with the average thalweg depth and stream gradient through a series of nomographs (in the BCCAP), to suggest the morphological description of the stream in question. Next, the researcher moves upstream through the study segment, measures and documents, based on stream type, the distance and level of aggradation and degradation observed. While the minimum length measured to document different disturbance levels is determined by the frequency with which conditions change, in uniform sections the maximum stream length recommended is six mean bank widths (Hogan et al., 1997). The resulting information describing the relative amount of stream aggrading, remaining stable or degrading is then summed to calculate the percentage of the study segment which is severely affected, moderately affected and/or stable (Appendix 1).

Habitat Complexity

The fourth riparian zone function studied was the effect of vegetation maintenance on habitat complexity, was determined by measuring the contributions of LWD from the adjacent riparian zone. In order to document the function of the LWD and the possible effect of vegetation management on LWD recruitment across a case study site, three separate parameters were either measured or described. First, each piece of LWD, defined as greater than 10 cm in diameter (B.C.E., 1996, B.C.E., 1996B), was measured through each study area. The number of pieces were then summed and averaged across the entire stream length through the study area, and expressed as number of pieces per meter of length of stream. Photographs were taken of representative reaches, habitats and associated LWD. The size and distribution of pools were also documented in the research site, including specific descriptions of undercut banks and side pools. Third, as the researchers moved through the site sketches were made of the stream condition through each study area. These diagrams include general stream path, orientation of LWD and associated pools, and significant morphological features including large boulders, braiding and side channels.

While the presence of an adequate volume of functioning LWD is critical for maintaining habitat complexity in LWD controlled streams, too much LWD can cause debris jams and become detrimental to habitat forming processes. Windthrow (trees that are pushed over by the wind) can form debris jams in streams and is often associated with streams located adjacent to cut blocks in working forests (BC Forest Practices Code, 1996). This potential impact of vegetation management activities was investigated by identifying if windthrow was present across a case study site. If observed at a case site each piece was counted and measured (including diameter of the pieces).

3.2.4 Collecting Site Data

An identical data collection procedure was employed at each of the 12 case study sites used in this study. The procedure involved obtaining information from three separate segments located sequentially along the case study sites and then comparing the results amongst each site. While the procedure employed in this work is similar to the work completed by Peterson in 1993, this project employed a downstream measurement site and focused on ecosystem function, rather than fish densities.

In order to set consistent stream reaches, the length of the stream passing through the ROW site was waded and measured. This was then designated as stream length, and colored flagging was placed at both the upstream and downstream edge of the ROW. Next we measured and marked one stream length downstream and one stream length upstream from the appropriate colored flagging. Temperature meters were triggered and deployed at the downstream edge of the most upstream study area, at the downstream edge of the ROW study area, and at the downstream edge of the most study segment. They were submerged by attaching them to large boulders with wire and marked with colored flagging to assist in retrieval. While not enclosed in any casing, they were placed under the substrate element to ensure shading. Visual observations confirmed that the case study site contained the same stream reach (B.C.E.,1996).

With the case study site delineated and temperature meters deployed, researchers then moved to the furthermost downstream edge of the case study site and applied the first step of BCCAP procedure (as described earlier) to establish the morphological description of the stream. Following that, we started again at the downstream edge of the case study site, and began moving upstream recording all data on separate data sheets for each of the three study segments. This time researchers measured and characterized numerous parameters: (1) the length of stream (with hipchain); (2) described and measured habitat units as well as pools and large woody debris; (3) sketched complete area (including habitat features and large woody debris); (4) documented the level of disturbance as per the second part of the BCCAP; (5) completed vegetation density measurements of all three study areas; (6) documented any evidence of rill erosion; (7) speciated and described tall growing, shrub layer and understorry vegetation extending 100 m at right angle; and (8) took representative photographs across the complete case study site.

3.2.5 Management Practices

The next component of the site evaluation was determining the actual vegetation management practices used at each site. This was completed in two steps. An analysis of BC Hydro's in-house document collection was conducted to provide work policies and practices and guided telephone interviews were conducted with BC Hydro transmission powerline technicians and vegetation biologists. Interviews were guided by an open-ended questionnaire (Appendix 3).The questions were divided into a short list of technical items concerning the vegetation management practices and maintenance cycles applied at a site.

Assessing the effect of documented management practices on the study sites completed final analysis. First, each site was evaluated independently by comparing vegetation management practices to similarities and differences among the variables representing ecosystem function. Second, a summary description was completed for each case study site, including any data suggesting a trend for an ecosystem function between the three case site segments. Third, the data for each function was compared across all sites by using appropriate XY comparisons including scatter plots and histograms. This process identified patterns among variables as well as suggested trends in ecosystem functions and generated some key findings.

3.3 Summary

In order to determine if vegetation management along ROWs can be integrated with maintaining functioning riparian zones the, case study method was applied in this research project. It was applied with experimental logic and involved collecting information about twelve separate cases study sites located throughout BC The resulting information about each site was used to provide detailed case descriptions and compare trends, based on riparian zone functions, between cases. The case study description and trends resulting from application of the methodology, are presented in Chapter 4.

CHAPTER 4
Case Study Results

4.0 Introduction

Case study data were collected, as per the methods described in Chapter 3, during the summer and fall of 1998. The process involved visiting each site once to collect the required site information and deploy the temperature meters. This was followed by a second trip later in the year, when trees still had leaves, to collect the temperature meters and light measurements. While the balance of the method worked as planned and was applied effectively, gathering water temperature and light data proved to be the most challenging components of the fieldwork. Of the twelve case study sites, two were dry when visited in the summer and thus had no water temperature data collected. For the remaining ten sites, five had all three meters collect data, two only had the upstream and ROW meter collect data and, the three remaining had only one meter collect data. The reasons for lack of success were launch failure, wire corrosion and subsequent breaking free of the meter, and internal battery failure. While the light meter procedure was effective for obtaining data, the warm sunny summer and fall enjoyed in 1998 made it difficult to obtain completely overcast conditions at all sites. Hence light data was not obtained at two sites.

The twelve case study sites are spread throughout the province of BC, as shown in Figure 2. Table 1 provides a summary of information describing the Case Study sites and shows that four cases are located on the east coast of Vancouver Island, three are located on the south coast of the BC mainland and five are located in the north.

Table 1 also presents site similarities and further supports the assertion presented in Chapter 3, that consistent site selection criteria were successfully applied to capture data from medium size streams, with a D/d ratio between 0.1 and 1.0. As a result, ten of the streams studied are either first or second order. Also they all have relatively short lengths, with seven of the streams between zero and ten kilometers long and the remainder between ten and twenty kilometers long. Although not presented in Table 1, because the criterion was not applied for site selection, most of the streams, (including the intermittent streams at Case Study 2 and Case Study 10) support fish populations.

To be relevant to this study, cases had to be located along electric transmission ROWs where vegetation management has occurred. Subsequently, none of the resulting case study sites are new electric transmission powerlines or corridors. The age of the sites used in the study ranged from five years to thirty years. The five year old site (Case Study 10) actually involves a wide and complex ROW that was first finished over twenty-five years ago but had a parallel component cleared and constructed five years ago. The remainder of the sites have been managed for a minimum of twenty years.

To reduce confounding variables, sites with any upstream bridge crossings were not selected. Four of the sites selected have no bridge crossing, while eight of the sites have bridge crossings located downstream of the ROW. Also nine of the twelve sites are in fairly broad and deep gullies, while the other three sites have minor depression associated with the small creeks. This is reasonable because larger gullies would make it more difficult to construct crossings and thus bridges would be less common. They are accessed less frequently and towers can be reached as effectively, and less costly, by using separate roads that end on either side of the gully.

Case Study	Stream Name	BC Region	Stream Order	Stream Length	Drainage Area	Site Age	Gully Present
1	Kelvin Creek	V.I.	2	10.4km	25.3km^2	25 yr	Yes
2	Currie Creek	V.I.	2	9.45km	11.6km^2	30 yr	No
3	Nile Creek	V.I.	2	16.65km	12.01km^2	25 yr	Yes
4	French Crk.Trib.	V.I.	1	3.2km	2.1km^2	30 yr	Yes
5	Noons Creek	F.V.	1	0.8km	0.35km^2	40 yr	No
6	Donegani Creek	F.V.	2	2.38km	1.25km^2	35 yr	Yes
7	Mahood Creek	L.M.	4	19.88km	19.43km^2	28 yr	Yes
8	Cluculz Creek	North	2	5.5km	8.38km^2	25 yr	Yes
9	Sweden Creek	North	2	12.4km	45.1km^2	25 yr	Yes
10	S. Sisters Creek.	North	3	16.5km	17km^2	5 yr	Yes
11	no name	North	1	Unknown	<1 km^2	20 yr	Yes
12	no name	North	1	Unknown	<1 km^2	20 yr	No

*V.I. = Vancouver Island; F.V. = Fraser Valley; L.M. = Lower Mainland

Table 1. Case Study Sites.

BC Hydro records were analyzed and the guided interviews were conducted during the spring and early summer of 1999. Because of travel constraints, four interviews were completed over the telephone, while one interview was conducted in person at a BC Hydro office. Record analysis provided information about vegetation management policy and site specific prescriptions. Interviews provided most of the practical site information including age, maintenance cycle, techniques and secondary uses.

Record analysis and interviews indicate BC Hydro is completing inventories of all stream crossings along all their electric transmission ROWs and placing that information into an integrated mapping system called LapMap. As of the spring of 1999, less than half of the information has been collected and entered onto LapMap, hence it was not available during the time of this study. Therefore it is impossible to quantify the representativeness of the study's stream sites in terms of all crossings along the complete BC Hydro transmission facility. The preliminary data shows that BC Hydro's 17,000 km of transmission lines crosses between 1750 and 2000 streams, of which the majority are in the same size range as the streams used in this study. Thus, findings from this study appear to be applicable to a significant number of riparian zones along BC Hydro ROWs.

This chapter presents the results obtained for the study. The results from record analysis and interviews are imbedded in each case study description. First, a case by case description, including vegetation management history, trends within the case, and photographs is provided. Second, a cross case summary of vegetation management and trends for each of the ecosystem functions is presented.

4.1 Case Studies

4.1.1 Case Study 1: Kelvin Creek

The first case study is located near Duncan on Vancouver Island and consists of an 85m wide ROW that crosses Kelvin Creek (Photos 1&2). Site access is from the south and stops 25m from the right bank with no bridge or other type of crossing. At the crossing, Kelvin Creek is a second order stream with a total drainage area of 25.3km^2, that flows through a broad, deep gully and is located within the Coastal Douglas Fir biogeoclimatic zone. The transmission support structures for the two 138kV circuits (one wood and one steel) are located on the gully crests and the powerlines do not sag deeply into the gully, providing some room for the growth of vegetation. The riparian vegetation across the ROW starts with a strip of topped red alder trees (on either creek bank) then gives way to the groomed ROW. Other uses are intermittent livestock grazing and motor biking.

Vegetation Management

The site has been managed every seven years since construction of the newer steel circuit in 1975. The predominant methods applied in the gully have been machine mowing and hand slashing of tall growing target species such as broad-leaf maple and conifers. Traditionally, riparian zone management included leaving the trees lining the stream bank. Over the last few years a prescription has been applied that involves planting Western red cedar, willow, red-elderberry, and red osier dogwood.

Riparian Ecosystem Function 1 - Energy Flow

The upstream control temperature meter was the only one successfully retrieved and downloaded. The ROW temperature meter failed to launch and the downstream meter was not found. The maximum diurnal water temperature range recorded was 17.0-19.25^{0}C (July 17, 1998). The ROW allows more light to access the stream with mean PPFD light levels of 155.18$_m$mols (upstream), 284$_m$mols (ROW) and 203.33$_m$mols (downstream).

Riparian Ecosystem Function 2 – Stream Hydrology

All three sites are heavily vegetated and display no signs of rill erosion anywhere inside the gully. The densities of tall growing trees are 8000stems/ha (conifer) in the upstream section, 15,000 stems/ha (deciduous) at the ROW and 11,000 stems/ha (mixed) downstream. The upstream and downstream sites have tall mature trees. Instead of tall trees the ROW is populated by juvenile trees or older tree clumps with multiple stems. Also the ROW has a dense understorey, described in Appendix 1, consisting of grasses, salmonberry, huckleberry, broom and red elderberry.

Riparian Ecosystem Function 3 – Bank stability

The two trends observed related to bank stability are a progressive decrease in mean depth from 57cm upstream to 40.8cm at the ROW to 19.75cm downstream, and an increase in D60 from 13.38cm upstream, to 13.39cm at the ROW to 20.0cm downstream. Further, all 3 stream segments had significantly eroded banks along their entire length.

Riparian Ecosystem Function 4 – Habitat Complexity

The trends for habitat complexity across the three stream segments is reduced pool volume from 60% deep pool in the upstream control, to 63% shallow pool (run) across the ROW, to 20% pool in the downstream section. This trend is correlated to a decline in LWD from 0.17pieces/m stream in the upstream section, to 0.05 pieces/m stream across the ROW, and 0.06pieces/m stream downstream. The LWD in the upstream segment results in complexity including bars, pools and undercut banks, but the ROW and downstream segments have less LWD, less complexity and much longer riffle stretches.

Photograph 1. Kelvin Creek and the Rightofway.

Photograph 2. Looking upstream through the Rightofway.

4.1.2 Case Study 2: Currie Creek

The second case study is located approximately 15 km west of Duncan on Vancouver Island and consists of a 185m wide, 238 kV ROW crossing Currie Creek (Photos 3&4) in the Coastal Douglas Fir biogeoclimatic zone. At the site Currie Creek is a small intermittent second order stream with a total drainage area of $11.6km^2$ spanned by one transmission powerline with steel support structures providing little overhead room for vegetation to grow. Access is from the east along with a bridge crossing at the downstream edge of the ROW. A decommissioned access road and bridge are located at the middle of the ROW. The predominant land use is forestry and active harvest sites are located by the site. Due to the presence of the bridge, and forest harvest activities along the stream a downstream study section was not applied at this case. Also, the pool distance and pieces of LWD at the old bridge crossing (center of ROW) were omitted from calculations. There is a large debris jam at the upstream edge of the ROW. Secondary uses are indirect forest harvesting, recreational motor biking and hunting.

Vegetation Management

The site has been managed every five years since final construction in 1975. The predominant methods have been machine mowing, hand slashing, and selective use of herbicides and girdling. No specific plans or techniques were applied in the riparian zone, until preparation of a site prescription in 1997. The prescription recommends girdling tall trees to encourage native low growing shrubs. There is no windthrow at the site.

Riparian Ecosystem Function 1 - Energy Flow

No temperature meters were launched because the channel was dry when the site was visited on July 22, 1998. The mean PPFD measurements were 16.64_{m}mols upstream and 122_{m}mols at the ROW. These results suggest the shorter vegetation along the ROW allows more light to strike the stream than the dense upstream vegetation canopy.

Riparian Ecosystem Function 2 – Stream Hydrology

Both sites are heavily vegetated and display no signs of rill erosion. Although the decommissioned access road down the middle of the ROW has exposed mineral soils there were no obvious signs of erosion. The upstream section has a mature second growth forest with a dense canopy, tall conifer trees and dense understorey. The groomed ROW has numerous shrubs (detailed in Appendix 1) no tall trees but several multiple coppice stems and juvenile young trees. The densities calculated for tall growing tree species are 10,000 stems/ha (conifer) upstream and 8000stems/ha (deciduous) across the ROW.

Riparian Ecosystem Function 3 – Bank stability

The data indicates that one trend in bank stability is that the ROW segment is two meters more narrow than the upstream segment. This is misleading because the difference can be explained by two measurements from the downstream edge of the segment where a large debris jam has widened the channel. There were no trends in mean gradient, D60 or mean depth. Another trend that was observed was an increase in amount of significant bank disturbance from 21% in the upstream section to 47% across the ROW segment.

Riparian Ecosystem Function 4 – Habitat Complexity

One trend in habitat complexity observed across the two sections is an increase from 39% pool habitat and no LWD in the upstream section (excluding debris jam) to 48% pool habitat and 0.05pieces LWD/m stream across the ROW. The increase in pool habitat through the ROW stream segment is often associated with old-growth root wads but in some cases, it is associated with undercut banks, covered by dense grasses and bushes.

Photograph 3. Currie Creek and the Rightofway.

Photograph 4. Looking upstream through the Rightofway.

4.1.3 Case Study 3: Nile Creek

The third case study is located near Qualicum Beach on Vancouver Island and consists of a 150m wide, 238 kV ROW crossing Nile Creek (Photos 5&6). At the site, Nile Creek is a third order stream with a drainage area of 12km^{2}, (within seven km of Georgia Straight) flowing through an irregular yet broad gully in the Coastal Douglas Fir biogeoclimatic zone. The metal support structures are located on the gully crests and although the powerlines sag into the gully there is room for trees to grow quite tall before being managed. Access is provided along an unpaved road that parallels the right bank but ends 150m upstream of the ROW at a water intake structure (upstream study segment). A portion of the upstream segment splits into two channels and those data were grouped for relevant calculations. Other uses are angling, walking, and salmon enhancement projects. There is no windthrow and the vegetation composition is presented in Appendix 1.

Vegetation Management

Being in the Qualicum Water Board, increased site environmental concern and as a result vegetation has been managed on a "as needed" basis since construction in the early 1980's. This involved topping, hand slashing and girdling trees as they threatened the powerlines. Hence, there are maple plants with multiple stems and hundreds of yet-to-fall girdled alder trees (10-15m tall) across the ROW. The site prescription, prepared in 1997, recommends topping of conifers, girdling and the planting of low growing species.

Riparian Ecosystem Function 1 - Energy Flow

There was a slight trend (0.5^{0}C) towards warmer water temperatures as daily diurnal ranges measured on July 28 were 12.25-13.75^{0}C upstream and 12.5-14.25^{0}C across the ROW. The downstream meter had broken free and no results were obtained. More light was measured on the

ROW, as the mean PPFD light levels were 90.7$_{m}$mols in the upstream section 199.3$_{m}$mols across the ROW and 75.25$_{m}$mols downstream.

Riparian Ecosystem Function 2 – Stream Hydrology

All three sites are heavily vegetated, as presented in Appendix 1, and display no signs of rill erosion. The upstream section has mature second growth trees. The ROW is partially groomed with numerous topped trees, multiple coppice stems or dense stands of red alder trees, 10-15m tall. The downstream section has a mature second growth forest with a dense canopy, tall conifer trees and dense understorey. The densities calculated for tall growing tree species are 257 stems/ha (conifer) in the upstream section, 29,700 stems/ha (mixed) across the ROW and 229 stems/ha (conifer) in the downstream section.

Riparian Ecosystem Function 3 – Bank stability

There were no trends suggested for stream width, mean depth, D60 or gradient. Although there is a debris jam in the middle of the ROW stream segment and significant erosion of the right bank the level of bank disturbance was lower in the ROW segment (31%) than in the upstream section (39%). The downstream segment had more highly eroded banks and 56% of its' length significantly disturbed.

Riparian Ecosystem Function 4 – Habitat Complexity

One trend in habitat complexity across the three segments is a steady reduction in pool habitat from 54% in the upstream segment to 34% across the ROW to 31% in the downstream section. Despite reducing pools the amount of LWD stays relatively constant across all three sites and is large old conifer trees. Although the LWD forming the debris jam in the middle of the ROW was included in relevant calculations it would be inundated only at high flows. There are few pools caused by undercut banks at the site.

Photograph 5. Nile Creek and the Rightofway.

Photograph 6. Looking upstream from the end of the ROW.

4.1.4 Case Study 4: French Creek Tributary

The fourth case study is located near Parksville on Vancouver Island and consists of a 125m wide, 238 kV ROW that crosses a tributary of French Creek (Photos 7&8). At the crossing, the creek is a small, shallow and continuously flowing first order stream (drainage area 2.1km^2) passing through a short, steep gully in a Coastal Western Hemlock biogeoclimatic zone. The steel ROW transmission support structures for the single circuit are located on the crest of the gully. The powerlines do not droop into the gully and trees can grow to a moderate height before requiring management. Access is east along a forestry road that crosses the creek about five km downstream of the ROW. The entire area was logged and natural regeneration has occurred within the last 25 to 40 years. The riparian vegetation across the ROW begins with a narrow strip of trees between 10 and 15 m tall that give way to the groomed ROW consisting of mixed berries, shrubs, grasses and young trees as presented in Appendix 1. There are several debris jams located along the creek. Other site uses include tree farming, hunting, motor biking and secondary harvesting. There is no windthrow at the site.

Vegetation Management

ROW vegetation has been managed every five years since final construction in 1975. Above the gully predominant methods have been machine mowing, slashing and selective application of herbicides. In the gully, the riparian trees are girdled as they approach tolerance limits, while the rest of the area has been slashed.

Riparian Ecosystem Function 1 - Energy Flow

Water moving through the site was subject to dramatic diurnal temperature fluctuations. The water temperature range recorded on August 13, 1998 was 14.0-16.0^{o}C upstream, 13.00-19.5^{o}C across the ROW and 14.0-23.0^{o}C downstream. The large increase in temperature was caused by debris jams creating large shallow pools that were then exposed to direct sunlight. The mean

PPFD levels increased from 4.0$_m$mols at the upstream section, to 24.0$_m$mols at the ROW and 18.8$_m$mols in the downstream section.

Riparian Ecosystem Function 2 – Stream Hydrology

All three sites are heavily vegetated and display no signs of rill erosion or impervious soils. The density of tall growing trees is 1283stems/ha (conifer) in the upstream section, 2459stems/ha (deciduous) at the ROW and 2166stems/ha (mixed) downstream. Upstream and downstream sites have densely spaced, moderately tall, second growth forests. All open spaces at the ROW are entirely covered by a very dense understorey of berries, grasses and shrubs, and are presented in more detail in Appendix 1.

Riparian Ecosystem Function 3 – Bank stability

There were no trends in mean width or mean gradient. One trend relative to bank stability that was observed was a decrease in mean depth from 47cm in the upstream segment, to 40cm across the ROW to 18cm downstream. D60 size did not follow this trend, but instead fluctuated from 17cm in upstream segment to 14cm at the ROW to 22cm downstream. The level of disturbance progressively decreased from 46% in the upstream segment to 30% at the ROW to no (0%) disturbance in the downstream segment.

Riparian Ecosystem Function 4 – Habitat Complexity

There is a trend for more pool habitat through the segments from 36% in the upstream site to 37% at the ROW to 53% in the downstream site. As alluded to, much of the downstream pools were associated with debris leading to heating of the water; further, the functional LWD found at all three sites is large and old.

Photograph 7. French Creek Tributary gully and vegetation downstream of Rightofway.

Photograph 8. Looking upstream through lower end of the ROW stream section.

4.1.5 Case Study 5: West Noons Creek

The fifth case study is directly north of Coquitlam and consists of a narrow (65m), 500kV ROW that crosses West Noon Creek (Photos 9&10) in the Coastal Western Hemlock biogeoclimatic zone. Access is from the east along a dirt road that crosses the creek downstream of the ROW. At the crossing, West Noons Creek is a first order stream with a moderately high gradient, total drainage area of 0.35km^2 that runs along the side of a ridge. The metal support structures for the two powerline are located back from the creek but provide little room for vertical growth of vegetation. Culverts impact the downstream section, thus no morphological data was used. The riparian community on the ROW is dense low growing species as well as tall growing species with coppice stems, as presented in Appendix 1. There is no windthrow but the upstream section is braided through large old growth LWD and there is a debris jam at the upstream ROW edge. Secondary uses are motor biking, walking and cycling along roads and paths.

Vegetation Management

The ROW has been managed every seven years since it was constructed in 1974. The predominant vegetation management method has been hand slashing and girdling of tall growing species. No management procedures have been applied explicitly to maintain the riparian zone. Upstream of the ROW the site has an old growth forest composed of large conifers that are estimated to be greater than 100 years old. The ROW section is groomed with shrubs, while the downstream section has red alder between 30 and 50 years of age.

Riparian Ecosystem Function 1 - Energy Flow

There was a 0.5^{0}C increase in temperature across the ROW but a recovery to above ROW temperatures within 65m downstream. The maximum diurnal water temperature range recorded on July 29, 1998 was 17.0-17.5^{0}C (upstream), 17.0-18.0^{0}C (ROW) and 16.8-17.5^{0}C (downstream). The mean PPFD light levels increased from 3.0$_{m}$mols upstream to 29.0$_{m}$mols at the ROW and decreased back to 1.0$_{m}$mols at the downstream section.

Riparian Ecosystem Function 2 – Stream Hydrology

All three sites are heavily vegetated and display no signs of rill. There is a notable difference in the observed densities of tall growing trees 1283 stems/ha (conifer) in the upstream section, 23,565 stems/ha (deciduous) at the ROW and 356 stems/ha (mixed) in the downstream sections. The ROW also has a dense understorey of willow, salmonberry and huckleberry grasses as well as modified cottonwood, red alder, maple and conifers.

Riparian Ecosystem Function 3 – Bank stability

The braided channels in the upstream site were combined for the following calculations: they suggest gradient increase from 3.17% upstream to 5.75% across the ROW. D60 at the sites increases from 0.14m upstream to 0.20m at the ROW. There is no trend in mean depth or width, but reach disturbance did increase from 0% upstream (heavy-forested area) to 85% at the ROW segment. Disturbance at the ROW is a function of degradation.

Riparian Ecosystem Function 4 – Habitat Complexity

With habitat complexity, the volume of pools drops from 46% in the upstream segment to 35% across the ROW. This is accompanied by a reduction in LWD from 1.57pieces/m stream upstream to 0.06pieces/m stream across the ROW. Upstream it is probable that there is too much LWD and is impacting site morphology. Conversely, the ROW stream segment is wetted bank to bank with only a few pieces of LWD at its most upstream end. Habitat complexity and pools in this segment are most often associated with boulders, bedrock, and in a few cases, undercutting of banks that are protected by willow trees.

Photograph 9.	Vegetation across Rightofway at Noons Creek

Photograph 10.	Looking upstream from the lower end of the ROW stream section.

4.1.6 Case Study 6: Donegani Creek

The sixth case study is located near Maple Ridge and consists of 85m wide 500kV ROW (Photos 11&12). Access is from the northeast along an overgrown road and bridge at the downstream edge of the ROW. At the crossing Donegani Creek is a second order stream with a total drainage area of 1.25km^2 zigzagging between towers, through a gentle gully in the Coastal Western Hemlock biogeoclimatic zone. The steel support structures for the single circuit are on the gully crests, but the powerlines restrict vertical growth of vegetation. There is a large boulder in the ROW stream segment but it does not constitute a reach break. There is some windthrow at the end of the downstream site and a debris jam at the upstream edge of the ROW. The riparian vegetation across the ROW is composed of coppice stems, juvenile trees, dense understorey, and has no secondary uses.

Vegetation Management

The site has been managed regularly every five years since final construction in 1973. The predominant method applied across the ROW is hand slashing of tall growing target species such as broad-leaf maple and selective use of herbicides. The site was last slashed in 1997 and debris is evident throughout the ROW. No special efforts have been made to maintain riparian ecosystem function. There are many multiple coppice stems of maple, cottonwood, red-alder and conifers as well as understorey of willow, red elderberry, mixed berries and a dense ground layer of grasses as presented in Appendix 1.

Riparian Ecosystem Function 1 - Energy Flow

The diurnal water temperature ranges recorded on July 29, 1998 were 17.75-22.0^{0}C in the upstream segment, 17.75-22.25^{0}C on the ROW and 17.0-21.75^{0}C downstream. They indicate a minimal (0.5^{0}C) increase in the diurnal temperature range through the ROW that is recovered to above ROW water temperatures a relatively short distance (80m) downstream. The mean PPFD results were 11.5$_m$mols (upstream), 40.13$_m$mols (ROW) and 44.5$_m$mols (downstream). These levels also suggests less sunlight is allowed to strike the upstream study segment than the ROW or downstream segment.

Riparian Ecosystem Function 2 – Stream Hydrology

All three sites are heavily vegetated and display no signs of rill. The observed densities of tall growing trees are 1875 stems/ha (conifer) in the upstream section, 6833 stems/ha (mixed) along the ROW and 3996 stems/ha (mixed) downstream. While the upstream site is composed of tall mature trees the ROW has more multiple stems, shrubs and juvenile trees. The downstream section has less of a gully, a vegetation community of red alder, cottonwood, maple and conifers and ends 80m downstream at a copse (Appendix 1).

Riparian Ecosystem Function 3 – Bank stability

Although the stream passes under a large bridge located at the downstream edge of the ROW it appears to have had minimal impact on stream morphology and as a result data from the downstream segment was compared to the upstream segments. The only trend relative to bank stability was a decrease in disturbance from 31% at the upstream segment to 0% at the ROW, increasing again to 46% disturbance for the downstream segment.

Riparian Ecosystem Function 4 – Habitat Complexity

The results for habitat complexity demonstrate the close relationship between LWD and complexity as pool area increases from 48% upstream, to 62% at the ROW and decreases to 46% downstream. This is correlated to an increase in LWD from 0.043pieces/m stream upstream, to 0.12 pieces/m stream at the ROW and a decrease to 0.05pieces/m stream downstream. All LWD is embedded and originated from an old growth conifer forest.

Photograph 11. ROW and stream facing downstream section at Donegani Creek

Photograph 12. Looking upstream in the middle of the ROW stream section.

4.1.7 Case Study 7: Mahood Creek

The seventh case study is located in Surrey and consists of a 130 m wide, 500 kV ROW that crosses Mahood Creek (Photos 13&14). The ROW land is privately owned and access is on foot from either side of the stream. At the crossing Mahood Creek is a fourth order stream with a total drainage area of 19.4km^2 flowing through a broad gully in the Coastal Western Hemlock biogeoclimatic zone. The creek forks into two channels upon reaching the ROW but returns to one deeper channel near the downstream edge of the ROW. The steel structures for the three powerlines are located on the gully crests and provide extensive room for vertical growth of vegetation. Moving out from the edge of the stream, the riparian zone consists of a small forested area of tall red-alder trees, willow and cottonwood. This extends for 20 m and gives way to the groomed ROW composed of low growing grasses, hardhack and salmonberry as presented in Appendix 1.

Vegetation Management

The ROW has been managed every seven years since construction in 1979. The methods used to maintain vegetation have been machine mowing, slashing and girdling of tall growing target species (such as broad-leaf maple, cottonwood, conifers). Traditionally trees adjacent to the stream have been retained until they pose a hazard to the powerline before being topped or cut. The site is in the second year of a plan to cut tall growing trees and plant low growing vegetation such as willow, elderberry and red osier dogwood.

Riparian Ecosystem Function 1 - Energy Flow

The downstream control temperature meter was the only one successfully retrieved and downloaded. The ROW temperature meter did not launch properly, while the battery failed in the upstream temperature meter. The maximum water temperature range was 18.75-20.0^{0}C, recorded on July 28, 1999. The PPFD levels were of 34.9$_m$mols (upstream), 65.10$_m$mols (ROW) and 52.8$_m$mmols (downstream) indicating more light at the ROW.

Riparian Ecosystem Function 2 – Stream Hydrology

All three sites are heavily vegetated and display no signs of rill. The observed densities of tall growing trees are 2005 stems/ha (mixed) in the upstream segment, 15,000 stems/ha (deciduous) across the ROW and 11,000 stems/ha (mixed) downstream. The upstream and downstream communities are tall mature trees whereas the ROW has few trees. In an urban setting hydrology is also impacted by development and impervious surfaces.

Riparian Ecosystem Function 3 – Bank stability

A large gravel bar has recently been deposited at the upstream edge of the ROW and while both banks are experiencing lateral erosion, the right bank (no tall vegetation) appears to be more at risk. Data for the two channels across the ROW were pooled and compared to the other segments. The comparison reveals that while no significant disturbance was present in the upstream or downstream stream segment, branching through the ROW has lead to significant disturbance of 42% of the ROW segment.

Riparian Ecosystem Function 4 – Habitat Complexity

The trend in habitat complexity is for more pool habitat and more LWD upstream and downstream of the ROW. The pool results are 82%(upstream), 55%(ROW) and 85% downstream while LWD results are 0.04 pieces/m stream (upstream), 0.02 pieces/m stream (ROW) and 0.08 pieces/m stream (downstream). Although the pools in the upstream and downstream segments are deeper, the trend is confounded because flow through the ROW is separated into two channels.

Photograph 13. East side of ROW with groomed section and riparian trees.

Photograph 14. Looking upstream in the middle of the ROW stream section.

4.1.8 Case Study 8: Cluculz Creek

The eighth case study is located west of Prince George, in the Sub-Boreal Spruce biogeoclimatic zone, and consists of 100m wide, 500kV ROW crossing Cluculz Creek (Photos 15&16). Access is west along a roadway that ends three quarters of the way down the gully. At the crossing, Cluculz Creek is a second order stream with a total drainage area of 8.38km^2 winding through a complex gully with a very steep right bank and gentle left bank. The support structures for the single transmission circuit are on the gully crest but provide little room for vegetation to grow vertically. No windthrow or debris jams are at the site. The riparian vegetation community at the ROW has tall growing trees and an understorey of willow, berries and salal (Appendix 1). Site secondary uses are motor biking, hunting and intermittent livestock grazing.

Vegetation Management

The ROW, except for the gully, has been managed every 15 years, by mowing, slashing and herbicide application, since construction in 1978. In the gully, vegetation is cut only when a tree grows too close to the powerline. The upstream section has been harvested (selectively) within the last 30 years but still has a mature riparian community of conifers and cottonwood trees. Although the lower one-third of the right bank of the ROW is very steep and supports little vegetation, the remainder of the ROW has a dense mixed community with trees up to 15m tall. The downstream section has a gentle gradient and supports a mature riparian community dominated by pine, spruce and cottonwood.

Riparian Ecosystem Function 1 - Energy Flow

The water temperature meter for the downstream section failed to launch properly. The other two meters worked properly and recorded drastic temperature fluctuations. The diurnal water temperature ranges recorded on August 13, were 12.25-21.75.0^{0}C in the upstream section and 12.25-24.25^{0}C across the ROW. The large increase in temperature is explained by large shallow stretches flowing over bedrock with little shading. The PPFD levels 153.36$_m$mols upstream, 284.73$_m$mols at the ROW and 203.3$_m$mols downstream, were collected during mixed overcast skies and suggest more sun strikes the ROW.

Riparian Ecosystem Function 2 – Stream Hydrology

All three sites are heavily vegetated, except where the steep slope prevents vegetation becoming established. These steep banks of the gully at the ROW have signs of erosion and sloughing and prevent vegetation from attaining a foothold. The densities of tall growing trees are 6833 stems/ha (conifer) in the upstream section, 23,565 stems/ha (mixed) across the ROW and 943 stems/ha (mixed) downstream. The upstream and downstream densities reflect tall mature trees while the ROW has no tall trees.

Riparian Ecosystem Function 3 – Bank stability

One trend related to bank stability was that the ROW segment was 2 m narrower than the upstream or downstream segments. There was also a trend for an increase in gradient from 1.0% upstream to 1.25% at the ROW to 1.5% downstream that matched an increase in stream disturbance from 48% upstream to 63% at the ROW and 83% downstream.

Riparian Ecosystem Function 4 – Habitat Complexity

The information for the downstream section was accidentally destroyed. The other two segments show a reduction from 50% pool habitat upstream to 34% pool habitat across the ROW. Correspondingly LWD reduces from 0.05 pieces/m stream upstream to 0.01 across the ROW. Anecdotally, the downstream section had similar morphology to the ROW including significant stretches of exposed bedrock and little LWD.

Photograph 15. The east side of ROW with access road and mixed vegetation.

Photograph 16. Looking upstream in the middle of the ROW stream section.

4.1.9 Case Study 9: Sweden Creek

The ninth case study is located west of Prince George and consists of a 100m wide, 500kV ROW that crosses Sweden Creek (Photo 17&18). Site access is from the west along a road that stops about 1.5 km away from the crossing. At the crossing, Sweden Creek is a second order stream with a total drainage area of 45.1 km^2 flowing through a large, broad gully in the Sub-Boreal Spruce biogeoclimatic zone. The metal support structures for the transmission powerline extend into the gully and provide little room for vegetation growth. The upstream section was selectively logged between 10 and 25 years ago and the vegetation across the ROW, detailed in Appendix 1, is sparse and provides no overhead cover to the shallow stream. Although BC Hydro built a wood bridge at the site in 1996, it has since washed away. The transportation of agricultural machinery, a secondary use of the site, is being accomplished by fording the stream, leading to erosion and as a result, the downstream morphological data were not used in analysis.

Vegetation Management

The ROW has been maintained every 15 years since construction in 1978. The methods used have been machine mowing and hand slashing of tall growing trees such as spruce and cottonwood. To date these techniques have also been applied throughout the riparian zone. BC Hydro staff now plan to change practices at the site by allowing trees in the gully to grow and girdling them only when they come too close to the powerline.

Riparian Ecosystem Function 1 - Energy Flow

The water temperatures recorded moving downstream suggests a minimal (0.5^{0}C) increase in the diurnal temperature range through the ROW that is negated by traveling one study reach (330m) downstream. The diurnal water temperature ranges recorded on August 13, 1998 were 12.0-20.5^{0}C in the upstream segment, 11.5-21.0^{0}C across the ROW and 11.5-19.5^{0}C downstream. The

PPFD levels were also higher on the ROW as the results were 51.33$_{m}$mols upstream ROW, 69.5$_{m}$mols across the ROW and 34.33$_{m}$mols downstream.

Riparian Ecosystem Function 2 – Stream Hydrology

All three sites are heavily vegetated but the bridge crossing at the downstream edge of the ROW show signs of rill erosion. The observed densities of tall growing trees are 28,512 stems/ha (mixed) in the upstream section, 204,073 stems/ha (mixed) across the ROW and 8019 stems/ha (conifer) downstream. The upstream site is composed of a mix of tall mature and juvenile trees while the ROW has a number of plants with multiple stems. The ROW section has a very dense covering of grasses and other low growing species.

Riparian Ecosystem Function 3 – Bank stability

There were no trends in mean depth, D60, gradient across the sites or level of disturbance. One trend that was observed was mean width which increased from 3.8m in the upstream segment to 4.8m across the ROW. Also degradation is the dominant mode of disturbance in the bottom half of the ROW segment and the downstream segment.

Riparian Ecosystem Function 4 – Habitat Complexity

There was no trend between the upstream segment and the ROW segment in terms of the amount of pool habitat. However, there was a trend across all three of the sites for an increase in LWD from 0.06 pieces/m stream in the upstream section to 0.08 pieces/m stream across the ROW to 0.12 pieces/m stream downstream. The LWD in the upstream segment and across the ROW was composed of large old growth conifers well embedded in the banks. Although LWD in the downstream segment often spanned across both banks and was associated with small woody debris it did not create much pool habitat.

Photograph 17. The vegetation, and stream across the ROW.

Photograph 18. Looking downstream at the lower end of the ROW stream section.

4.1.10 Case Study 10: South Sisters Creek

The tenth case study is located near Quesnel and consists of a 300m wide, 500kV and 230 kV ROW that crosses Kelvin Creek (Photo 19&20). At the crossing, South Sisters Creek is a third order intermittent stream with a total drainage area of $17km^2$, flowing through a deep gully, in the Interior Douglas Fir biogeoclimatic zone. The corridor is occupied by three 500kV powerlines on steel structures and one 230 kV powerline supported by wooden structures. The gully provides moderate room for vegetation to grow before threatening the powerlines. The land is privately owned, with approximately one third of the ROW used for cattle grazing, and access is from the south. Because of cattle and road impacts, the bottom 70m of the ROW and the downstream segment were not used in morphological analysis. The ROW riparian vegetation community is presented in Appendix 1. The vegetation in the upper 200m of the ROW is dense and diverse, whereas in the lower 100m it is sparse. There is no windthrow at the site.

Vegetation Management

Although, the majority of the circuits passing through this corridor were constructed between 20 and 25 years ago, the most recent addition was a 500kv powerline built along the downstream side of the ROW in 1994. The ROW, to the upper edge of the gully, is mowed every ten years by BC Hydro. Vegetation in the gully is either maintained by private landowners, or BC Hydro girdles and cuts trees as they approach the powerlines.

Riparian Ecosystem Function 1 - Energy Flow

No temperature meters were launched because the channel was dry when the site was visited on August 16, 1998. The mean PPFD levels were 61.67_{m}mols at the upstream section, 53.92_{m}mols at the ROW and increased to 92.42_{m}mols at the downstream section.

Riparian Ecosystem Function 2 – Stream Hydrology

Although all three sites are heavily vegetated, the area associated with the access road and bridge crossing at the downstream edge of the ROW show signs of rill erosion. The observed densities of tall growing trees are 1708 stems/ha (conifer) in the upstream section, 18,042 stems/ha (mixed) along the ROW and 891 stems/ha (conifer) downstream. The upstream site is composed of a mix of tall mature trees. The ROW is densely vegetated with many coppice stems and has a dense understorey. The downstream site supports spruce, pine and deciduous trees and a dense understorey.

Riparian Ecosystem Function 2 – Bank Stability

There are no trends between the upstream and ROW stream segments in mean width, mean depth, mean gradient or D60. One trend that was observed was an increase from 0% significant disturbance in the upstream section to 19% disturbance across the ROW (excluding habitat below the bridge crossing) and both sections have sound stream banks.

Riparian Ecosystem Function 4 – Habitat Complexity

There was no trend in habitat distribution (amount of pools) between the upstream and the ROW. However, when the data from all three segments is used there is a increase in LWD from 0.16pieces/m in the upstream section and a similar amount of 0.13pieces/m stream across the ROW up to 0.56pieces/m in the downstream section. The LWD upstream and across the ROW is composed mostly of large old conifer debris that is functioning and well embedded in undercut banks. It should be noted that some potential LWD in the upstream section has been cut by chainsaw and removed thereby reducing the amounts potentially observed. Downstream, the LWD was smaller (10-20cm), accompanied accumulations of small debris and did not often contribute to forming pools.

Photograph 19. The ROW, creek and vegetation looking north.

Photograph 20. Looking upstream through the middle of the ROW stream section.

4.1.11 Case Study 11: no name creek

The eleventh case study is located between Chetwynd and Tumbler Ridge and consists of a 60m wide, 238 kV ROW that crosses a no name creek on Elephant Ridge (Photo 21 & 22). Access is obtained along a BC Hydro access road that has a bridge crossing at the lower end of the ROW and parallels the electric transmission corridor. No name creek is a small shallow perennial first order stream with a small gentle gully that occurs in the Northern White Spruce biogeoclimatic zone. The creek is spanned by one powerline with wooden support structures and provides very little room for vegetation to grow before it becomes a safety problem. The riparian vegetation across the ROW is described in Appendix 1 and consists of a dense understorey, composed almost exclusively of grasses, with a few taller shrub and tree species. While the predominant land use is forestry, there are no active harvest sites near the ROW. Due to the presence of the bridge and a steep reach break downstream of the ROW a downstream study section was not applied at this case, leaving two 60m long research segments to compare data. There is no windthrow at the site but there is a debris jam at the upstream edge of the ROW. The site is located in a remote location and is used for hunting and trapping.

Vegetation Management

The site has been managed every 15 years since final construction 30 years ago. Traditionally the ROW was machine mowed, and in some cases this has left portions of the corridor in an almost tree free condition. More recently certain areas, including around riparian areas, have been cut at waist height in order to create winter browse for large ungulates. These animals now maintain the vegetation in these areas by continually eating trees and bushes, thereby pruning the vegetation and keeping it at a safe height.

Riparian Ecosystem Function 1 - Energy Flow

The upstream temperature meter worked properly but the ROW meter failed to launch properly. The maximum diurnal water temperature range recorded at the upstream site occurred on August 18, 1998 and was 7.5-11.0^{0}C. Poor light conditions (sunny and scattered clouds) at both site visits prevented the collection of sunlight data.

Riparian Ecosystem Function 2 – Stream Hydrology

Both sites are heavily vegetated but exposed soils at the downstream edge of the ROW could lead to rill erosion. The upstream section has a small, incised gully but has smaller second growth spruce forest above the gully. The ROW is groomed with some multiple coppice stems and some young trees. The densities calculated for tall growing tree species are 74,735 stems/ha (conifer) in the upstream control and 4395 stems/ha (deciduous) across the ROW.

Riparian Ecosystem Function 3 – Bank stability

The mean width of the upstream section is 1.77m while the ROW segment is much wider at 2.93m. There are no trends apparent between mean depth, D60 or reach disturbance. The upper section has a gradient of 7.33% while the ROW is gentler at 5.67%.

Riparian Ecosystem Function 4 – Habitat Complexity

One trend across the two stream segments is a reduction in pools from 25% upstream to only 13% pool habitat across the ROW stream segment. In addition, the ROW is dominated by a long continuous riffle while the upstream section has more complexity and alternating habitats. LWD also decreases moving downstream (excluding the debris jam) from 0.20 pieces/m stream upstream to 0.02 pieces/m stream across the ROW and in both cases invariably involves pieces of conifer between 10 to 30cm in diameter.

Photograph 21. The ROW looking south from the left bank of the creek.

Photograph 22. Looking upstream from the middle of the ROW.

4.1.12 Case Study #12: no name creek

The twelfth case study is located between Chewtynd and Tumbler Ridge on and consists of a 60m wide, 238 kV ROW that crosses a no name creek on Elephant Ridge (Photo 23&24). It is very close in distance and similar in size to Case Study 11, but also has many different attributes. Access is obtained along a BC Hydro access road that has a small, rarely used ford crossing at the upper end of the ROW and parallels the electric transmission corridor. No name creek is a small perennial first order stream in a small gentle gully that occurs in the Northern White Spruce biogeoclimatic zone. The creek is spanned by one powerline with wood support structures that prevents trees from growing very tall. Riparian vegetation across the ROW is described in Appendix 1 and consists of bunches of red alder and willow that line the creek and an understorey composed almost exclusively of grasses. Due to the presence of a large beaver dam at the downstream edge of the ROW a downstream study section was not applied at this case, leaving an upstream segment 42m long and a 72m long ROW stream segment. There is no windthrow at the site but there are debris jams upstream of the ROW. The site is located in a remote location and other uses include hunting and trapping.

Vegetation Management

As with Case Study 11 this site is managed every 15 years and was constructed 30 years ago. As an alternative to traditional machine mowing, which has left large portions of the corridor in an almost tree free condition, this site has also more recently been managed to integrate the needs of large ungulates with the needs of BC Hydro electrical transmission facility. Vegetation is cut at waist height to allow the foraging and eating activities of moose and elk to prune the vegetation and maintain it at safe limits from the powerline.

Riparian Ecosystem Function 1 - Energy Flow

The temperature meters recorded an increase in water temperature as it moved downstream through the ROW stream segment. On August 18, 1998 the maximum diurnal water temperature range recorded upstream of the ROW was 9.5-15.0^{0}C, while across the ROW the water temperature range recorded was 9.5-18.5^{0}C. Poor light conditions (sunny and scattered clouds) on both visits prevented light data collection.

Riparian Ecosystem Function 2 – Stream Hydrology

Both sites are heavily vegetated and display no signs of rill erosion. The upstream section has a small encised gully but has a second growth spruce forest above the gully. The densities calculated for tall growing tree species are 8000stems/ha (conifer) in the upstream control but very few young deciduous stems across the ROW. Although, the ROW has no tall trees, the riparian zone is heavily vegetated with lower growing species.

Riparian Ecosystem Function 3 – Bank stability

There are no trends between mean width, mean depth or D60. The upstream section has a higher gradient at 5.25% than the section through the ROW at 4.42%. One large difference was while 71% of the upstream section was significantly disturbed only 10% of the ROW segment was significantly disturbed. Upstream disturbances are most often due to boulders, which block the narrow gully and deflect water against either bank.

Riparian Ecosystem Function 4 – Habitat Complexity

While there is no trend involving pool habitat the lower section has more LWD. The ROW section has 0.07 pieces/m stream whereas the upstream section has 0.02 pieces/m stream. The upstream section ended at a large debris jam 42m upstream of the ROW.

Photograph 23. The ROW and crossing looking north along the corridor.

Photograph 24. Looking upstream from the middle of the ROW.

4.2 Case Summaries

Although each case study site has a unique set of parameters such as topography, location in the province, powerline configuration, growth rates, and stream size there are some common themes concerning the impacts of vegetation management on the riparian zone ecosystem. A summary of information about vegetation management and ecosystem function is presented Table 2. This section of the thesis elaborates on the information presented in Table 2 by identifying patterns that are common across the case studies.

4.2.1 Vegetation Management

The interviews and record analysis completed for this study, revealed that a limited number of vegetation maintenance techniques are used across the BC Hydro transmission facility. At all sites vegetation management occurs to prevent the growth of tall growing tree species into the overhead powerlines. The methods which are applied can be grouped according to two different themes: (1) cut the vegetation when it is young and small, where re-sprout often occurs or, (2) wait and cut it when it becomes larger, taller and less likely to re-sprout.

In most cases the vegetation management targets are tall growing species. While all coniferous tree species are managed, there are also many quickly growing deciduous target tree species including black cottonwood (*Populus trichcarpa*), big-leaf maple (*Acer macrophylum*), red alder (*Alnus rubra*) and paper birch (*Betula papyrifera*).

Case Study	Vegetation Management	Trends for Ecosystem Functions (across the ROW) Energy Flow	Hydrology	Bank Stability	Complexity
1	-mowed, cut -leave strip	-increase light	-no trends	-decrease depth -increase D60	-decrease pools -decrease LWD
2	-mowed, cut -no leave strip	-increase light	-no trends	-increase width -increase in sig. Disturbance	-increase pool -increase LWD
3	-girdle, cut, top -tall,dense,veg.	-increase temp -increase light	-no trends	-decrease sig. Disturbance	-decrease pool
4	-slash, girdle -leave strip	-increase temp -increase light	-no trends	-decrease depth -decrease sig. Disturbance	-increase pool
5	-mow,cut,girdle -no leave strip	-increase temp -increase light	-no trends	-increase slope	-decrease pool -decrease LWD
6	-slash -no leave strip	-increase temp -increase light	-no trends	-increase sig. Disturbance	-increase pool -increase LWD
7	-top,cut,slash -leave strip	-increase light	-no trends	-increase sig. Disturbance	-decrease pool -decrease LWD
8	-girdle,slash -mixed veg.	-increase temp -increase light	-no trends	-decrease width -increase slope -increase sig. Disturbance	-decrease pool -decrease LWD
9	-girdle,slash -mixed veg.	-increase temp -increase light	-no trends	-increase width	-increase LWD
10	-girdle,slash -tall,dense,veg.	-increase light	-no trends	-increase sig. Disturbance	-no trends
11	-mow, cut -no leave strip	-no data	-no trends	-increase width -decrease slope	-decrease pool -decrease LWD
12	-mow, cut -no leave strip	-increase temp	-no trends	-decrease slope -decrease sig. Disturbance	-increase LWD

Table 2. Vegetation Management And Ecosystem Function Trends.

The frequency of vegetation maintenance differs according to the growth rates of a particular area. In some southern and northern coastal areas aggressive tree species can grow up to six m per year and maintenance occurs every two years. In the north and southern interior areas even trees with aggressive growth require a fraction of maintenance used on the coast and are cut every fifteen to twenty years.

At sites with more room for vegetation to grow before it threatens powerlines, such as Nile Creek (Case Study 3), BC Hydro maintenance staff groom to the edge of the gully by cutting trees when they are young and low to the ground. Within the gully, trees are often allowed to grow until they threaten a powerline before being cut. At five of the twelve sites the riparian vegetation along the ROW included narrow strips of trees running along the sides of the creek. The increased tall tree canopy at these sites provides some shade and can, if left long enough, provide some smaller pieces of LWD.

In some cases herbicides are sometimes applied to control target vegetation. But herbicide use is limited to tree specific application either as an adjunct to slashing or girdling, or independently by capsule injection or foliar spray. Broadcast herbicide use is not applied along any BC Hydro powerlines. According to BC regulations governing the use of pesticides, herbicide usage is limited to 10 m away from standing water (BC Hydro 1997a).

The interviews also suggest that there is increased recognition of the need to reduce frequency and magnitude of incursions into the riparian zone. The preferred method now selected to reduce impacts is girdling, which involves waiting for trees to approach tolerance limits and then cutting a continuous strip through the bark, around the tree. When done properly girdling kills the tree and it then falls to the ground.

Tree topping is another method which has been used to manage tall trees in riparian zones. As the name indicates, this involves simply cutting the top of a tree off and allowing re-sprout. While this method has many short term advantages; it can sometimes cause increased risk to a powerline (quick regrowth). Topped trees have a higher potential of failure because re-growth is not well attached and increases the risk falling limbs and debris. Maintenance staff use this method only after assessing the risks (to the public and the powerline) associated with a site.

In the past vegetation maintenance methods were selected for given stretches of powerline and then applied according to a schedule determined by prior experience. For example, a section of powerline would be mowed or slashed from point a to point b, every five years. In this process work was accomplished according to tried and true past practices and schedules.

In 1997 BC Hydro began changing its electric transmission powerline vegetation maintenance approach and processes. This is being done to be more selective in treatments and focus more resources at problem areas while shifting resources away from areas that pose less of a threat to the powerlines (BC Hydro 1997a). The new approach to vegetation management also provides a vehicle that allows for site sensitivities to be integrated with site work plans.

BC Hydro's new vegetation management process depends on improved mapping, computer technology and staff visits to complete a site inventory, define work requirements (by species, growth rate and topography) and site sensitivities. These factors are then integrated to prepare a site specific work plan, called a prescription. In many cases riparian zones have different sensitivities and therefore their prescriptions are different than adjacent areas on the corridor. An example of this is in northern BC, near Case Study sites 11 and 12, where areas along the electric transmission have been managed to create wildlife browse (Stacey, 1998).

4.2.2 Ecosystem Function 1: Energy Flow

The methods applied in this study assured that the temperature data used was from the hottest day recorded. The summer of 1998 was extremely warm for extended periods of time, with no precipitation. As a result, the water temperature data reflects extreme and almost worst-case conditions.

The first trend observed at the case studies was for more sunlight to strike the ROW study section than either the upstream section or the downstream. At all sites where light measurements were taken, more light was measured across the ROW than at the upstream section. At eight of the ten sites where light measurements were collected light measurements were higher along the ROW than the downstream section.

The second trend observed at the 7 case studies, where sufficient data was collected to compare above ROW to ROW, water temperatures increased by 0.0 to 3.5^{0}C across the ROW. Further, of the four sites where data was also collected below ROW, three sites had streams cool to or near to upstream temperature levels within one stream segment length downstream (Table 3). Of the sites that recorded increases, Cases 4 and 8 experienced the most dramatic temperature changes and Case 8 was the only site where water temperatures approached levels lethal to fish (24.25^{0}C was recorded on August 13, 1998). At Case Study 8 temperature increases were due to the presence of very shallow pools and riffle flowing (for long stretches) over fully exposed bedrock through the ROW stream section. At Case Study 4 increases in temperature were caused by broad, shallow pools exposed to direct sunlight.

Site	Upstream diurnal range	ROW diurnal range	Downstream diurnal range	max. change at ROW	*difference downstream
3	12.25-13.75	12.5-14.25	N/A	+0.5	N/A
4	15.0-16.0	13.0-19.5	14.0-22.0	+3.5	+6.0
5	17.0-17.5	17.0-18.0	16.5-17.5	+0.5	0.0
6	17.5-22.0	17.0-22.0	17.0-21.5	0.0	-0.5
8	12.5-22.0	12.5-24.25	N/A	+2.5	N/A
9	11.5-20.5	11.5-21.0	11.5-19.5	+0.5	-1.0
10	9.5-15.0	95-18.0	N/A	+3.0	N/A

* = difference between maximum temperature upstream of ROW and maximum temperature for segment downstream of ROW

Table 3: Diurnal Temperatures

4.2.3 Ecosystem Function 2: Hydrology

The trends observed among parameters selected to describe hydrology suggest this function has not been compromised at any of the Case Study sites. Rill erosion was not encountered at any of the sites, except at some bridge crossings downstream of the ROW. Vegetation densities varied dramatically, with ROW sections sometimes having higher stem densities than the adjacent study sections. The upstream section invariably had a vegetation community of single stem tall growing trees. The ROW often involved younger trees with multiple stems and wider interspersed spaces between them. Also, the small trees that were present on the ROW often had several, if not hundreds, of stems from repeated cuttings that have occurred since the electric transmission powerline was constructed.

All the case studies had a denser and more mixed understorey community across the ROW section. The constant mowing and cutting of tall growing trees has allowed other species, such as willows and mixed berries, to flourish and dominate the ground cover. In addition, grass cover was dense at all case study sites. The lack of obvious signs of erosion or impervious surfaces indicates suggests the vegetation management activities at the sites studied has established vegetation communities that are able to attenuate precipitation inflow into the adjacent streams.

4.2.4 Ecosystem Function 3: Bank Stability

There were no trends across the cases with regards to bank stability. This was because no pattern was noted between bank stability and the level of significant disturbance. As presented in Figure 4 there was also no trend concerning processes of disturbance, for example, degradation did not outweigh aggradation as the most dominant form of disturbance across the sites or between biogeoclimatic zones.

4.2.5 Ecosystem Function 4: Habitat Complexity

Each of the stream morphologies used in this study were controlled by volume and function of LWD. As a result, the volume and function of LWD determines the in-stream habitat complexity across stream reaches. In general, the amount of pool habitat in the streams studied was most often associated with, and created by, individual pieces of LWD. Across the ROW stream

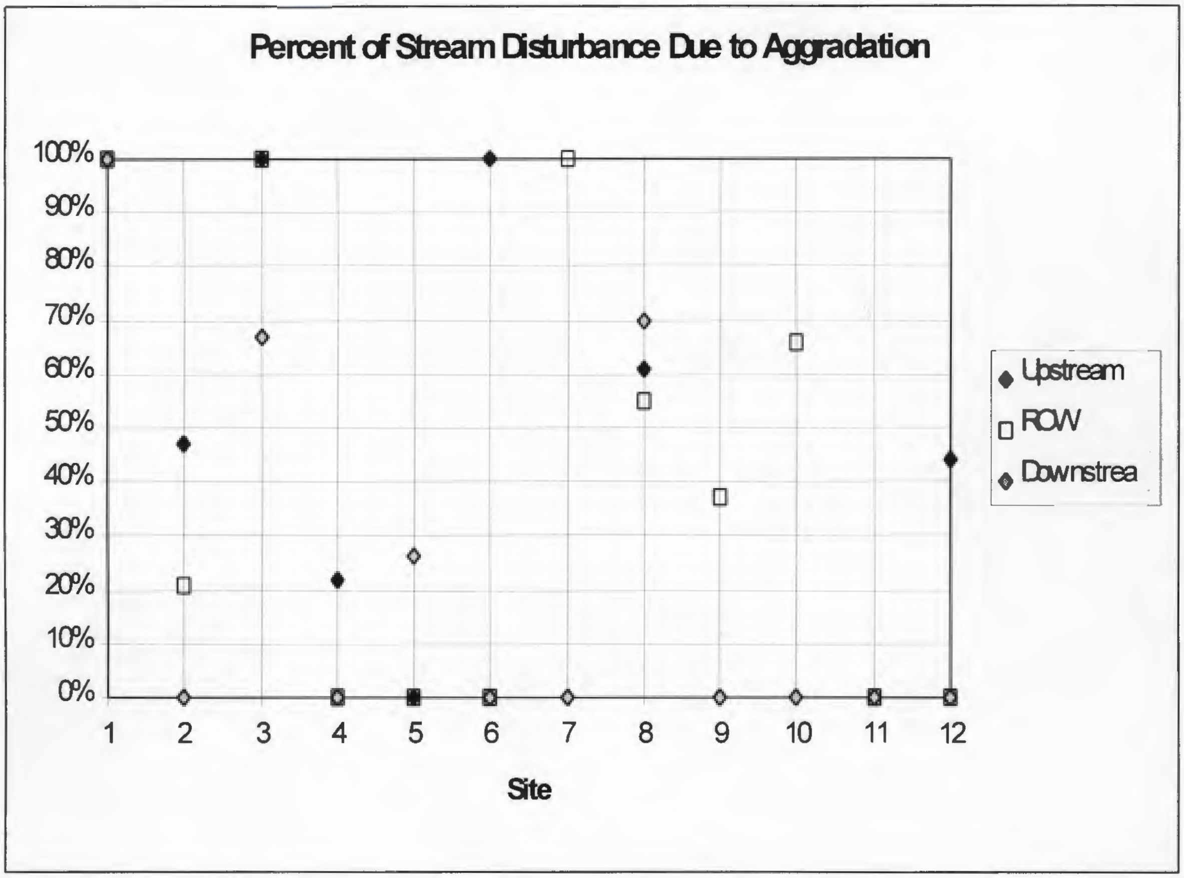


Figure 4: Distribution of Aggradation Across the Case Study Sites.

segments pools were also found in association with boulders and undercut banks covered with grasses, berry bushes and willows trees.

Two separate, yet highly related trends that were observed suggest vegetation management at the case studies will, overtime, reduce habitat complexity in the ROW stream segment. First, pool habitat in the ROW segment decreased at 50% of the case study sites and was not related to the presence or absence of a leave strip. Second, the amount of LWD also decreased at 50% of the case study sites and again did not correlate to the presence of a leave strip. All the LWD located on the ROWs was large, old and well embedded in the banks, therefore represents contributions from past vegetation communities. There are no sites where ROW vegetation will generate large riparian trees that will eventually grow, fall and replace the LWD.

4.3 Summary

Management of vegetation by cutting tall growing trees increases stream exposure to solar energy, and reduces habitat complexity. On the other hand, vegetation management activities appear to have minimal effect on the variables measured as indicators of bank stability or hydrology. These trends, the magnitude of impact and implications to BC Hydro's vegetation management strategies, are discussed in the next chapter.

CHAPTER 5
Analysis

5.0 Introduction

While direct statistical comparison of data describing each ecosystem function is not valid because of the uncontrolled confounding variables at each site, it is valid to indicate prevailing patterns. This chapter begins by exploring the key findings concerning vegetation management along BC Hydro electric transmission ROWs. Then the results concerning each of the four ecosystem functions studied were analyzed to determine the impact of vegetation management, potential negative and positive impacts, and important confounding variables that should be taken into consideration.

5.1 Vegetation Management

The data collected in the field support the trends about historical and current vegetation management practices indicated by both the interviews and record analysis. This portion of the discussion explores the triangulation between the three separate information sources.

In the past vegetation management at riparian zones located along BC Hydro ROWs most often involved machine mowing or hand slashing of target trees. Cut stumps and multiple coppice stems are common at the case study sites and attest to the vegetation management technique used. In some cases these techniques were accompanied by back-pack spray or capsule injection application of herbicides, as evidenced in areas with a noticeable lack of multiple coppice stems or girdled trees. Interviewees indicated that mowing no longer occurs within riparian zones of the case study sites. Instead, riparian vegetation is now hand slashed, girdled or topped as it approaches the limits of tolerance. According to the data collected the presence or absence of a gully contributes to determining both the frequency and method of vegetation management applied in a riparian zone. In sites with steeper and deeper gullies it is more difficult to operate machinery and trees can be allowed to grow higher. For example 75% of the case study sites have some type of gully associated with the crossing. Of these gullied sites three had leave strips of trees running along the stream and the other four sites had riparian vegetation with mixed heights that extended well back from the bank of the stream.

The remaining sites provide additional confirmation that gully depth affects vegetation maintenance activities. At Donegani Creek (Case Study 6), the complete riparian zone had been slashed the previous year, making it impossible to assess if target trees had reached tolerance limits. Regardless, short growing species such as willow have been left undamaged by the previous year's work. In the last case with a gully (Case Study 11), the gully is very shallow and the powerline support structures provide very little vertical growth tolerances. The remaining three sites that did not have gullies Currie Creek, West Noons Creek and no name creek (Cases 2, 5, and 12), have been managed (cut) up to the stream and have few tall growing trees.

The information collected also supports the assertion that BC Hydro is implementing a new vegetation management processes for integrating site sensitivities with vegetation management plans. Of the twelve case study sites visited in this study six have riparian zone prescriptions that were completed since the new process was introduced in 1997. At Kelvin Creek (Case study 1) the prescription involves establishing a more diverse riparian community by planting low growing species and western red cedar. Eventually the strip of red alder trees at the site will be cut to release the younger vegetation. For Nile Creek (Case Study 3) the prescription involves maintaining the current type of community by girdling deciduous trees, topping target conifers trees and planting native low growing stock. At Mahood Creek (Case Study 7) the prescription involves transforming the site to a more stable low growing community that requires less frequent and drastic maintenance from BC Hydro. Over a period of 3 years the prescription calls for all tall trees to be cut and removed. The prescription for French Creek Tributary (Case Study 2), is very similar to Kelvin Creek. The other two prescriptions, Currie Creek (Case Study 2) and West Noons Creek (Case Study 5) are nearly identical (no gully exists at either site) and involve the removal of all tall trees and establishing dense low growing vegetation communities.

The goal of these prescriptions is to maintain, to the extent possible, stream bank stability and shading (Appendix 1). Rather than pioneering new vegetation management techniques these prescriptions involve different combinations of existing tools. They assume that by establishing a relatively stable lower growing riparian vegetation community (that requires less frequent incursions for management) the riparian ecosystem will function more effectively, providing increased benefits to the stream. They do not identify hydrology or LWD inputs as key riparian functions and do not involve ongoing monitoring or field validation at test sites. Further, they do not enroll stakeholders or interested parties in helping set goals. Instead, BC Hydro technical staff interacts with resource regulators to define work methods that satisfy their respective interests.

Other information that supports the prescription process as an effective platform for combining site maintenance and environmental needs stems from interviewees suggesting that prescriptions allowed for more effective relationships with regulators and for better internal work planning.

Analysis indicates that in the past, BC Hydro managed riparian zones no differently than the rest of the ROW. The utility has subsequently changed vegetation work practices in riparian zones in an effort to reduce impacts on stream ecosystems. It is now implementing a system which appears to be a standard, effective method for integrating varied technical information into practical more holistic vegetation management work plans.

5.1.1 Ecosystem Function 1: Energy Flow

The data collected at the case study sites confirm that vegetation management at each site has helped increase stream temperature and sunlight striking streams. This section analyses the increases in stream temperature, temperature recovery, impacts observed relative to watershed level thermal regulation and impacts of increased sunlight on stream productivity.

The energy flow trend was investigated by exploring the relationship between light and change in temperature. Increases in water temperature are correlated to amount of light allowed to access a stream (Figure 5). But the variance of the data also suggest that other factors help determine stream susceptibility to increases in water temperature. The extreme light measurements in Figure 5 were collected during partly cloudy skies, allowing sunshine to break through. Regardless, the light data indicates that more energy strikes the ROW stream segment than either upstream or downstream segments. This can lead to increases in water temperatures.

Stream Heating

On the warmest day of the collection period the maximum increase in water temperature adjacent to the ROW ranged between 0.0 and 3.5^{0}C. These increases are smaller than those observed elsewhere in BC. Brownlee (1988) found the maximum water temperatures in some smaller streams flowing through logged areas near Prince George, BC increased between 5.5 and 9 ^{0}C. Holtby and Newcombe (1982) found mean water temperatures in Carnation Creek increased by 7^{0}C when 39% of the watershed had been logged. Still others have documented 15^{0}C

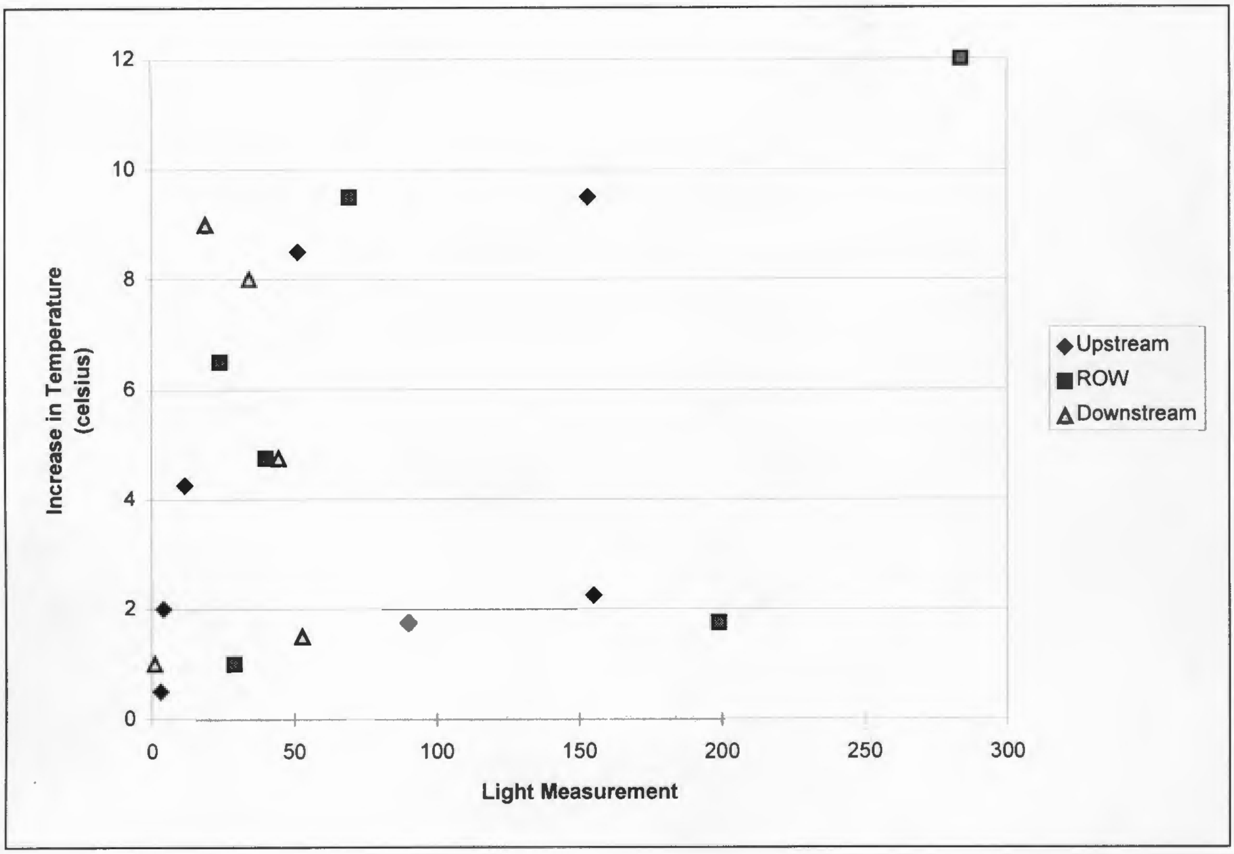


Figure 5. Correlation Between Light Levels and Increases in Water Temperatures.

increases after logging (Beschta.et al., 1987). Similarly, the increases in temperature are smaller than those observed in several streams flowing through logged areas elsewhere in the Pacific Northwest (Beschta et al., 1987; Scrivener and Anderson, 1994; Macdonald et al., 1998; DFO unpublished data). In most of these other studies the mean temperature values are consistent with the data collected at the BC Hydro sites, while maximum increases (used in calculating the mean value) were higher than those obtained in this study. These temperature findings are also consistent with work done by Peterson (1993) on ROWs crossing small streams in New York.

Given these other results it is reasonable to suggest that the vegetation management along the ROWs is maintaining a canopy that provides varying amounts of shade to the stream. At sites susceptible to increases in water temperature, shade is a critical and a substantial ROW riparian community may moderate water temperature. This will only be effective at stream sites where gully morphology or powerline clearances allows for vegetation to grow to sufficient height to shade a stream. It is also possible that temperature changes may have been more extreme in the first few years after clearing when very little shade would be provided to a stream.

The data indicates that warm water temperatures were experienced for longer periods of time at ROW stream segments than at the other segments analyzed (Appendix 1). Barton et al. (1985) also observed this relationship and concluded that unshaded streams reach their maximum temperatures earlier in the day and show greater daily variation than shaded streams. As a result, the partially shaded ROW sections experience a longer duration of higher temperatures than the shaded adjacent sections.

Conversely, the lack of water temperature change at some sites with very little shade (Case Study 6) affirms that vegetation canopy is one of several important thermal regulation variables. Water temperatures depend on the influence of many variables including: headwater lakes, watershed orientation, channel morphology, stream depth, ambient air temperatures, flow levels, ground water contributions and length of time exposed (Beschta et al., 1987; Scrivener and Anderson, 1994). An example of the interaction of these temperature control variables is Clucluz Creek (Case Study 8) where the minimum to maximum water temperatures range was

12.5-24.25^{0}C on August 13, 1998. At this site the ROW site supports more tall trees than most of the other study sites and they partially shade the stream. The large diurnal ranges and near lethal temperatures can be attributed to riverbed erosion and degradation at the sites, that have created long stretches of shallow water flowing over bedrock. Bedrock is more efficient than gravels at accepting and conducting heat (Beschta et al., 1987). Erosion results in shallow morphology and acts in synergy with increased sunlight to increase water temperatures.

None of the other sites had water temperatures that approached lethal levels for fish. This finding supports the assertion presented in Beschta et al. (1987) that in general stream temperatures in deforested Pacific Northwest watersheds, are invariably warmer than when in a forested state, but they rarely approach the tolerance limits of resident fish species. However, as discussed in Chapter 2, small but long term changes in temperature regimes can also have sub lethal but significant affects on fish populations. Recent work on streams in North Central BC suggests that forestry operations can change summer and winter water temperature regimes and affect the timing of fry emergence and the probability of successful outmigration (Macdonald et al., 1998).

Temperature Recovery

At most of the sites where data were collected at all 3 monitoring stations the increase in water temperature was most often cooled to pre-ROW levels within one study segment distance downstream of the ROW (Table 3). In fact some of the sites actually cooled to temperatures lower than those observed prior to entering the ROW stream segment.

When working on streams in California, McGurk (1989) observed that stream waters were cooled by 1.0 to 1.5^{0}C within a distance of 130 m downstream. Temperature recovery is a phenomenon associated with the balance and transference of energy between air and water

(Beschta, 1987; Teti, 1998). Water is warmed when passing through an exposed area but then loses thermal energy when flowing in cooler forested areas. The exception to a quick recovery in water temperature was French Creek Tributary on Vancouver Island (Case Study 4). At this site water temperatures increased by 3 ^{0}C across the ROW site and then increased a further 4.0^{0}C downstream of the ROW. The progressive increase was attributed to the presence of small shallow pools that had access to direct sunlight through openings in the sparser downstream canopy. Further, the small stream flows north to south and is situated on a south-facing slope, providing conditions for intercepting direct sunlight during the warmest periods of the day.

These results again emphasize that each is unique with respect to temperature fluctuation. The interaction of several potential variables such as morphology, bedrock, groundwater inflows, orientation, shade and area hydrology above, at and below the ROW affect fluctuation. For this study ground water contributions on maintaining water temperature were not considered and it is assumed they do not play a role at the case sites.

The temperature recovery results indicate that incremental increases in water temperature across the ROW stream segment do not constitute a significant impact when an appropriate mix of conditions exist conditions, such as ample shade in the downstream section, for water temperature recovery to occur.

Watershed Level Processes

In investigating vegetation removal and water temperature there is a direct relationship between the amount of watershed logged and impact (increase) in mean stream temperatures (Holtby and Newcombe, 1982; Beschta et al., 1987). Because no information was collected on percentage of a watershed impacted by transmission ROWs, this study cannot be used to assess the potential role of vegetation management at the case study sites on cumulative impacts in their respective watersheds.

From a stream network perspective, research has been completed on the relative impact of tributary inflow on the water temperature regimes of larger streams. Independent of the importance of the smaller streams to life histories of species found in a watershed, studies suggest that first through third order streams do not have significant impact on the water temperatures of fourth or higher order stream temperatures (Beschta et al., 1987; Teti, 1998).

Temperature Trends

In general, the results from this study suggest that vegetation management can be designed to maintain some shade but allows enough sunlight through to cause a moderate increase in water temperatures at many of the ROW stream crossings. Where an increase in water temperature does occur it is often reduced or eliminated within a short distance past the ROW. It is doubtful that the majority of streams used in this study (first through third order) contribute to water temperature changes in receiving streams.

Increased Exposure to Sunlight

While the effects of increased sunlight suggest that the vegetation maintenance may increase water temperatures, the increase in sunlight striking a stream may also have the effect of increasing overall productivity. Several researchers have found that removing the canopy above small and medium streams dramatically increases a stream's primary productivity and carrying capacity (Murphy and Hall, 1980; Newbold et al., 1980; Murphy et al., 1986; Gregory et al., 1987; Feminella et al., 1989; Keith et al., 1998). These results are not independent but based on vegetation removal activities not affecting habitat complexity, cover and other key channel features (Gregory et al., 1987; Carslon et al., 1990, Keith et al., 1998). In other work, a team of researchers removed riparian canopy from two streams and documented an increase in sunlight striking the stream resulting in, significantly higher accrual rates of chlorophyll *a* and higher densities of benthic invertebrates in the open areas (Hetrick et al., 1998a; Hetrick et al., 1998b).

Increased sunlight does not in itself have a negative effect on fish foraging activities (Keith et al., 1998). It is the interaction of factors including habitat complexity, cover, food availability and water temperatures that determine foraging activities (Bilby and Bisson, 1987; Gregory et al., 1987; Keith et al., 1998). When increased sunlight is a product of land disturbances that also effects other riparian factors stream productivity is often reduced. Other recent research proposes that increased solar radiation may affect development and reduce juvenile fish survival in fresh water habitats; however this has not been widely investigated (Walters and Ward, 1998).

5.1.2 Ecosystem Function 2: Hydrology

This section analyzes the trends relative to stream hydrology, compares findings to the literature and identifies potential confounding variables.

Site Hydrology

The data demonstrates that although the ROW have fewer tall trees present they often have higher stem densities and are completely covered by an extremely dense lower canopy composed of willows, miscellaneous berry species and numerous different shrubs and grasses. Vegetation diversity also is higher in groomed areas than in the forested areas. These variables represent hydrological function because they describe vegetation communities continue to effectively intercept precipitation and allow percolation into the groundwater because. While no direct hydrological variables were measured such as precipitation, ground water flow or soil moisture these variables suggest ROW management does not affect key hydrologic functions.

A riparian ecosystem's ability to intercept and help infiltrate precipitation into the groundwater table is critical for maintaining a stream's ability to support a wide variety of aquatic life (Gregory et al., 1991). The presence of dense vegetation communities along the ROW significantly reduces the probability that the ROW sites contribute to flashier stream flows. In investigating the effects of urbanization on a watersheds ability to attenuate flows, Honer et al (1994) found that the steepest rate of decline in biological functioning of streams occurs as the amount of impervious land cover increases from zero to six percent of a watershed. Hetherington (1982) found that extensively logged areas of Carnation Creek increased flows and caused increased erosion. While it is possible that this study was confounded by climate change issues Castelle et al. (1994) describe other research hat concluded forest vegetation and litter lowered one stream's one hundred-year flood stage from 9.9 m to 5.3 m. These findings support the hypothesis that the vegetation community plays a large role hydrological function.

Impervious surfaces in BC are most often associated with urban areas, but at many locations with little moisture, susceptible soil compositions and no vegetation, exposed soils not in developed areas can quickly become impervious surfaces. While none of the study sites had impervious soils, except along access roads, in many semi-arid areas of the southern United States of America, bare exposed ground acts as an impervious layer. Hence, major precipitation events are not intercepted or attenuated and instead can cause flash floods (Leopold 1994).

The lack of rill erosion at any of the case study sites can also support the hypothesis that the riparian zones along the ROWs is intercepting precipitation and providing conditions for the rain to infiltrate into the ground water table. Conversely, the presence of rills (numerous small eroding channels) could be an indicator either that the soils are, or are not, impervious and that a significant amount of precipitation is not being intercepted, but instead flows unabated into the stream.

Watershed Hydrology

Although this study did not focus on watershed level hydrologic processes, the information that was collected can help point to potential impacts of ROW vegetation maintenance on some broader scale functions, such as the relationship between snow accumulations and water yield.

In colder climates such as the northern sites (Case Study 8 through Case Study 12), riparian vegetation plays a major role in maintaining hydrology by intercepting snow. Snow strikes the vegetation and often is melted or evaporates before striking the ground. When the tall tree crown cover is reduced there are greater snow accumulations and increases in the amount of sunlight that strikes the ground which can result in quicker melts and increased peak flows (Beaudry, 1998; Heinonen, 1998). In discussing the effects of snow on stream hydrology, Beaudry (1998) proposed that riparian areas are often considered to be of disproportionality high importance to peak-flow runoff. Oppositely, when investigating the effects of logging in the Bowron watershed (central BC) Wei and Davidson (1998) found no significant impacts on spring snow melt or winter base-flow. This suggests that watershed specific features must be identified and understood to predict the cumulative impacts of forest removal in a given watershed (Hogan et al., 1998).

There are few tall trees at any of the northern ROW sites and it is difficult to propose a mechanism where the low growing vegetation species help reduce snow accumulations or prolong snow melt.

Evaporation

Evaporation and evapotranspiration are two different yet highly related processes also connected to riparian vegetation. In this context evaporation refers to the rate of water loss from sunlight striking an exposed stream surface and vaporizing the water, thereby removing it from the stream (Mitsch and Gosselink, 1993). This effect can be moderated by shade. Evapotranspiration on the other hand involves the water that vaporizes from the soil or water together with the moisture that passes through vascular plants to the atmosphere (transpiration).

There are many empirical calculations to estimate rates of evapotranspiration but none are entirely satisfactory because they can not account for the host of meteorological and biological factors associated with a site specific situation (Mitsch and Gosselink, 1993). Most models require rooting depth, leaf area index and soil moisture data. These data were not collected as part of this study hence it is impossible to quantify the difference in evaporation between the three study segments at each case study site.

Still, general conclusions can be drawn about a ROW community's composition and ability to help regulate general evaporation processes based on research done in forestry. In a mature forest, clear cutting immediately reduces the rate of evapotranspiration by 30-70% (Swanson et al., 1998). However when cover density returns to approximately 50% of pre-harvest conditions evapotranspiration returns to pre-harvest levels. Because of their quicker growth rates and leaf shape deciduous stands recover quicker (Swanson et al., 1998). Since the ROW communities often resemble naturally regenerating cut blocks it seems reasonable that one effect of ROW vegetation management is reduced rates of evapotranspiration.

Conversely, when reviewing work on wetlands Mitsch and Gosselink (1993) suggested that vegetation has a minimal impact but rather it is the interaction of features, such as size of the waterbody, topography and soil composition which determines the net impact of riparian vegetation on site hydrology. It is assumed that this hypothesis is confined to smaller scale sites as opposed to watershed level processes where vegetation clearly impacts hydrology

The delicate balance between hydrology, morphology and evapotranspiration can be found in the management of riparian zones in the southern USA. In arid areas it has been a long-standing agricultural practice to cut riparian vegetation in the belief that transpiration is reduced thus conserving water for irrigation purposes (Mitsch and Gosselink, 1993). Ironically, researchers have found that dense stream bank vegetation prevents erosion and often results in stream aggradation (Li et al., 1994; Elmore and Beschta, 1987). As the stream aggrades and "rises" in the channel the groundwater level also rises. In these situations restoring the riparian zone can transform streams from intermittent to continuously flowing (Elmore and Beschta, 1987; Li et al., 1994).

Hicks et al., (1991) found that forest harvesting increased annual water yield. Increased snow accumulation occurs in clear cuts and in the absence of transpiration, more water moves into the ground and into streams, especially in upslope areas (Macdonald et al., 1998; Swanson et al., 1998). As this is largely a cumulative impact correlated to the amount of vegetation removed and the percent of watershed dedicated to roads if a ROW has only small impact on vegetation it can be speculated that these activities do not cause large hydrological disruption. However, ROW access roads must be factored into any assessments about potential impacts.

Ecosystem Function 3: Bank Stability

A stream's bank stability is largely controlled by the grain size of the bank material, the amount of bed material carried in the channel and the riparian vegetation cover (Sullivan et al., 1997). It appears that vegetation management on the ROWs is maintaining bank stability. Analysis includes comparing these observations with the literature and a discussion about confounding variables and alternative explanations

Form Resistance

All riparian zones in this research project were heavily vegetated with a dense, mixed vegetation community sometimes associated with undercut stream banks and associated pool habitat. An indicator of recent disturbance and the resulting processes to help return bank stability is the presence of pioneer species such as alder and willow.

Riparian vegetation contributes to bank stability by establishing dense root systems that increase channel form flow resistance (Wilzbach, 1989; Huang and Nanson, 1996). Removal of the riparian vegetation reduces bank stability and may lead to changes the hydraulic geometry of the channel (Elmore and Beschta, 1987). As a result, disturbances often lead to increased erosion which introduces more sediment, reduces the volume of pools, and widens the stream (Hawkins et al., 1983; Beschta and Platts, 1986). Huang and Nanson (p.241, 1996) found that, "channels which possess non vegetated banks can be roughly two to three times wider than those with banks that are densely vegetated".

The process to re-stabilize eroded banks begins with the germination of tough, quick growing pioneer vegetation species such as willow, birch, maple and alder. These species establish themselves and reduce water velocities along the stream banks, leading to sediment deposition and accretion of the stream banks (Hupp, 1992; Church, 1995). As pioneer species mature, other succession vegetation species grow in the recently colonized areas and establish larger deep root systems. The bank continues to move inwards until the stream reaches a new equilibrium that balances grade with sediment transfer and flow regime (Elmore and Beschta, 1987; Hupp, 1992; Church, 1995).

Recognizing the ability of riparian vegetation to affect bank stability, some researchers suggest that removing tall growing trees and replacing the trees with low growing vegetation can quickly improve bank stability and increase fish densities (Smith, 1980; Wilzbach, 1989, Peterson 1991). Peterson (1991) also found that vegetation management along ROWs promoted dense vegetation along streams crossing ROWs and concluded that bank stability had in fact been improved by construction and management of the ROWs. These conclusions need to be balanced by the need for larger root systems during extreme high water events (Wilzbach, 1988; Gregory et al., 1991).

The results from this study suggest that there is no direct correlation between the ROW vegetation management and bank disturbance, aggradation or degradation. The presence of dense vegetation communities composed of pioneer species supports the hypothesis that sites were impacted when the ROW was constructed and that the current vegetation community contributes to bank stability by propagating lower growing pioneer species. ROW vegetation management activities at case study sites are not having an impact on bank stability.

Confounding Variables

If vegetation management appears to be having no impact on bank stability the focus then turns to the other fluvial factors that affect bank stability: (1) the grain size of the bank material, and (2) the amount of bed material carried in the channel. Knighton (1984) reviewed the relative role of each in maintaining bank stability and suggested that although the role of vegetation is important it is highly variable and difficult to quantify. Richards (1976) investigated the oscillation in channel width between riffles and pools and although it did not explore the role of vegetation the study found that channel width is determined by the capacity of the stream to erode its bank (a function of flow and sediment).

More recent research proposes that riparian vegetation is less important to bank stability than individual roughness elements (Huang and Nanson, 1997). Instead, Huang and Nanson (p. 245, 1996) suggest that, "the influence of bank vegetation on channel width can be overridden by the effect of roughness elements". These studies suggest that the cumulative impacts associated with development and watershed differences in variables such as flow, climatic events, LWD functions, gradient, bank composition and the resulting changes changes to flow or sediment characteristics ultimately drive the stream's capacity to erode bank material. It is possible that the impact of ROW vegetation on site bank stability is being overwhelmed by larger influences.

The BCCAP used in this study is intended to identify disturbances relative to watershed level impacts such as forestry and slope failures (BCFPC, 1995). This is accomplished by determining the level of disturbance in a reach and then comparing the results to other reaches of the same river system. In this study the BCCAP was modified to delineate differences between sites, sometimes less than 100 m in length, within the same stream reach. Therefore, the method may not have been able to detect small scale impacts of vegetation management on bank stability across shorter lengths of stream. It is also possible that the method worked well but the impacts at the stream segments were too small to be detected relative to the effects of disturbances in the upstream watershed or that pre ROW activities have influenced site morphology.

5.1.4 Ecosystem Function 4: Habitat Complexity

A none of the case study sites can BC Hydro allow tall riparian communities to develop. None of the ROW riparian zones will produce the LWD that is required for watershed level habitat complexity. Riparian leave strips observed during the study were too narrow to contribute adequate LWD to maintain site habitat complexity. LWD contributes to establishing the long profile and helps determine the riffle pool sequences (Sedell and Swanson, 1984; Bisson et al., 1987; Hogan et al., 1998). In the Pacific Northwest, McDade et al. (1990) found that 11% of LWD originated from within 1 m of the stream while 70% originated from within 20 m. Other researchers also looking at streams throughout the Pacific Northwest found that riparian trees at least 50 years old are required to provide an adequate source of LWD (Andrus et al., 1988; Bragg et al., 1998). Small riparian leave strips were inadequate for providing sufficient LWD to maintain stream complexity.

At Kelvin Creek (Case Study 1) ample LWD exists upstream of the ROW, but few pieces exist across the ROW segment. The upstream segment has habitat complexity and some very deep pools associated with LWD. There are fewer pools adjacent to the ROW and little other habitat complexity.

Bilby and Ward (p.2505, 1991) predict "a decrease in LWD over time as a result of decay of wood present in the channel prior to disturbance coupled with decreased input from the riparian area." These researchers found that the volume of LWD decreased by 22% from old growth levels 5 years after harvest and 35% after 50 years in streams 5 m wide. Peterson (1991) who found considerably less LWD across ROW stream sections than upstream control sites also observed a reduction. In a worst case scenario, there maybe more than one hundred times more LWD in small coastal streams before forest harvesting (Sedell et al., 1988).

Although all research sites for this project are at least 5 years old there wasn't a trend for less LWD at the ROW stream segments sites. The difference in these finding from the literature cited above can be attributed to different clearing practices during ROW construction. Harvesting often involved salvage, stream cleaning (for culverts) and yarding (Sedell et al., 1988; Bilby and Ward, 1991; Bilby and Beschta, 1991) whereas some ROW construction projects may have involved less salvage and less stream cleaning. Another reason could be that original construction activities actually contributed LWD to the BC Hydro ROW stream crossings by increasing blowdown immediately following construction (Sedell, 1988). These hypotheses are supported by the presence of several large debris jams immediately upstream of the ROW that could be accumulations of blowdown. At all sites trends with LWD can be confounded with other roughness elements such as boulders or exposed bedrock.

Both the Bilby and Beschta (1991), and Peterson (1991) suggest that decreasing inputs of LWD is indicated by the absence of newer less imbedded LWD. Similarly, all the LWD found along the ROW stream segments used in this study were well embedded structures from older pre-construction vegetation communities. At Donegani Creek (Case Study 6) more pool habitat and LWD are found along the ROW stream segment even though no tall trees are present anywhere on the ROW.

The results and the literature support the hypothesis that over time the amount of LWD will progressively decrease with an accompanying decrease in habitat complexity and reduced abundance of aquatic life across ROW stream segments.

5.2 Summary

A comparison of these results with the literature has supported several key findings. BC Hydro has created a process whereby site sensitivities can be incorporated into work plans. Current vegetation activities are having a minimal impact on water temperature and are probably increasing primary productivity of stream segment flowing through ROWs. While site hydrology is largely unaffected by vegetation maintenance, it is possible that in some instances ROW maintenance affects watershed level processes. Bank stability appears to be unaffected by vegetation activities relative to larger stream capacity processes. Vegetation management is negatively impacting habitat complexity and over time, as wood decays, it is expected that the volume of pools at and immediately downstream of the ROW will progressively decrease. This will lead to reduced stream productivity and carrying capacity levels. The next chapter uses these findings to propose opportunities and constraints to integrating vegetation management with ecosystem function.

CHAPTER 6
Conclusions and Recommendations

6.0 Conclusions

This chapter presents the key findings from this study. It begins by drawing conclusions about the opportunities and constraints for managing for riparian values at streams located along ROWs. This is accomplished by summarizing the impact of vegetation maintenance activities on the four riparian ecosystem functions that were studied, and conclusions are presented about the management process used by BC Hydro for riparian zones located on its transmission facility. These findings lead to a final conclusion about the possibility of integrating the management of riparian zone function with ROW vegetation management, as well as recommendations for activities that support opportunities, mitigate constraints and identify information gaps requiring more study.

6.0.1 Ecosystem Function

Vegetation maintenance at the case study sites has had minimal impact on two of the riparian ecosystem functions studied. The dense lower growing vegetation communities found on ROWs continue to intercept precipitation and help regulate site hydrology. They appear also to maintain stream bank stability; this latter finding is tied to the presence of hardy pioneer vegetation species which are known for their ability to protect bank stability. Further, there was no consistent difference between the amount of stream disturbance calculated for the ROW sites and the control sites.

These findings suggest vegetation maintenance techniques have, and will continue to transform the vegetation community to dense low growing communities but this does not impact the variables studied to describe the riparian ability to regulate hydrology or bank stability. The conclusion about bank stability must be tempered by the fact that it is possible that the assessment method used in this study may have been unable to detect changes within the stream study reach. Further, ROW crossings create smaller scale exposures that may have negligible impact on stream disturbance relative to larger scale watershed disturbances and processes. Also, site specific roughness features may be exerting more influence on stream morphology than the channel roughness of the stream bank at the study sites.

The research does indicate that vegetation management does impact energy flow processes. Increased exposure to solar energy may provide both opportunities and constraints to managing for riparian zones along transmission ROWs.

Vegetation management at the case study sites reduces shading across the ROW and allows more sunlight to strike the stream than in forested areas. The increased exposure to sunlight resulted in increases in water temperature of between 0 and 3.5^0C. Temperature increases of this magnitude are smaller than those that have been measured in BC or elsewhere in the Pacific Northwest. None of the increases resulted in water temperatures lethal to the fish present in the streams visited. Also, the majority of streams experienced a rapid cooling in water temperatures to above ROW conditions, after flowing a relatively short distance downstream of the ROW. Where recovery does not occur, the literature indicates that smaller order streams have a negligible impact on the temperature regime of larger receiving streams.

These findings support the hypothesis that while vegetation cover does play a significant role in thermal regulation it is the interaction of a variety of factors (including size of clearing, stream depth, morphology, site topography and orientation) that regulate stream water temperatures. Some sites are more susceptible to temperature increase impacts than others but most sites in this study experienced minimal temperature increases. Most of the factors identified are not directly impacted by ROW vegetation management activities. However, efforts must be made to maintain shade at sites with a high sensitivity to increases in water temperature.

Increased access to sunlight has an impact on water temperatures and also represents a significant opportunity for improving stream productivity and potential carrying capacity. By increasing the sun energy in a stream, ecosystem primary productivity improves significantly. In streams where habitat complexity is maintained, this will result in more productive ecosystems than those in shaded forested areas.

Opportunities arise because vegetation management on electric transmission ROWs appears to have limited impacts on energy flow processes into a stream, that are restricted to relatively short distance of the ROW stream segment. While temperature increases are usually minor, where increases are more drastic and recovery does not occur impacts are restricted to smaller order streams. Conversely, increased access to sunlight potentially improves stream productivity.

While there are opportunities inherent in the increase access to solar energy, there are also constraints associated with the impacts. The reduction of shade and increase in water temperature may contribute to more subtle site specific sub-lethal temperature impacts such as changes in winter temperature regimes, small scale changes in species behavior and reductions in juvenile survival. Further, constraining this impact is that the sub-lethal impact on fish species, especially winter temperatures is poorly understood (Macdonald et al., 1998). Also, there are no tools currently in use to identify sites more at risk for temperature increases in order to factor this risk into site vegetation management activities. The opportunity that increased access to sunlight may be benign or potentially benefit the stream ecosystem must be compared to the potential for vegetation management to result in more subtle chronic impacts from sub-lethal temperature changes.

Although there are positive and negative aspects to moderating access to sunlight, there is no doubt that a constraint to integrating riparian zones with ROW management is that maintenance impacts stream habitat complexity. Cutting vegetation on ROWs will continue to avoid threatening electric transmission powerlines. Further, areas without gullies will continue to require more frequent cutting than gullied areas. As a result, most ROWs will be managed to support vegetation communities that are dominated by young trees, cut stumps and a dense understorey. While large old pieces of LWD were present in equal proportion at most case study sites it is very likely that continued cutting will prevent future recruitment of LWD into ROW stream segments and progressively reduce habitat complexity. In small and medium sized streams, less LWD will change the riffle-pool morphology and lead to reduced habitat complexity, retention time and fish carrying capacity.

For cleared forested areas it takes a minimum of 50 years for a riparian area to re-grow and begin contributing LWD to streams. At ROW sites the riparian zones will not be provided that time and without a change in management practice the stream segment flowing through ROWs will become less productive. Fortunately there are many existing enhancement and management methods, including LWD placement, debris catchers and placing logs along banks, to mitigate the situation at ROW stream crossings when problems occur.

6.0.2 Integrated Resource Management

An opportunity for managing riparian values along ROWs is provided by BC Hydro's new (1997) vegetation management prescription process for its electric transmission facility. The process is being progressively implemented and half of the study sites are now being managed under unique riparian prescriptions. While the range of available techniques for vegetation management are relatively unchanged, the prescriptions are created by multidisciplinary teams composed of vegetation biologists, fisheries biologists and transmission maintenance staff. This approach appears to be having an impact on riparian ecosystem function. For example, at sites on small streams vegetation communities can be transformed to more stable low growing communities that require less frequent incursion. At larger gullies, the intervals between working at sites can be extended to allow trees to grow, and then they are either girdled or topped, providing for more stream shade, a source of litter input and SWD. The prescription process is significant as a management approach because it is an effective approach for integrating complex issues into a practical work plan.

Integrated management approaches are increasingly being recognized as a preferred method for combining the management of several different, and at times, conflicting resource management issues (Lang, 1990). The BC Hydro vegetation management process satisfies three of the four IRM components identified by Born and Sonzogi (1995) as critical for a successful IRM process. First, it is comprehensive in scope. This means that is applicable for all riparian zones at all transmission powerline stream crossings in the BC Hydro electric transmission facility. Second, it is interconnective and uses new mapping technology to capture and present site specific topographical, anthropogenic and bio-physical parameters. Third, the process is strategic; it reduces and aggregates the multitude of concerns possible for each ROW stream crossing site into a smaller more workable set of concerns, goals and objectives. In practice, the new BC Hydro prescription process has modified work practices at case study sites to consider key ecosystem functions.

The new BC Hydro prescription process not interactive/coordinative (Born and Sonzogi, 1995) as it does not engage interested parties and complete a process of shared goal setting and decision making. Without this component it is very difficult to address key societal values, enroll key parties or build a broader vision of desired outcomes or mutual accountabilities for the vegetation management process.

Although the prescription process has the ability to integrate ROW and ecosystem issues, it has not yet been completely implemented throughout system. Ongoing cost constraints, especially those associated with company restructuring and anticipated market deregulation, combined with the remoteness of many of the sites and the practical challenges of implementing large operational changes may limit the practicality of implementing other, potentially more expensive, operational processes. As all field vegetation work on BC Hydro transmission ROWs is completed by contract staff, another challenge is training and providing contract specifications that ensure the terms of the prescription are implemented effectively and are cost effective. A confounding variable is although BC Hydro has easements that provide access to the ROWs, the utility does not own the majority of the land along its electric transmission facility. Therefore the interaction of key parties, such as First Nations and land owners, is critical to implementing different management paradigms at many ROW stream crossings.

6.0.3 Summary

The findings indicate that it is possible to integrate riparian zone function with current vegetation management practices along electric transmission ROWs in BC. BC Hydro is committed to design management systems for ROWs that consider riparian zones function. Traditional vegetation management for ROWs look to be compatible with newer management strategies as they do not appear to have a significant impact on most riparian ecosystem functions. Also, where impacts do occur they can be mitigated by applying existing vegetation maintenance and stream enhancement techniques. Beyond ecosystem level issues an IRM approach to vegetation management can be accomplished by expanding the prescription process to include other key parties affected by landscape management of ROWs.

6.1 Recommendations

The opportunities identified by the analysis represent the elements supporting the possibility of managing electric transmission ROWs for riparian values. However, to accomplish an integrated resource management approach to this issue the constraints must also be addressed. In order to achieve IRM the following must also occur:

1) ecosystem functions should be used as assessment criteria for determining the impact of electric transmission ROW vegetation maintenance on riparian zones;
2) guidelines should be developed for assessing stream sensitivity to impacts on energy flow based on depth, width, morphology, orientation and potential for water temperature recovery;
3) guidelines should be developed for evaluating, contributing and monitoring LWD in streams at ROW crossings;

4) the ROW vegetation management process should proactively engage and address key parties with regards to riparian zone management goal setting and work practices;
5) BC Hydro must be prepared to change practices, including reviewing the options for higher towers and changing ROW routes, in the face of public scrutiny; and
6) a commitment is necessary for completing stream inventories and prescriptions for all riparian sites along the transmission facility.

As resource managers are increasingly pressured to develop new management models that integrate anthropogenic and biophysical issues, research into different practical applications is critical. This study contributes to the riparian ecosystem body of knowledge by testing and confirming the value of using functional assessment criteria to evaluate the impact of landscape management activities on riparian zones. From a technical aspect, key information gaps exist and more research is required into (1) the chronic impacts of sub-lethal changes in water temperatures on fish, and (2) different methods for detecting site specific morphological trends. This study also contributes to the IRM body of knowledge by confirming an integrated approach is appropriate (and provides a description of necessary conditions) for successful management of environmentally sensitive areas also critical for the electric utility industry. This is important because there are few studies that compare current IRM theory to field situations and affirm that different and apparently mutually exclusive management objectives can be combined into compatible elements of managing a landscape.

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Appendix 1

The Case Study Data.

Case Number #1 **Location** Off of Jackson Road, Cowichan, V.I. **Stream Name** Kelvin Creek
Direction of Flow East **Orientation of Crossing** Right angle

General Information:

Date: June 10, July 30, 1998
Crew: JS, JM
Time: 07:00 -12:00
Weather: Sunny, hot
General photograph roll ID and #'s: 1, 1-24

Site Description:

Region of BC: Vancouver Island
Biogeoclimatic Zone: Coastal Douglas Fir
Transmission Line Id: 1l10/11/14
Tower Numbers (as power flows): 27/3D to 27/4E
Width of rightofway: 70 m
Stream segment length: 85 M
Sideslope angles (%): n 45% | S 25% | e | w
Vertical distance from nearest stream bankfull width to top of gully (m or N/A): n 60 m | s 50m | e | w
Landuse immediately upstream: Dormant
Predominant type of watershed land use: Farming, Residential (very low density), private logging
Distance from closest tower to nearest stream bank full width: LEFT 100 m RIGHT 150 m
Fish Present: Yes
Species utilizing stream: Co, Cm, Ch, St,Ct

Comments: This site involves a relatively narrow Righofway, occupied by 1 wood pole 138 kv circuit and 1steel tower 138 kV structure. This stream is located in fairly deep gully While not very steep the transmission structures are located on the top of the gully, therefore the span is very long. There is floodplain at the foot of the gully. The area is only accessible along a rough 4*4 gated road. There is thin strip of topped alder tree (about 15 m tall), 1-3 trees deep beside the stream through the ROW. The stream section passing through the Righofway is wetted from bank to bank, with no exposed bars. In the upstream stretch there is significant bars, pools are formed by LWD. All 3 segments display degradation with various levels of aggradation.

Crossing:

Type: None
Condition: N/A
Age: N/A
Specifications: N/A
Comments: N/A

Riparian Ecosystem Function 1 - Energy flow:

	Treated Section	*Upstream Control Section*	*Downstream Section*
Temperature (Diurnal range)	N/A	17.0-19.25	N/A
Light (mean PPFD)	284	155.18	203.33

Riparian Ecosystem 2 - Stream Hydrology:

	Treated Section	*Usptream Control Section*	*Downstream Section*
Vegetation Density	15,000 stems/ha (deciduous)	8,000 stems/ha (conifer)	11,000 stems/ha (coniferous)
Vegetation Diversity	10% conifer,10% red alder, 60% maple (clumps), 10% willow, 10% cottonwood	10% red alder, 5% willow, 80% conifer (large and tall), 5% cottonwood (mature)	10% cottownwood, 40% red alder, 10% willow, 40% conifer
Understory	*Dense 30% salmonberry, 20% huckleberry* 40% broom, 10% elderberry	*Dense 30% bracken fern, 30% salal, 40%* (huckleberry and red elderberry)	*Sparse 40% brackenfern, 30% mixed berry,* 20% Salal, 10% Willow

Riparian Ecosystem Function 3 - Bank Stability:

	Treated Section						*Upstream Control Section*						*Downstream Section*				
Transect	1	2	3	4	5	Mean	1	2	3	4	5	Mean	1	2	3	4	Mean
Bankfull Width (Wb)	8.85	8.60	7.10	7.20	8.30	8.01	9.90	9.70	11.90	12.80	14.10	11.68	8.50	8.90	9.60	8.40	8.85
Thalweg Depth	48.00	64.00	52.50	62.00	42.00	53.70	1.47	80.00	48.00	13.00	60.00	40.49	50.00	80.00	55.00	75.00	65.00
Mean Depth (d)	35.00	46.00	45.00	38.00	40.00	40.80	70.00	127.00	50.00	18.00	20.00	57.00	24.00	18.00	20.00	17.00	19.75
D60 (D)	12.00	13.25	12.50	15.10	14.10	13.39	16.00	15.10	14.10	9.60	12.10	13.38	0.17	0.24	0.17	0.21	0.20
Gradient (%)	0.9	0.86	1.18	0.78	0.79	0.90	0.87	1.23	1.23	0.02	0.96	0.86	1.4	1.50	1.50	1.00	1.33
D/Wb	1.36	1.54	1.76	2.10	1.70	1.67	1.62	1.56	1.18	0.75	0.86	1.19	2.82	2.02	2.08	2.02	2.23
D/d	0.34	0.29	0.28	0.40	0.02	0.26	1.62	1.56	1.18	0.00	0.02	0.88	0.02	0.03	0.02	0.03	0.02
(D/d)(D/Wb)	0.4649	0.4438	0.4890	0.8334	0.0320	0.4429	2.6120	2.4233	1.4039	0.0013	0.0137	1.29	0.0565	0.0545	0.0358	0.0506	0.0495
Stream Type	RPc	RPc	RPc	RPc	Rpc	RPc	RPc	RPc	RPg	Rpg	Rpg	RPc-g	RPc	RPc	RPc	RPc	RPc
Importance of LWD	Controlled						Controlled						Controlled				
Reach Disturbance	100 percent						100 percent						100 percent				

Riparian Ecosystem Function 4 - Habitat Complexity

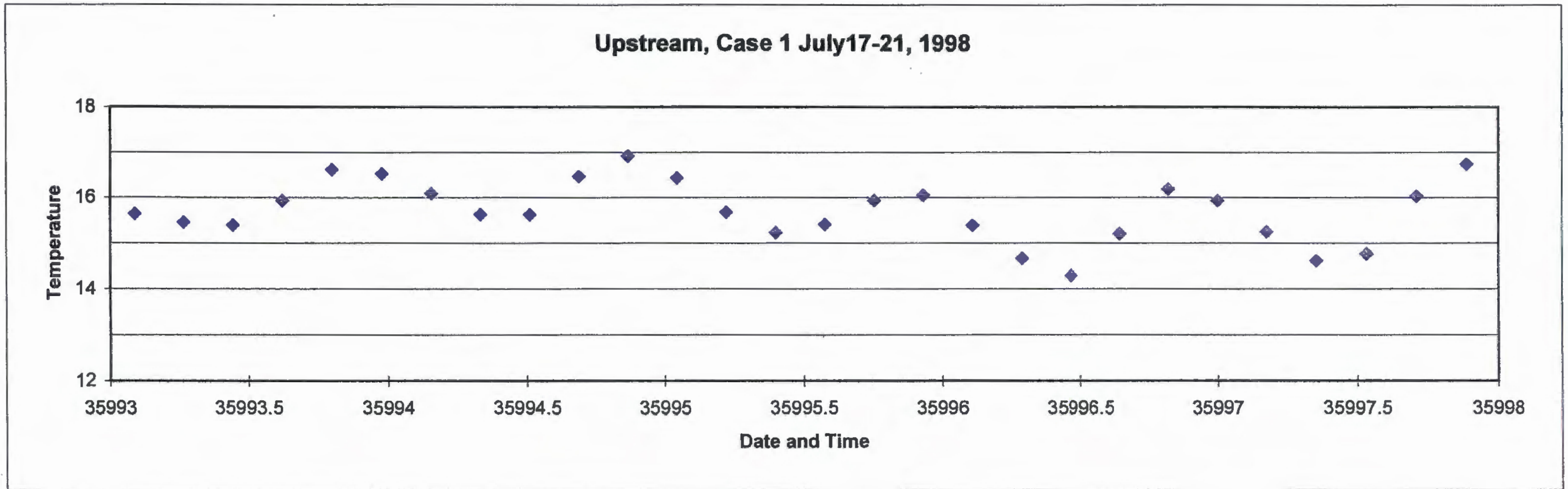
	Treated Section	*Upstream Control Section*	*Downstream Section*
Length distribution of habitat (m)	63% shallow pool, 37% riffle	60% deep pool(LWD), 40% rffle	20% pool (mix), 80% riffle
Total Length Reach Length(Thalweg)	85 m	87 m	87 m
Volume of LWD (Pieces/m stream)	0.05	0.17	0.06

Windthrow

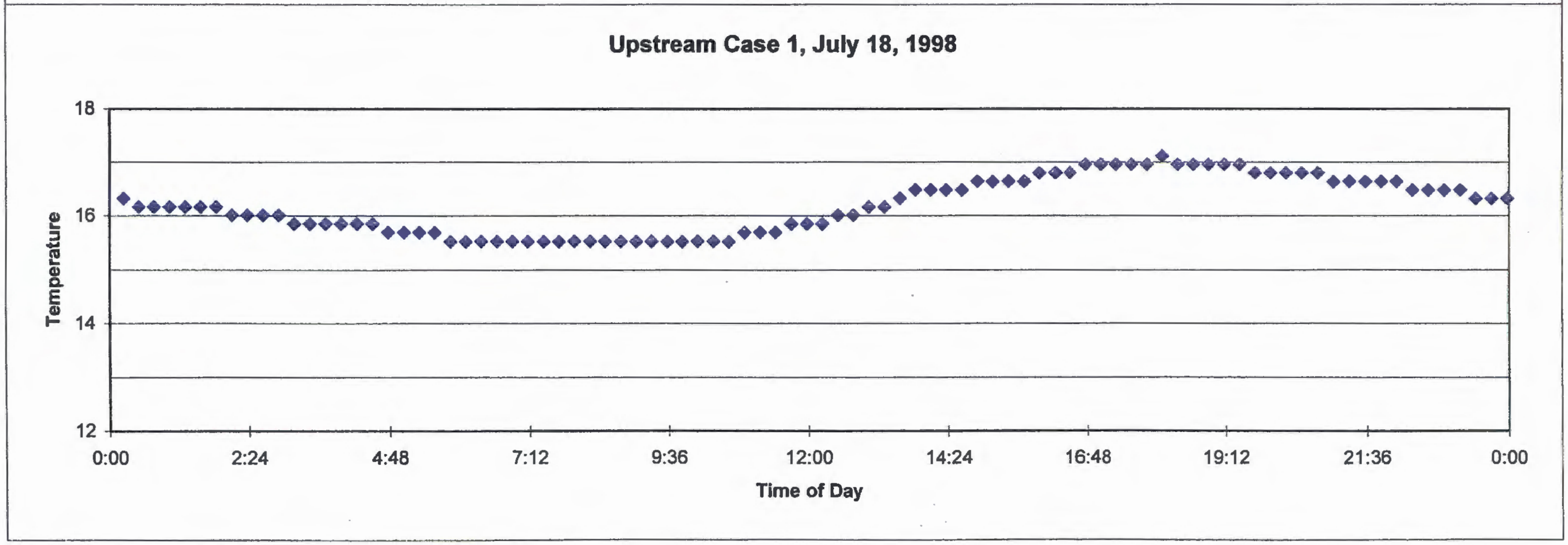
	Treated Section	*Upstream Control Section*	*Downstream Section*
Present	None observed	None Observed	None observed
Type	N/A	N/A	N/A
Species	N/A	N/A	N/A
Distance From Stream	N/A	N/A	N/A
% riparian zone vegetation	N/A	N/A	N/A
Photographs roll ID and #'s	N/A	N/A	N/A

Vegetation Management:

Observations The vegetation on the left bank (facing downstream) has been aggressively managed to create an almost
The vegetation on the left bank (facing downstream) has been aggressively managed to create an almost field like condition
field like condition, there are very few tall growing species other than a few maple tree clumps, in addition grasses are the dominant ground cover and there is no sign of rill erosion or surface flow. The right side has been less aggressively managed and as such there are many more clumps of tall growing maples and as well as naturally occurring coniferous trees. This side has also been planted out with cedars. The left side has dense pockets of scotch broom.



Upstream, Case 1 July17-21, 1998
Temperature
18
16
14
12
35993
35993.5
35994
35994.5
35995
35995.5
35996
35996.5
35997
35997.5
35998
Date and Time



Upstream Case 1, July 18, 1998
Temperature
18
16
14
12
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
21:36
0:00
Time of Day

Riparian Prescription

Stream Name: Kelvin Creek

Circuit: 1L10-11-14 (7/3-7/4)

Prescription

The following prescription is designed to ensure transmission powerline security while maintaining riparian zone ecosystem function. The uninterrupted transfer of power demanded by communities can only be achieved by keeping vegetation from growing within tolerable limits of approach. In addition, riparian zones are some of the most vital ecosystems to both aquatic and terrestrial habitats. Therefore, prescription will be designed as per the riparian management process to integrate operational and environmental needs.

Firstly, to protect aquatic habitat vegetation, work will be executed in a manner which prevents bank disturbance and increased erosion.

Secondly, to ensure shade and bank stability and reduce the need for future incursions into the area, vegetation control methods will be applied which encourage the native low growing community on the site.

Thirdly, where possible, safe and practical, tall growing trees will be topped and/or girdled and only felled when necessary.

Lastly, in cases where tree removal negatively impacts the site replanting will occur as per the attached planting standard.

Site Characteristics

This stream has a 50m wide shallow, braided channel with riffle run sequences and provides habitat to coho, chum, chinook, cutthroat, and steelhead.

Maintenance Plan

1. Selectively top conifers as they grow into the limits of approach.

2. Girdle or remove tall growing deciduous species as they grow into the limits of approach.

3. Encourage low growing species.

Case Number #2 **Location** Currie Creek, Mainlie Rd **Stream Name** Currie Creek
Direction of Flow East **Orientation of Crossing** Right Angle

General Information:

Date: June 10/98; July 22, 1998 | Crew: JS, JM | Time: 12:30 -3:30
Weather: Overcast; Sunny and Hot | General photograph roll ID and #'s: roll #2, 1-24

Site Description:

Region of B.C.: Vancouver Island | Biogeoclimatic Zone: Coastal Dougals Fir
Transmission Line Id: 2L170/126 | Tower Numbers (as power flows): 2.10 to 2.20
Width of rightofway: 185 m | Stream segment length: 195 m | Sideslope angles (%): n 2.5% s 5% e w
Vertical distance calculated from nearest stream bankf full width to top of gully (m or N/A): n 20 m s 10 m e w
Landuse immediately upstream: Logging
Predominant type of watershed land use: Logging
Distance from closest tower to nearest stream bank full width: LEFT | RIGHT 30m .
Fish Present: Yes | Species utlizing stream: Ct

Comments: This is a wide Rightofway for 2 separate steel structure 238 kV circuits. Currie Creek passes at right angles to the Rightofway. It crosses under a large access road bridge on the downstream side of the Righofway. The stream supports fish but is also intermittent. There's a narrow band, 1-3 trees wide, of riparian vegetation composed of willows and red alder. The Righofway has relatively few large coppice root wads, suggesting selective use of herbicide. In addition an old decommissioned bridge is located in the middle of the Rightofway (see below). The entire Righofway is low gradient and exhibits relatively no gully. When visited the stream was dry downstream of the ROW. Therefore no data were collected for the downstream section.

Crossing:

Type: Wooden Bridge | Condition: Dismantled | Age: > 20 years | Specifications: N/A

Comments: There is an old timber crib bridge which wood have spanned the middle Righofway. All that is left are a few timber logs, which would have formed the cribbing. The deck of the bridge has been removed from the site It appears a few of the large logs from the bridge have moved up to 30 m downstream. A pool has formed where the crossing used to exist, and is not included in the habitat descriptions/calculations.The old access road is well vegetated and there are no signs of rill erosion.

Riparian Ecosystem Function 1 - Energy flow:

	Treated Section	*Upstream Control Section*
Temperature (Diurnal range)	N/A	N/A
Light (mean PPFD)(micro mols)	122	16.64

Riparian Ecosystem 2 - Stream Hydrology:

	Treated Section	*Upstream Control Section*
Vegetation Density	8,500 stems/ha (decidous)	10,000 stems/ha (coniferous)
Vegetation Diversity	10%conifer, 90% deciduous (red alder,willow)	10% decidous, 90% conifer (tall), 60-80 years old.
Understory	20% bracken fern, 10% salal, 15% huckleberry 10% red elderberry, 5% goose berry, 40% broom	70% salal, 15% red elderberry, 15 mixed broad leaf shrub

Riparian Ecosystem Function 3 - Bank Stability:

	Treated Section						*Upstream Control Section*					
Transect	1	2	3	4	5	Mean	1	2	3	4	5	Mean
Bankfull Width (Wb)	2.80	3.30	2.90	3.00	3.20	3.04	8.50	5.30	4.50	4.40	4.90	5.52
Mean Depth (d)	50.00	48.00	42.00	42.00	42.00	44.80	35.00	50.00	30.00	50.00	57.00	44.40
D60 (D)	15.00	16.00	14.00	13.00	15.00	14.60	13.00	14.00	14.00	18.00	18.00	15.40
Gradient (%)	3	3.75	4.25	4.12	1.66	3.36	2.5	3.50	5.00	3.00	4.00	3.60
D/Wb	5.36	4.85	4.83	4.33	4.69	4.80	1.53	2.64	3.11	4.09	3.67	2.79
D/d	0.30	0.33	0.33	0.31	0.36	0.33	0.37	0.28	0.47	0.36	0.32	0.35
(D/d)(D/Wb)	1.6071	1.6162	1.6092	1.3413	1.6741	1.5651	0.5681	0.7396	1.4519	1.4727	1.1600	0.9677
Stream Type	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg
Importance of LWD	Controlled						Controlled					
Reach Disturbance	47 percent						21 percent					

Riparian Ecosystem Function 4 - Habitat Complexity

	Treated Section	Upstream Control Section
Distribution of habitat	48 percent pool, 52 percent riffle	39 percent pool, 61% percent riffle
Total Reach Length(Thalweg)	195 m	194 m
Volume of LWD (Pieces/m stream)	0.05	0

Windthrow

	Treated Section	Upstream Control Section
Present	None observed	None observed
Type	N/A	N/A
Species	N/A	N/A
Distance From Stream	N/A	N/A
% riparian zone vegetation	N/A	N/A
Photographs roll ID and #'s	N/A	N/A

Vegetation Management:

Observations: This site appears to have been managed aggressively over the years. The lack of tall growing trees/saplings along the wide Rightofway suggests herbicides have been used. This is further substantiated by the 2-3 deep band of deciduous trees which compose the riparian vegetation and coincide with a 10m pesticide free zone. In addition it appears that vegetation work has been completed at the site within the least 2 year. Some of the young deciduous trees have coppice and put on between 2 to 4 meters of growth, well within annual growth yields for these species within these biogeoclimatic zones. There is a significant debris jam at the upstream edge of the Righfofway, the material was either been placed there, during construction or it has been brought downstream and collected there. The material is mostly compose off large coniferous trees and associated smaller deciduous trees caught in the debris jam. This has lead to significant upstream aggradation.

Riparian Prescription

Stream Name: Currie Creek

Circuit: 2L126/170 (2/2-3/1)

Prescription

The following prescription is designed to ensure transmission powerline security while maintaining riparian zone ecosystem function. The uninterrupted transfer of power demanded by communities can only be achieved by keeping vegetation from growing within tolerable limits of approach. In addition, riparian zones are some of the most vital ecosystems to both aquatic and terrestrial habitats. Therefore, prescription will be designed as per the riparian management process to integrate operational and environmental needs.

Firstly, to protect aquatic habitat vegetation, work will be executed in a manner which prevents bank disturbance and increased erosion.

Secondly, to ensure shade and bank stability and reduce the need for future incursions into the area, vegetation control methods will be applied which encourage the native low growing community on the site.

Thirdly, where possible, safe and practical, tall growing trees will be topped and/or girdled and only felled when necessary.

Lastly, in cases where tree removal negatively impacts the site replanting will occur as per the attached planting standard.

Site Characteristics

This stream provides habitat to cutthroat. The streambed consists of incised bedrock, and the stream channel has a significant amount of LOD. There is an abundance of shrub streamside understory namely salmonberry, oceanspray, wild rose, stika willow on this site therefore planting is not required.

Maintenance Plan

1. Girdle all Red alder, Cottonwood trees greater than 4cm at girdle height on streamside to release understory in 1998.

2. The bridge will be replaced in 1998, a Q100 has been completed and a Section 9 permit has been applied for to complete in stream works

3. Girdle remaining alder and maple as their stems grow to the specific girdle width.

4. Encourage all low growing species. See diagram in field notes for details.

Case Number #3 **Location** Between Parksville and Union Bay, off of old Island Hwy. **Stream Name** Nile Creek

Direction of Flow East **Orientation of Crossing** 45 degrees

General Information:

Date: July 16/98
Crew: JS, AP
Time: 11:10am -3:10pm
Weather: Cloudy, overcast
General photograph roll ID and #'s: 2, 11-24

Site Description:

Region of BC: Vancouver Island
Biogeoclimatic Zone: Coastal Douglas Fir
Transmission Line Id: 2L123/128
Tower Numbers (as power flows): 64/3 to 65/1
Width of rightofway: 150 m
Stream segment length: 261 m
Sideslope angles: n 25% | s 30% | e | w
Vertical distance calculated from nearest stream bankfull width to top of gully (m or N/A): n 30 m | s 45 m | e | w
Landuse immediately upstream: Domestic Watershed, Dormant
Predominant type of watershed land use: Limited logging and farming
Distance from closest tower to nearest stream bank full width: LEFT 30m RIGHT
Fish Present: Yes
Species utilizing stream: Cm, Ctt, Pnk, Rbt,Std

Comments: This is a wide Rightofway with 2 steel structure 238 kV circuits. Nile Creek passes through the ROW at 45% angle and is in a fairly deep, broad gully. The site is located within 5 km of the streams confluence with the ocean, and has noroad crossing. It is low gradient and has many enhancement groups. activities. There are no signs of erosion although the area is heavily used by local residents as a greenway for walking and fishing.
While there is no debris jam usptream, the Rightfway has a debris jam in the middle casuing significant lateral movement of the stream. The upstream section is 150 m long ending at an area manipulated by the waterboard, thereby reducing confounding variables. The upstream section is composed of two channels, data was collected for both.

Crossing:

Type: None
Condition: N/A
Age: N/A
Specifications: N/A

Comments: There is crossing at this site but a waterboard access road parallels the right bank of the Creek. It remains at least 80 m from the stream at all times across the Rightofway.The road is gated and receives very little use.

Riparian Ecosystem Function 1 - Energy flow:

	Treated Section	Upstream Control Section	Downstream Section
Temperature (Diurnal range)	12.00 - 13.75	12.50 - 14.25	N/A
Light (mean PPFD)(micro mols)	199.3	90.7	75.25

Riparian Ecosystem 2 - Stream Hydrology:

	Treated Section	Upstream Control Section	Downstream Section
Vegetation Density	29,700 stem/ha (predominantly decidous)	257 stem/ha, conifer (large >60ft mature conifer) 596 stem/ha, deciduous	229 stems/ha, conifer (trees,>70ft) 523 stem/ha, deciduous (>50ft large,)
Vegetation Diversity	60% red alder, 30% big leaf maple, 10% coniferous	60% cedar, 30% hemlock, 10% fir, conifer red alder, deciduous (near open areas near the road beside Nile Crk)	70% hemlock, 20% cedar, 10% fir
Understory	50% salmonberry,30% thimbleberry, 10% brackenfern,10%mixed herbacious	very little, sword fern, salmon berry (where light allows), thimbleberry	70% salmonberry, 10% swordfern, 10% thimble berry, 10% mixed herbacious,where the canopy is open

Riparian Ecosystem Function 3 - Bank Stability:

	Treated Section						Upstream Control Section						Downstream Section				
Transect	1	2	3	4	5	Mean	1(L)	2(L)	3	4 (R)	5(R)	Mean	1	2	3	4	Mean
Bankfull Width (Wb)	14.80	14.00	16.00	10.80	12.30	13.58	10.90	13.80	8.60	9.60	5.80	9.74	11.80	12.40	14.00	14.20	13.10
Mean Depth (d)	0.40	0.90	0.86	0.73	0.85	0.75	0.85	0.65	0.81	0.72	0.85	0.78	66.00	60.00	54.00	60.00	60.00
D60 (D)	0.22	0.21	0.16	0.24	0.22	0.21	0.24	0.17	0.23	0.11	0.16	0.18	20.00	17.00	21.00	21.00	19.75
Gradient (%)	1.5	2.00	2.00	2.00	2.00	1.90	2	1.50	2.50	4.00	2.00	2.40	2.5	1.00	2.00	2.50	2.00
D/Wb	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.03	0.01	0.03	0.02	0.02	0.01	0.02	0.01	0.02
D/d	0.55	0.23	0.19	0.33	0.26	0.28	0.28	0.26	0.28	0.15	0.19	0.23	0.30	0.28	0.39	0.35	0.33
(D/d)(D/Wb)	0.0082	0.0035	0.0019	0.0073	0.0046	0.0043	0.0062	0.0032	0.0076	0.0018	0.0052	0.0044	0.0051	0.0039	0.0058	0.0052	0.01
Stream Type	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc
Importance of LWD	Controlled						Controlled						Controlled				
Reach Disturbance	31 percent						39 percent						56 percent				

Riparian Ecosystem Function 4 - Habitat Complexity

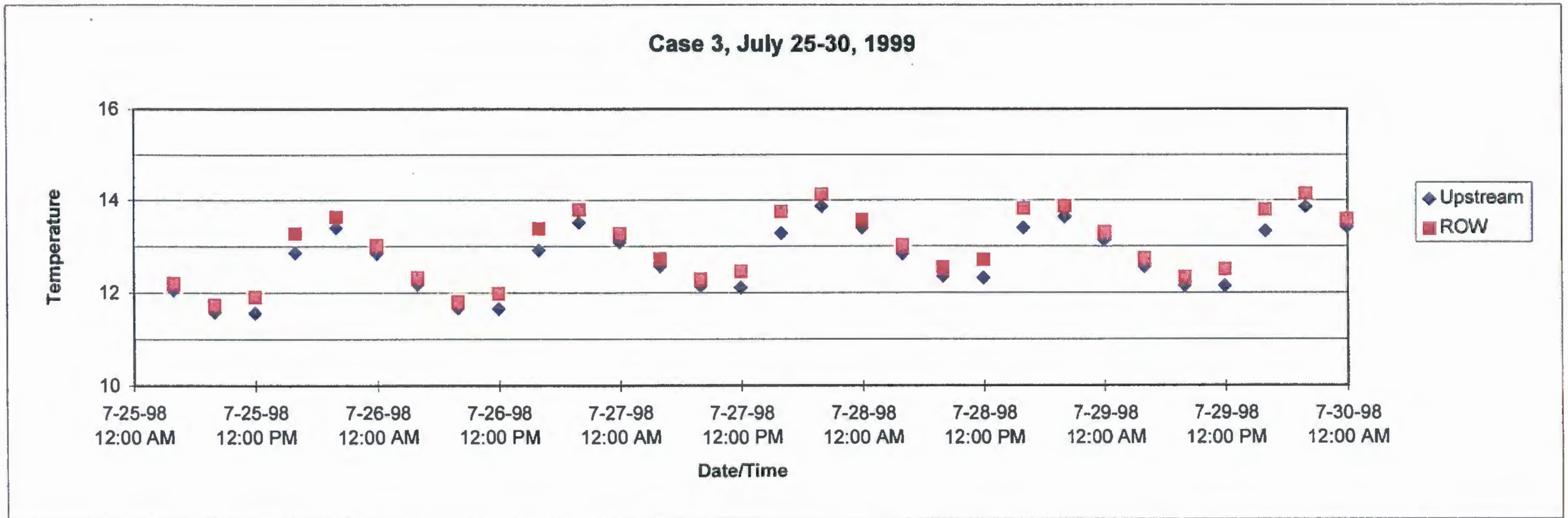
	Treated Section	*Upstream Control Section*	*Downstream Section*
Distribution of habitat	34 percent pool, 66 percent riffle	54 percent pool, 46 percent riffle	31 percent pool, 69 percent riffle
Total Reach Length(Thalweg)	261 M	147.00	215.00
Volume of LWD (Pieces/m stream)	0.08	0.08	0.10

Windthrow

	Treated Section	*Upstream Control Section*	*Downstream Section*
Present	None	None	None
Type	N/A	N/A	N/A
Species	N/A	N/A	N/A
Distance From Stream	N/A	N/A	N/A
% riparian zone vegetation	N/A	N/A	N/A
Photographs roll ID and #'s	N/A	N/A	N/A

Vegetation Management:

Observations: The site, except for the gully with the riparian zone has been managed aggressively over the past 10 to 20 years. There is a lack of tall growing spp. Instead the Righofway vegetation is dominated by low growing shrub species, broom and mixed berry species. Nile Creek crosses the Rightofway at approximately a 45 degrees through a shallow yet morphologically complex gully. The creek is part of the local waterboard water source. Little vegetation work seems to have occurred ,except for selective slashing since the line was built 25 yrs ago. The vegetation of the site is composed of massive maple root wads with up 200 stems per wad, tall conifer trees and red alders with DBH's up to 60 cm. A significant portion of the vegetation is now threatening the powerline, almost all existing alders have been girdled and will fall. Maple root wads have been slashed again and where appropriate it appears conifer species have been topped. While there is significant conifer recruitment in the mixed stands. In the areas composed of red alder (@70% of the right bank), the understorry is predominantly composed of thick salmonberry bushes, eliminating the opportunity for young conifer species to get established it appears that as the area is opened to light (as girdled trees fall) the potential for tall growing trees will be significantly reduced.The clearances in this gully would allow the growth of conifers species which could be topped on 20 to 25 year cycles.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14
12
10
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7-27-98 12:00 AM
7-27-98 12:00 PM
7-28-98 12:00 AM
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7-29-98 12:00 AM
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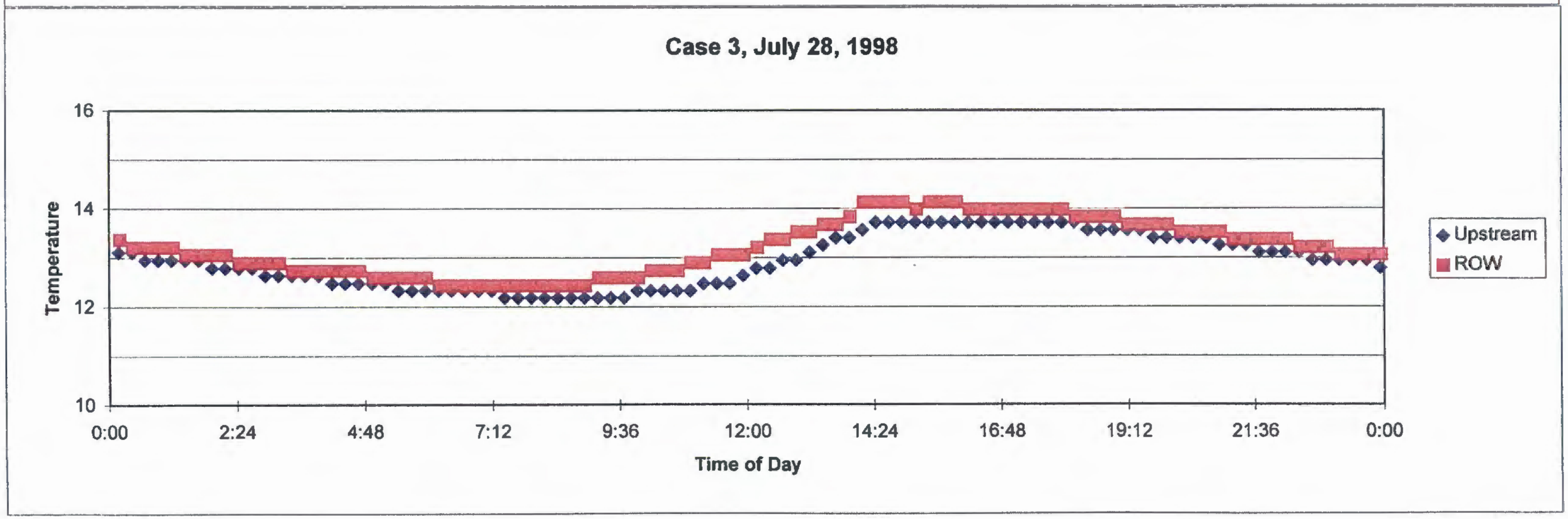
7-30-98 12:00 AM
Date/Time
Upstream
ROW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12:00
14:24
16:48
19:12
21:36
0:00
Time of Day
Upstream
ROW

Appendix 3 Examples of Implemented Site-Specific Prescriptions for Management of Riparian Vegetation in Transmission ROWs

Location: **Nile Creek**

Power Line: 5L29/31

Setting: The stream side vegetation surrounding the 185 m section of Nile Creek, near Qualicum Beach B.C., where it crosses underneath power line 5L29/31, is a productive riparian ecosystem. However, it is also an area where vegetation must be maintained to ensure the flow of power to Vancouver Island is never interrupted. At this crossing site, tall growing vegetation is dominated by deciduous species including big leaf maple, red alder and black cottonwood. In addition, the site has tall coniferous species which include hemlock, western red cedar and Douglas fir. Currently, the tallest of the red alder, black cottonwood, hemlock and Douglas fir are reaching heights of between 10 to 15 m, bringing some within the transmission line's limit of approach. The dense lower canopy of the site is dominated by salmonberry, elderberry, bitter cherry, ferns and other berry species.

Nile Creek is classified as a S2 stream, utilized by coho and chum salmon as well as resident trout species. The section of creek flowing through this site, has a gradient of <2.0%, exhibits predominantly run-riffle habitat (with few pools) and substrate dominated by large gravel and cobble. In the upstream 90 m of the crossing the stream demonstrates multiple channels and good habitat complexity. However, the remaining 95 m of the crossing the creek remains in a single channel, has ample shading but lacks habitat complexity. To compensate for this, enhancement activities have involved placing large organic debris (LOD) within the stream or cabling it to the stream bank.

Nile Creek has significant social value. This area is readily accessible and heavily utilized by both sport fishers and hikers. The crossing lies within the traditional lands of the Qualicum Indian Band Habitat. In addition habitat conservation is also a major concern of the Nile Creek Hatchery Society.

Rationale: The following work is planned for the area which falls within the 50 m riparian zone around this S2 stream. Over a 8 year (figure 1) period the current tall growing largely deciduous riparian community will be altered into a mixed low growing deciduous and taller growing coniferous community. This plan will maintain the current functions of the riparian community but will lead to less frequent and drastic incursions into the area. In addition, developing the largely coniferous stream side community will contribute to hydraulic stability and habitat complexity (through the natural addition of LOD). In the future, riparian zone vegetation management will involve removal of hazard trees from the site rather than major site disturbance.

Procedure:

1. Prepare a site work plan including access, planting strategies and goals for the site, which is discussed with work crews during all tailboard meetings.
2. Girdle 1/3 of tallest deciduous trees throughout the site with priority given to the tallest and those clumps which provide the best natural regeneration.

3. Selectively crown reduce (by up to 1/2) all coniferous trees, >20m tall.
4. Do not modify species which will not grow tall enough to enter limits of approach.
5. Prepare and implement plan a which maintains biodiversity at the site including;
    a) Enhancing willow, red elderberry, Indian plum and other native low to medium height deciduous species found at the site,
    b) Where appropriate and beginning directly adjacent to the high water mark of the stream plant minimum 1 m tall acceptable conifer species.
    c) Monitor site and ensure good survivals
6. Ensure no machinery enters stream or damages banks.
7. Selectively create wildlife trees where safe, practical and effective.

Year 1	1) Girdle 1/3 of riparian deciduous trees 2) crown reduce coniferous trees (>20m) 3) selective planting where required
Year 2	1) Girdle 1/3 of riparian deciduous trees
Year 3	1) Girdle 1/3 of riparian deciduous trees
Year 4	1) Monitor planted site 2) Girdle selected vegetation
Year 5	1) Monitor site
Year 7	1) Monitor site
Year 8	1) Girdle selected vegetation 2) Monitor site

Proposed Schedule for Vegetation Management in the Riparian Area of Nile Creek

Case Number #4 **Location** Immediately west of Nanaimo **Stream Name** French Cr. Trib.5

Direction of Flow East **Orientation of Crossing** Right Angle

General Information:

Date: July 17/ 98
Crew: JS, AP
Time: 10:00am - 2:00pm
Weather: Sunny
General photograph roll ID and #'s: 3, 1-24, 4,

Site Description:

Region of BC: Vancouver Island
Biogeoclimatic Zone: Coastal Western Hemlock
Transmission Line Id: 2l123/28
Tower Numbers (as power flows): 48/1 to 48/2
Width of Rightofway: 125 m
Stream segment length: 125 m
slideslope angles: n 120% | s 130% | e | w
Vertical distance calculated from nearest stream bankfull width to top of gully (m or N/A): n 45 m | s 40 m | e | w
Landuse immediately upstream: Dormant, logged over 15-20 years ago
Predominant type of watershed land use: Logging
Distance from closest tower to nearest stream bank full width: LEFT | RIGHT 36m
Fish Present: Yes
Species utilizing stream: unknown

Comments: The crossing includes a small stream at the bottom of a relatively short yet very steep gully. The gully is crossed by one span to span length of the wood pole structures and hardware. As such the line itself does not enter the gully but rather stretches across it. The riparian vegattaion is composed of bushes and shorter species, except for a band of decidous trees 1-5 individuals deep, adjacent to the stream. The site is relatively remote and the access road would be predominantly used by hunters and logging companies. There are debris jams located at several points along the study area.

Crossing:

Type: None
Condition: N/A
Age: N/A
Specifications: N/A

Comments: There is no crossing a this steep little gully, rather access to each tower on the other side of gully is accomplished by using a crossing approximately 2 km downstream of the site and then back tracking along existing roads.

Riparian Ecosystem Function 1 - Energy flow:

	Treated Section	Upstream Control Section	Downstream Section
Temperature (Diumal range)	13.00 - 19.50	14.00 - 16.00	14.00 - 23.00
Light (mean PPFD)(micro mols)	24.00	4.00	18.80

Riparian Ecosystem 2 - Stream Hydrology:

	Treated Section	Upstream Control Section	Downstream Section
Vegetation Density	2459 stems/ha	1283 stems/ha	2166 stems/ha
Vegetation Diversity	90% red alder, 10% cedar	40% cedar, 30% hemlock, 30% red alder	40% red alder, 30% cedar, 30% hemlock
Understory	40% willow sp., 20% huckleberry, 30% salmonberry, 10% salal	20% berry, 40% brackenfern, 25% willow sp., 15% salal	30% mixed berry,available light near ROW edge 30 willow sp. 30% brackenfern, 10% salal

Riparian Ecosystem Function 3 - Bank Stability:

	Treated Section						Upstream Control Section				Downstream Section			
Transect	1	2	3	4	5	Mean	1	2	3	Mean	1	2	3	Mean
Bankfull Width (Wb)	4.00	4.00	2.70	3.10	4.30	3.62	2.50	4.20	3.70	3.47	4.10	2.80	5.10	4.00
Mean Depth (d)	0.35	0.42	0.37	0.43	0.44	0.40	0.44	0.44	0.52	0.47	0.29	0.17	0.07	0.18
D60 (D)	0.10	0.12	0.10	0.21	0.16	0.14	0.18	0.16	0.16	0.17	0.12	0.13	0.42	0.22
Gradient (%)	3.5	5	1	5	6	4.10	5	5.5	5	5.17	5	10	4	6.33
D/Wb	0.03	0.03	0.04	0.07	0.04	0.04	0.07	0.04	0.04	0.13	0.07	0.06	0.01	0.04
D/d	0.29	0.29	0.27	0.49	0.36	0.34	0.41	0.36	0.31	0.36	0.41	0.76	6.00	1.26
(D/d)(D/Wb)	0.0071	0.0086	0.0100	0.0331	0.0135	0.0131	0.0295	0.0139	0.0133	0.0481	0.0293	0.0464	0.0824	0.0558
Stream Type	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc
Importance of LWD	Controlled						Controlled				Controlled			
Reach Disturbance	30 percent						46 percent				0 percent			

Riparian Ecosystem Function 4 - Habitat Complexity

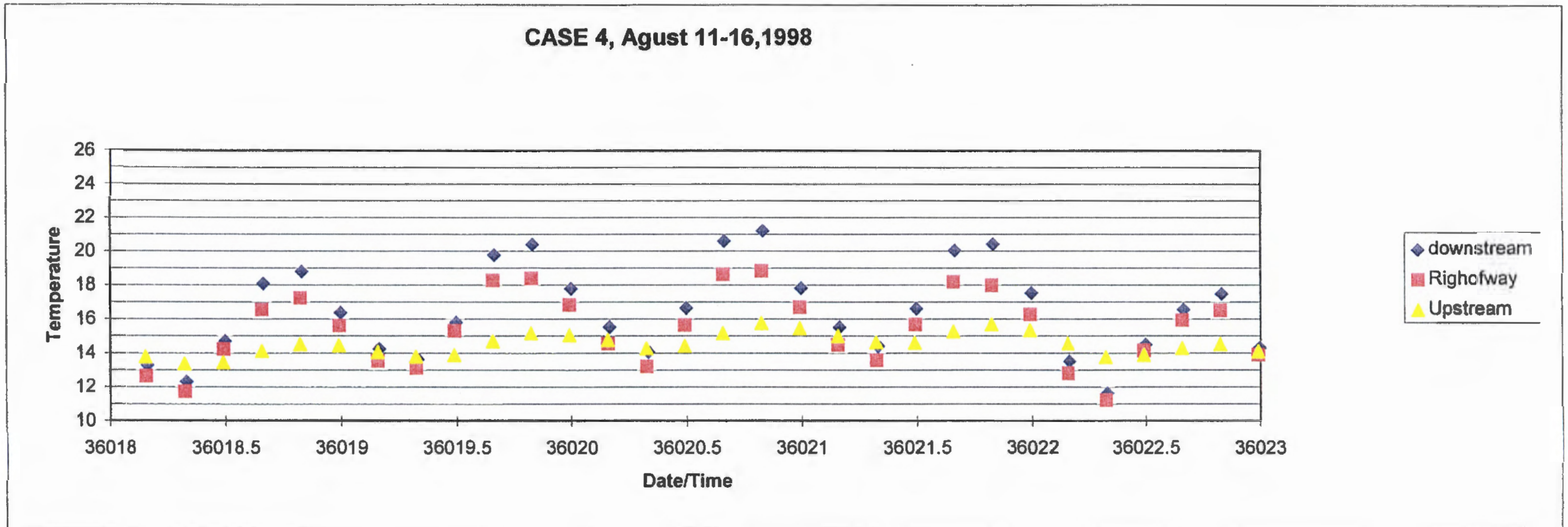
	Treated Section	Upstream Control Section	Downstream Section
Distribution of habitat	37 percent pool/ 63 percent riffle	36 percent pool/ 64 percent riffle	53 percent poool/ 47 percent riffle
Total Reach Length(Thalweg)	125.00	73.00	47.50
Volume of LWD (Pieces/m stream)	0.0213	0.06	0.09

Windthrow

	Treated Section	Control Section	Downstream Section
Present	None	None	None
Type	N/A	N/A	N/A
Species	N/A	N/A	N/A
Distance From Stream	N/A	N/A	N/A
% riparian zone vegetation	N/A	N/A	N/A
Photographs roll ID and #'s	N/A	N/A	N/A

Vegetation Management:

Observations: The vegetation along the ROW, except for the riparian gully has been managed aggressively. The right bank, above the gully has numerous conifers and seems to be either a Christmas tree farm or managed wood lot. The left side of the gully has been managed more extensively and there is very few tall growing stems. The gully has bee slashed and managed except for a stretch of trees adjacent to the stream. This combined with the noticeable presence of tall trees, except for the strip next to the stream, suggests slashing and treating has been accomplished to the 10 m pesticide free zone.
This has resulted in a very dense layer of berry (salmonberry) plants and other mixed shrub layer. There is a dense and diverse tall growing deciduous strip through the Righofway but a noticeable lack of opportunity for conifer recruitment.
The clearances at this site seem to suggest conifers could be topped ever 10 to 20 years and not effect line safety.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24
22
20
18
16
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12
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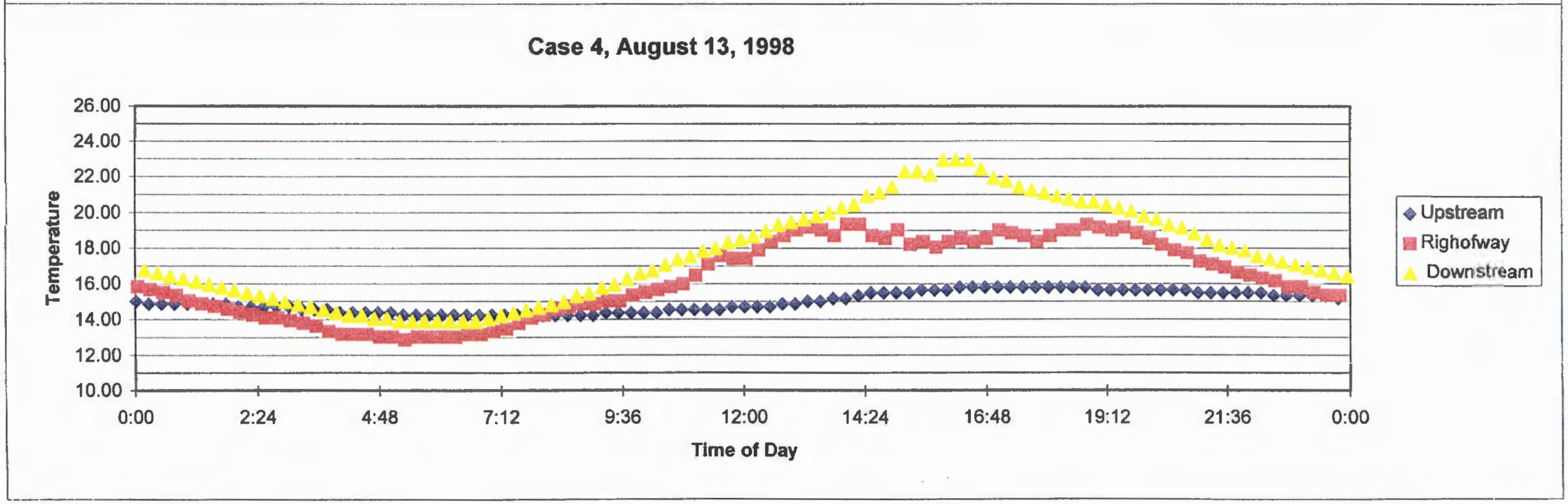
36018
36018.5
36019
36019.5
36020
36020.5
36021
36021.5
36022
36022.5
36023
Date/Time
downstream
Righofway
Upstream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9:36
12:00
14:24
16:48
19:12
21:36
0:00
Time of Day
Upstream
Righofway
Downstream

Case Number #5 **Location** Top of Westwood Plateau, Coquitlam B.C. **Stream Name** Noons Creek

Direction of Flow South **Orientation of Crossing** Right angle

General Information:

Date: July 21/98 Crew: JS, JM Time: 10:30 - 2:30

Weather: Sunny, hot General photograph roll ID and #'s: 4, 1-24

Site Description:

Region of BC: Lower Mainland Biogeoclimatic Zone: Coastal Western Hemlock

Transmission Line Id: 5L45 Tower Numbers (as power flows): N/A to N/A

Width of rightofway: 65 m stream segment length: 65 m slideslope angles: n | s | e 5% | w 5%

Vertical distance calculated from nearest stream bankfull width to top of gully (m or N/A): n | s | e 10 m | w 10 m

Landuse immediately upstream: Dormant (hill above development)

Predominant type of watershed land use: The watershed is predominantly used for residential development

Distance from closest tower to nearest stream bank full width: LEFT 42m RIGHT

Fish Present: Yes Species utilizing stream: Yes, unknown

Comments: This site is located at Noons Creek above Westwood Plateau, near Meridian Substation, in Coquitlam B.C.. The site involves a narrow Righofway and single steel 238 kv circuit. There is a large debris jam at the upstream edge of the ROW. The stream has a fairly high gradient, however the site is not located in a gully, rather it flows down the is of the mountain. There is a well used Rightofway access at the downstream edge of the Rightofway. There are 3, 1 m diameter culverts which pass under the road. The downstream section of the case study site is significantly higher gradient. A large barrier (falls) is located 67 m downstream of the Righofway. The upstream section is composed of large conifers which appear to be >100 yr. old.

Crossing:

Type: Culverts (3) Condition: Good Age: N/A Specifications: 3 of 1.0 m

Comments: The culverts are located at the downstream edge of the ROW. They pass under the gated Rightofway access road. It is heavily used by recreation enthusiasts and in good condition.

Riparian Ecosystem Function 1 - Energy flow:

	Treated Section	*Upstream Control Section*	*Downstream Section*
Temperature (Diurnal range)	17.0 - 18.0	17.0 - 17.5	16.75 - 17.5
Light (mean PPFD)	29.00	3.00	1.00

Riparian Ecosystem 2 - Stream Hydrology:

	Treated Section	Upstream Control Section	Downstream Section
Vegetation Density	23,565 stems/ha (deciduous)	1,283 stems/ha (conifer)	356 stems/ha (decidous)
Vegetation Diversity	5% other, 5% cottonwood, 20% willow species, 70% red alder.	90% conifer (tall),60-100 yrs old.,10% decidous (red alder and cottonwood) at edge of ROW's	5% cottownwood, 5% hemlock, 90% red alder. the alder are of uniform height and spacing
Understory	5% spruce, 45% huckleberry, 50% salmonberry.	Minimal shrub.	Sparse of brackenfern, few salmonberries.

Riparian Ecosystem Function 3 - Bank Stability:

	Treated Section					Upstream Control Section				Downstream Section				
Transect	1	2	3	4	Mean	1	2	3	Mean	1	2	3	4	Mean
Bankfull Width (Wb)	3.70	3.80	3.90	4.00	3.85	2.40	2.10	3.40	2.63	5.70	6.60	8.60	5.90	6.70
Mean Depth (d)	0.40	0.68	0.66	0.50	0.56	0.36	0.45	0.67	0.49	0.46	0.52	0.35	0.70	0.51
D60 (D)	0.19	0.23	0.22	0.16	0.20	0.16	0.12	0.14	0.14	0.17	0.24	0.17	0.21	0.20
Gradient (%)	3	8	4	8	5.75	2.5	3.00	4.00	3.17	11	3.00	7.00	10.00	7.75
D/Wb	0.05	0.06	0.06	0.04	0.05	0.07	0.06	0.04	0.19	0.08	0.08	0.04	0.12	0.08
D/d	0.48	0.34	0.33	0.32	0.37	0.07	0.06	0.04	0.05	0.03	0.04	0.02	0.04	0.03
(D/d)(D/Wb)	0.0244	0.0205	0.0188	0.0128	0.0190	0.0044	0.0033	0.0017	0.0100	0.0024	0.0029	0.0008	0.0042	0.0022
Stream Type	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPg	RPc-g	RPc	RPc	RPc	CP-RPc	RPc
Importance of LWD	controlled					controlled				controlled				
Reach Disturbance	85 percent					0 percent				100 percent				

Riparian Ecosystem Function 4 - Habitat Complexity

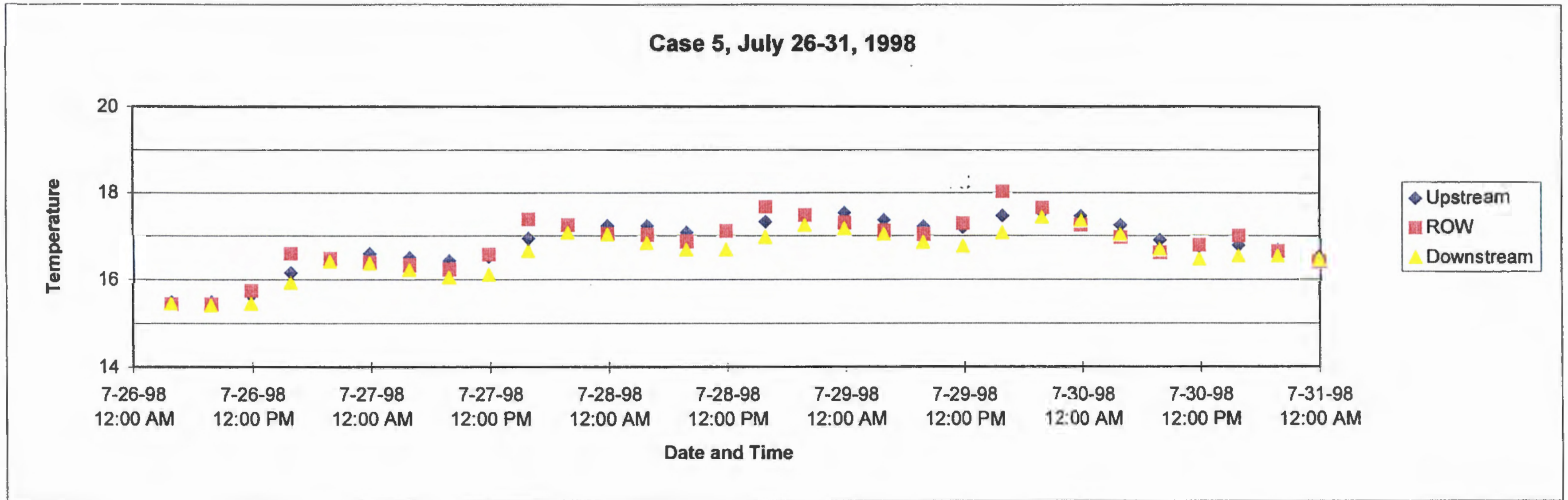
	Treated Section	*Upstream Control Section*	*Downstream Section*
Length distribution of habitat	35 percent pool, 65 percent riffle	46 percent pool, 54 percent riffle	38 percent pool, 62percent riffle
Total Length Reach Length(Thalweg)	65.00	74.00	65.00
Volume of LWD (Pieces/m stream)	0.02	1.50	0.05

Windthrow

	Treated Section	*Upstream Control Section*	*Downstream Section*
Present	None	None	None
Type	N/A	N/A	N/A
Species	N/A	N/A	N/A
Distance From Stream	N/A	N/A	N/A
% riparian zone vegetation	N/A	N/A	N/A
Photographs roll ID and #'s	N/A	N/A	N/A

Vegetation Management:

Observations: The site has high stem densities and exhibits numerous tall growing tree species. This suggests that the vegetation has been slashed and/or mowed. The site does not include a pronounced gully. There is no strip of riparian trees but rather the entire riparian zone is densely populated by salmonberry, willow, maple and red alder which in many cases have massive coppice stems and provide cover. The site displays 3 separate vegetation communities. Upstream the site is a very old second growth forest with heavy canopy and little light access. The Rigtofway section is composed of mixed species, with very few young conifers. The downstream section is predominantly composed of red alder. They appear to be between 30 to 50 years old and provide a fairly dense canopy, the canopy gives way to a clearing at the downstream edge of the section.



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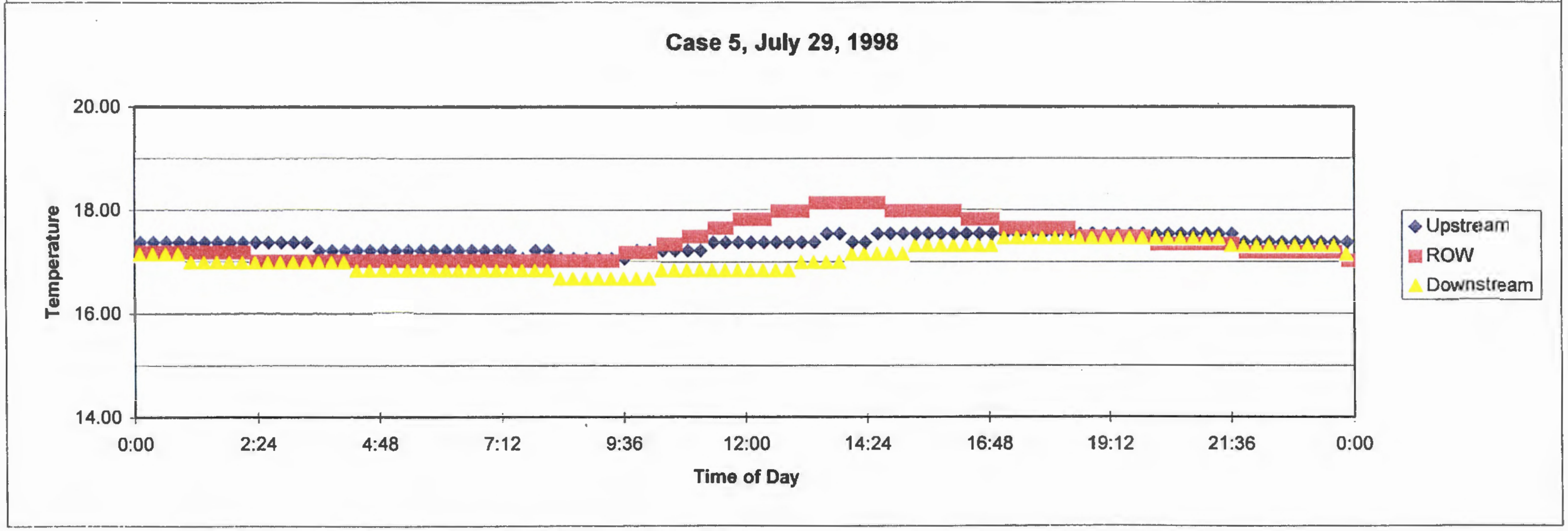
Date and Time
Upstream
ROW
Downstream



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14.00
0:00
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9:36
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14:24
16:48
19:12
21:36
0:00
Time of Day
Upstream
ROW
Downstream

Case Number #6 **Location** UBC Research Forest,Maple Ridge B.C. **Stream Name** Donegani Crk.
Direction of Flow S/W **Orientation of Crossing** Zig-zag

General Information:

Date: July 22/98
Crew: JS, JM
Time: 10:00am-3:00pm
Weather: Sunny, very hot
General photograph roll ID and #'s: 4, 1-24, 5, 1-24

Site Description:

Region of BC: Lower Mainland
Biogeoclimatic Zone: Coastal Western Hemlock
Transmission Line Id: 5L82
Tower Numbers (as power flows): 141/2 to 141/3
Width of rightofway:
Stream segment length: 175 m
slideslope angles: n 10% | s 15% | e | w
Vertical distance calculated from nearest stream bankfull width to top of gully (m or N/A): n 15 m | s 15 m | e | w
Landuse immediately upstream: None
Predominant type of watershed land use: Research into forestry and logging practices
Distance from closest tower to nearest stream bank full width: LEFT 56m RIGHT .
Fish Present: Yes
Species utilizing stream: Yes, Unknown

Comments: The site involves a wide Righofway, single steel 500 kv circuit and a salmonid stream which meanders between towers in a zigzag manner, but crosses at about 45 degrees. The stream flows out of the UBC research forest hills and then meanders through the bottom of forest across the case site. There is a large rock, and step falls in the latter end of the ROW, however it does not constitute a reach break.
The stream passes under a very large bridge located at the downstream edge of the Righofway. The stream does not appear to be affected by the large bridge.The site is very remote, with a very overgrown access raod. A large debris jam is loacted at the suptream edge of the rightofway. Through the Rightofway, there is no riparian strip of tall trees, rather dense understorry growth. All functioning LWD is old growth conifer.

Crossing:

Type: Bridge
Condition: Good
Age: >20yrs
Specifications: 10m by 5m

Comments: The bridge is at the downstream edge of the ROW. The deck of the bridge is located @ 20 m above the river bed. As stated above the timber cribbing is large (over 1.5 m in diameter) and located 15 m from each other. It appears the stream morphology is minimally affected by the large structure.

Riparian Ecosystem Function 1 - Energy flow:

	Treated Section	Upstream Control Section	Downstream Section
Temperature (Diurnal range)	17.5 - 22.25	17.75 - 22.0	17.0 - 21.75
Light (mean PPFD)	40.13	11.50	44.50

Riparian Ecosystem 2 - Stream Hydrology:

	Treated Section	Upstream Control Section	Downstream Section
Vegetation Density	6,833 stems/ha (Tall growing)	1875 stems/ha	3,996 stems/ha
Vegetation Diversity	20% maple/cottonwood, 10% hemlock 20% Fir, 10% cedar, 40% red alder	10% cottonwood, 40% alder, 50% conifer.	5% cottonwood, 80% red alder, 15% cedar
Understory	20% red elderberry, 20% willow, 20% mixed berries, 40% salmon berry	Dense in pockets, 40% red elderberry, 30 salal, 10% thimble berry, 10% huckleberyy, !0% mixed	Very dense understory, 5% brackenfern, 5% thimble berry, 90% salmonberry.

Riparian Ecosystem Function 3 - Bank Stability:

	Treated Section						Upstream Control Section					Downstream Section					
Transect	1	2	3	4	5	Mean	1	2	3	4	Mean	1	2	3	4	5	Mean
Bankfull Width (Wb)	4.10	5.00	2.90	3.60	3.90	3.90	4.00	5.70	5.80	3.50	4.75	4.00	4.20	5.20	5.30	4.50	4.64
Mean Depth (d)	0.46	0.50	0.63	0.59	0.57	0.55	0.09	0.18	0.52	0.60	0.35	0.46	0.55	0.47	0.49	0.40	0.47
D60 (D)	0.17	0.12	0.14	0.14	0.12	0.14	0.51	0.61	0.08	0.11	0.33	0.18	0.18	0.14	0.20	0.18	0.18
Gradient (%)	2.3	3	3	1	1	2.06	2.5	3.00	2.00	2.00	2.38	0	4.00	1.00	3.00	4.00	2.40
D/Wb	0.04	0.02	0.05	0.04	0.03	0.04	0.13	0.11	0.01	0.03	0.07	0.05	0.04	0.03	0.04	0.04	0.04
D/d	0.37	0.24	0.22	0.24	0.21	0.25	5.67	3.39	0.15	0.18	0.94	0.39	0.33	0.30	0.41	0.45	0.37
(D/d)(D/Wb)	0.0153	0.0058	0.0107	0.0092	0.0065	0.0089	0.7225	0.3627	0.0021	0.0058	0.0650	0.0176	0.0140	0.0080	0.0154	0.0180	0.0141
Stream Type	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg
Importance of LWD	controlled						controlled					controlled					
Reach Disturbance	0 percent						31 percent					46 percent					

Riparian Ecosystem Function 4 - Habitat Complexity

	Treated Section	Upstream Control Section	Downstream Section
Distribution of habitat	62 percent pool, 38 percent riffle	48 percent pool, 52 percent riffle	31 percent pool, 69 percent riffle
Total Reach Length(Thalweg)	174.00	120.00	75.00
Volume of LWD (Pieces/m stream)	0.12	0.04	0.05

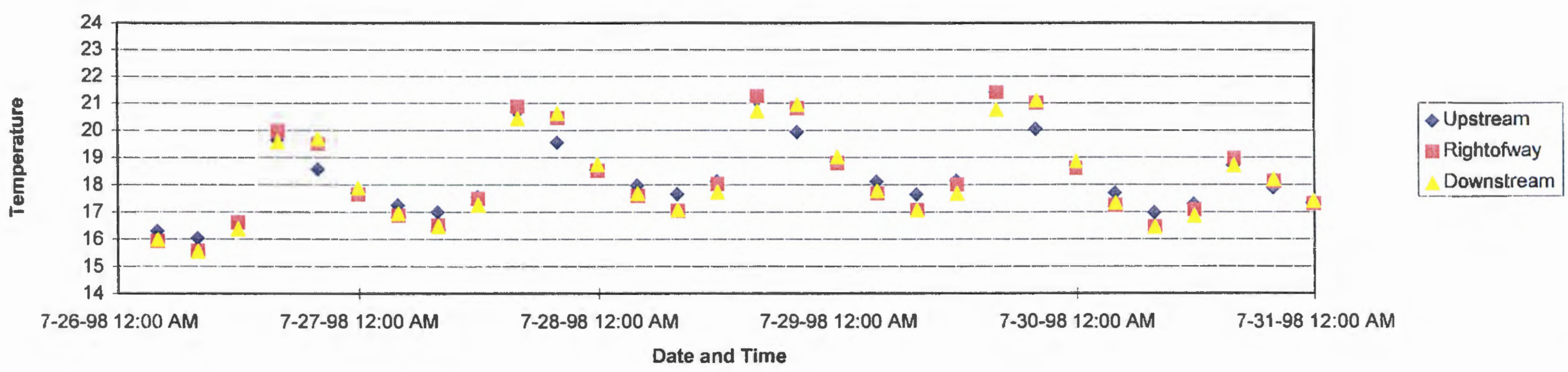
Windthrow

	Treated Section	Upstream Control Section	Downstream Section
Present	None	None	Yes
Type	N/A	N/A	Young trees bent over, roots intact
Species	N/A	N/A	red alder
Distance From Stream	N/A	N/A	Over and in stream
% riparian zone vegetation	N/A	N/A	@2.5 percent
Photographs roll ID and #'s	N/A	N/A	Photo 3

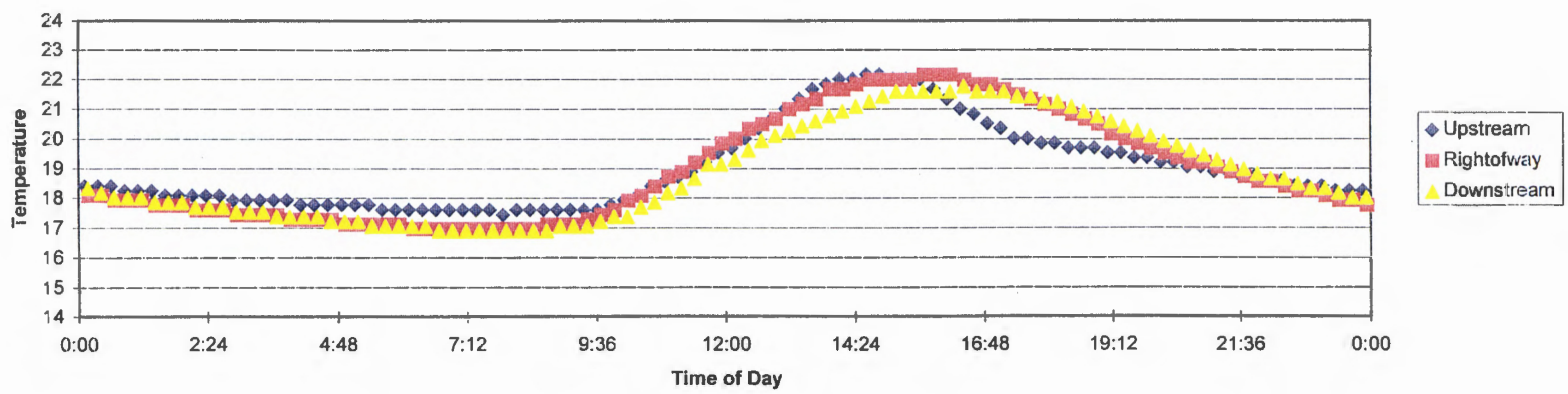
Vegetation Management:

Observations: Very dense vegetation in ROW area, has been slashed recently. The ROW crossing appears to have been managed within the last 2 years. This is suggested by the fact all tall trees species have been slashed and lie horizontal on the ground. The usptream community is composed of mature second growth forest in a braod gully, the
Righofway is composed of low growing species in high densities, the Downstream section is mature and composed of mixed conifer and deciduus species.

Case 6, July 26-1,1998



Case 6, July 29, 1998



Case Number #7

Location Surrey; 184street and 80th Avenue

Stream Name Mahood Creek

Direction of Flow South

Orientation of Crossing Right angle

General Information:

Date	July 23/98	Crew	JS, JM	Time	11:00 - 14:00
Weather	Sunny, very hot	General photograph roll ID and #'s			1, 1-24

Site Description:

Region of BC: Lower Mainland

Biogeoclimatic Zone: Coastal Western Hemlock

Transmission Line Id: 5L40/5L81

Tower Numbers (as power flows): to

Width of rightofway: 130m

Stream segment length: 140 m

	n	s	e	w
Sideslope angles	n	s	e 35%	w 20%
Vertical distance calculated from nearest stream bankfull width to top of gully (m or N/A)	n	s	e 20 m	w 14 m

Landuse immediately upstream: Residential development,2 km upstream fo the site

Predominant type of watershed land use: Residential development

Distance from closest tower to nearest stream bank full width: LEFT RIGHT 68 m.

Fish Present: Yes

Species utilizing stream: Co, Cm, Rbt, Ctt

Comments: This site is located in the middle of Surrey, B.C. and is composed of a tributary of Bear Creek, in a gentle gully, and crosses at right angles to the double steal structure, 500 kV transmission circuit. There is no debris jam or road crossing. Residential development stops well back from the gully which runs along the stream. Instead the gully is occupied by large lots and hobby farms. Bear Creek is a quality Lower mainland salmon stream. Bear Creek is wide and displays a large deep run before entering the ROW, where it breaks into 2 channels, before returning to 1 channel near the end of ROW.

Crossing:

Type	None	Condition	N/A	Age	N/A	Specifications	N/A

Riparian Ecosystem Function 1 - Energy flow:

	Treated Section	*Upstream Control Section*	*Downstream Section*
Temperature (Diurnal range)	N/A	N/A	N/A
Light (mean PPFD)	65.10	34.90	52.88

Riparian Ecosystem 2 - Stream Hydrology:

	Treated Section	**Upstream Control Section**	**Downstream Section**
Vegetation Density	149 stems/ha (con), 1,848 stems/ha (decid)	2,005 stems/ha	1,848 stems/ha
Vegetation Diversity	90% red alder, 10% young cedar	10% cottonwood, 10% maple, 80% red alder.	40% conifer (cedar, douglas fir), 60% deciduous 20% cottonwood, 30% alder, 50% maple).
Understory	25% red elderberry, 30% hardhack, 20% salmonberry, 10% thimbleberry, 15% willow	10% hardhack, 40% willow species, 50% mixed berry (salmon, red elderberry, thimble).	20% mixed berries, 20% willow species, 50% Hardhack

Riparian Ecosystem Function 3 - Bank Stability:

	Treated Section						**Upstream Control Section**			**Downstream Section**				
Transect	1	2	3	4	5	Mean	1	2	Mean	1	2	3	4	Mean
Bankfull Width (Wb)	3.50	7.00	8.00	5.50	4.00	5.60	9.50	10.00	9.75	11.40	10.00	8.50	7.50	9.35
Mean Depth (d)	0.45	0.51	0.51	0.43	0.33	0.45	0.53	0.30	0.42	0.50	0.51	0.48	0.60	0.52
D60 (D)	0.07	0.05	0.09	0.07	0.08	0.07	0.10	0.08	0.09	0.08	0.14	0.09	0.10	0.10
Gradient (%)	0.50	0.50	0.50	0.50	2.50	1.50	1	0.50	0.75	0.5	0.00	3.00	0.50	1.00
D/Wb	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
D/d	0.16	0.10	0.18	0.16	0.24	0.17	0.19	0.27	0.2169	0.16	0.27	0.19	0.17	0.20
(D/d)(D/Wb)	0.0031	0.0007	0.0020	0.0021	0.0048	0.0024	0.0020	0.0021	0.0020	0.0011	0.0038	0.0020	0.0022	0.0022
Stream Type	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg
Importance of LWD	controlled						controlled			controlled				
Reach Disturbance	42 percent						0 percent			0 percent				

Riparian Ecosystem Function 4 - Habitat Complexity

	Treated Section	Upstream Control Section	Downstream Section
Distribution of habitat	55 percent pool/ 45 percent riffle	82 percent pool/ 18 percent riffle	85 percent pool/ 15 percent riffle
Total Reach Length(Thalweg)	140.00	146.00	177.00
Volume of LWD (Pieces/m stream)	0.015	0.04	0.08

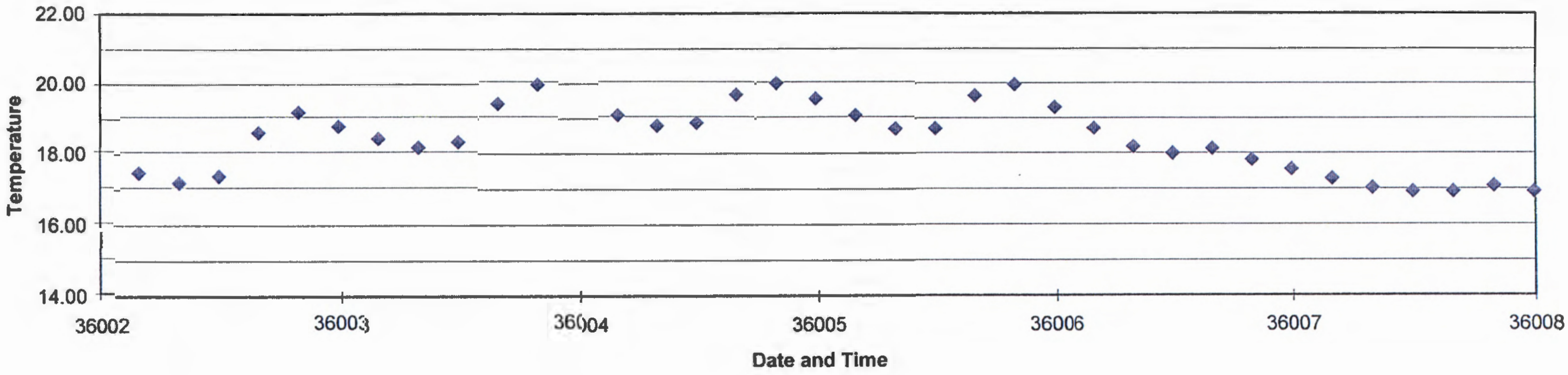
Windthrow

	Treated Section	Upstream Control Section	Downstream Section
Present	None	None	None
Type	N/A	N/A	N/A
Species	N/A	N/A	N/A
Distance From Stream	N/A	N/A	N/A
% riparian zone vegetation	N/A	N/A	N/A
Photographs roll ID and #'s	N/A	N/A	N/A

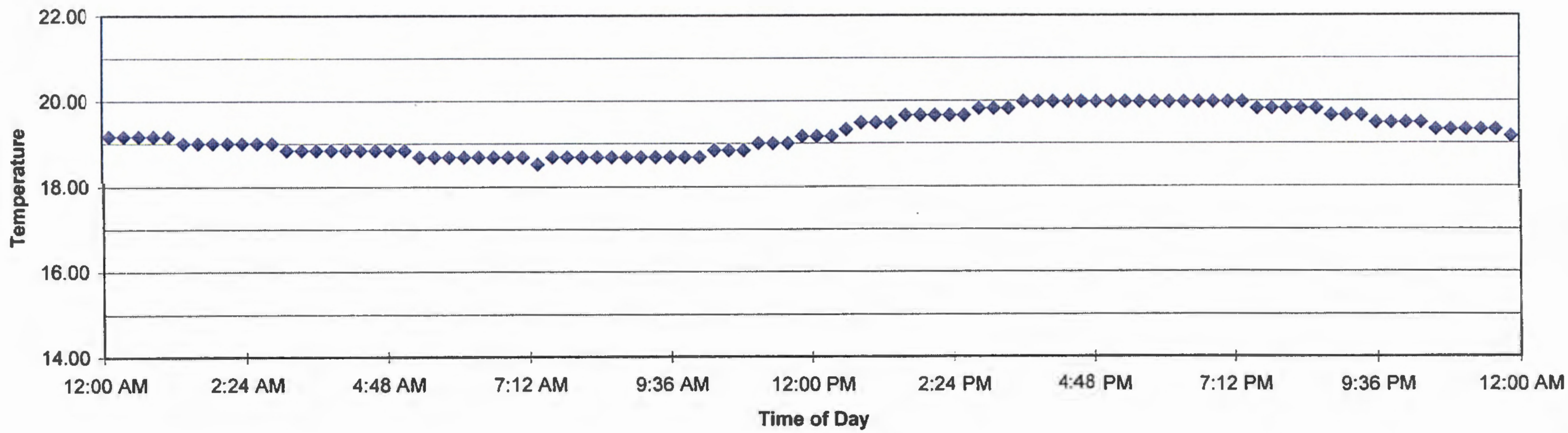
Vegetation Management:

Observations: The Rightofway has been managed very aggressively and there is berry little evidence of tall growing species except in the gully where Bear Creek crosses the Righofway. This area is very moist and has dense skunk cabbage pockets. The Rightofway crossing site appears not to have been managed for over 10 years. the site is dominated by tall mature alders. The process for the site appears to involve waiting for the trees to mature and pose a line hazard, then coming in and removing them, like a small logging operation. The site is currently in the second of a 3 year plan to cut or top all tall growing trees. During 1997 a mis-communication resulted in almost all vegetation being removed on the left bank. Both banks are suffering from significant lateral erosion, however the right bank, now devoid of tall vegetation appears to be moving more quickly. The site morphology also changes significantly though the site with energy being expended on eroding laterally as a result a large gravel bar has been deposited on the most upstream edge of the Righofway crossing.

Downstream , Case 7, July 26-Aug 01, 1998



Downstream Case 7, July 28, 1998



Case Number #8 **Location** @60 km West of Prince George, immediately of off Hwy 17 **Stream Name** Cluculz Creek

Direction of Flow South **Orientation of Crossing** 45 degree angle

General Information:

Date: August 8/98
Crew: JS, JM
Time: 10:30am - 2:30pm
Weather: Sunny and warm
General photograph roll ID and #'s: roll 1, 1-37

Site Description:

Region of BC: Northern Interior
Biogeoclimatic Zone: Sub-Boreal Spruce
Transmission Line Id: 5L61
Tower Numbers (as power flows): 42 / 5 to 43 / 1
Width of rightofway: 100 m
Stream segment length: 334 m
sideslope angles: n | s | e 40% | w 10%
Vertical distance calculated from nearest stream bankfull width to top of gully (m or N/A): n | s | e 28 m | w 15 m
Landuse immediately upstream: Spot was selectively logged within 30yrs, no other intrusions (roads, etc.)
Predominant type of watershed land use: Farming and logging
Distance from closest tower to nearest stream bank full width: LEFT 28 m RIGHT
Fish Present: Yes
Species utilizing stream: unknown

Comments: This site is complex, involving a creek meandering through a wide, single steel structure, 500 kV circuit Righofway, morphologically complex gully with a right bank which is steep (sheer in some places) but more gentle left bank. There is no crossing, the creek crosses the Rightofway at @ 450 angle. In many places the banks of the gully are composed of highly erodible sand deposits, , where it is impossible for vegetation to become established. As a result in many places the stream has degraded to bedrock. In still other aggradation has occurred leading to large sediment bars. While ATV tracks were seen around the site it is fairly remote along a rugged 4*4 road, and would be visited by hunters, and farmers only. There is no debris jam upstream of the ROW Being fairly deep in a gully there is no riparian leave strip, rather the entire riparian area is fairly heavily vegetated with a mix of species.

Crossing:

Type: None
Condition: N/A
Age: N/A
Specifications: N/A

Comments: While no formal crossing is present the stream could be forded at low flow.

Riparian Ecosystem Function 1 - Energy flow:

	Treated Section	*Upstream Control Section*	*Downstream Section*
Temperature (Diurnal range)	12.25 - 24.25	12.25 - 21.75	N/A
Light (mean PPFD)	284.73	153.36	203.33

Riparian Ecosystem 2 - Stream Hydrology:

	Treated Section	*Upstream Control Section*	*Downstream Section*
Vegetation Density	23,565 stems/ha	6,833 stems/ha	943 stems/ha
Vegetation Diversity	10% red alder, 10% birch, 30% cottonwood, 40% spruce.	10% cottonwood, 10% alder, 10% birch, 70% spruce.	10% cottonwood, 10% red alder, 20% birch, 60% spruce.
Understory	10% salal, 10% mixed berries, 80% willow	20% mixed berries, 80% willow species.	5% cow parsley, 45% mixed berries, 50% willow

Riparian Ecosystem Function 3 - Bank Stability:

	Treated Section					*Upstream Control Section*					*Downstream Section*					
Transect	1	2	3	4	Mean	1	2	3	4	Mean	1	2	3	4	5	Mean
Bankfull Width (Wb)	7.50	7.70	5.90	8.60	7.43	9.20	10.80	8.00	8.90	9.23	10.80	6.20	10.00	10.20	9.90	9.42
Mean Depth (d)	0.65	0.88	0.69	0.71	0.73	0.85	0.74	0.86	0.76	0.80	0.65	0.55	0.73	0.61	0.73	0.65
D60 (D)	0.14	0.19	0.14	0.20	0.17	0.14	0.18	0.13	0.13	0.15	0.20	0.20	0.21	0.17	0.15	0.19
Gradient (%)	1	1	2	1	1.25	0.5	0.50	0.25	1.00	0.56	0.5	2.00	1.50	1.00	2.50	1.50
D/Wb	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.03	0.02	0.02	0.02	0.02
D/d	0.22	0.22	0.20	0.28	0.23	0.16	0.24	0.15	0.17	0.18	0.31	0.36	0.29	0.28	0.21	0.2886
(D/d)(D/Wb)	0.0040	0.0053	0.0048	0.0066	0.0052	0.0025	0.0041	0.0025	0.0025	0.00	0.0057	0.0117	0.0060	0.0046	0.0031	0.0060
Stream Type	RPg	RPg	RPg	RPg	RPg	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc	RPc
Importance of LWD	Controlled					Controlled					Controlled					
Reach Disturbance	63 percent					48 percent					83 percent					

Riparian Ecosystem Function 4 - Habitat Complexity

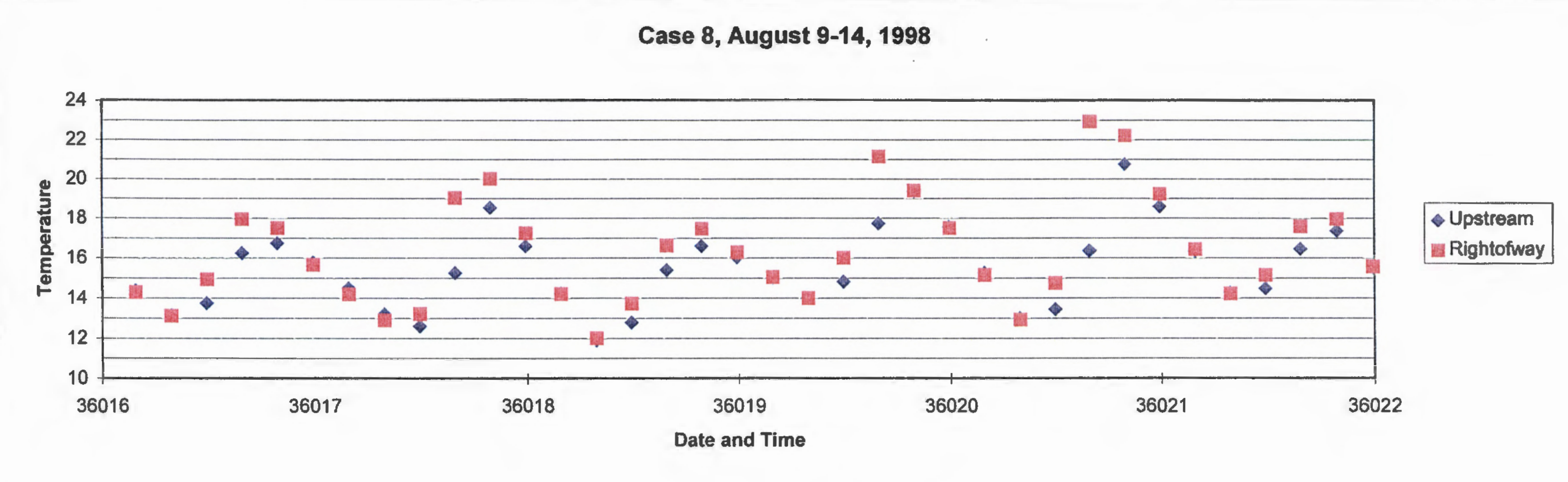
	Treated Section	Upstream Control Section	Downstream Section
Distribution of habitat	34 percent pool/ 66 percent riffle	50 percent pool/ 50 percent riffle	N/A
Total Reach Length(Thalweg)	334.00	295.00	297.00
Volume of LWD (Pieces/m stream)	0.01	0.05	N/A

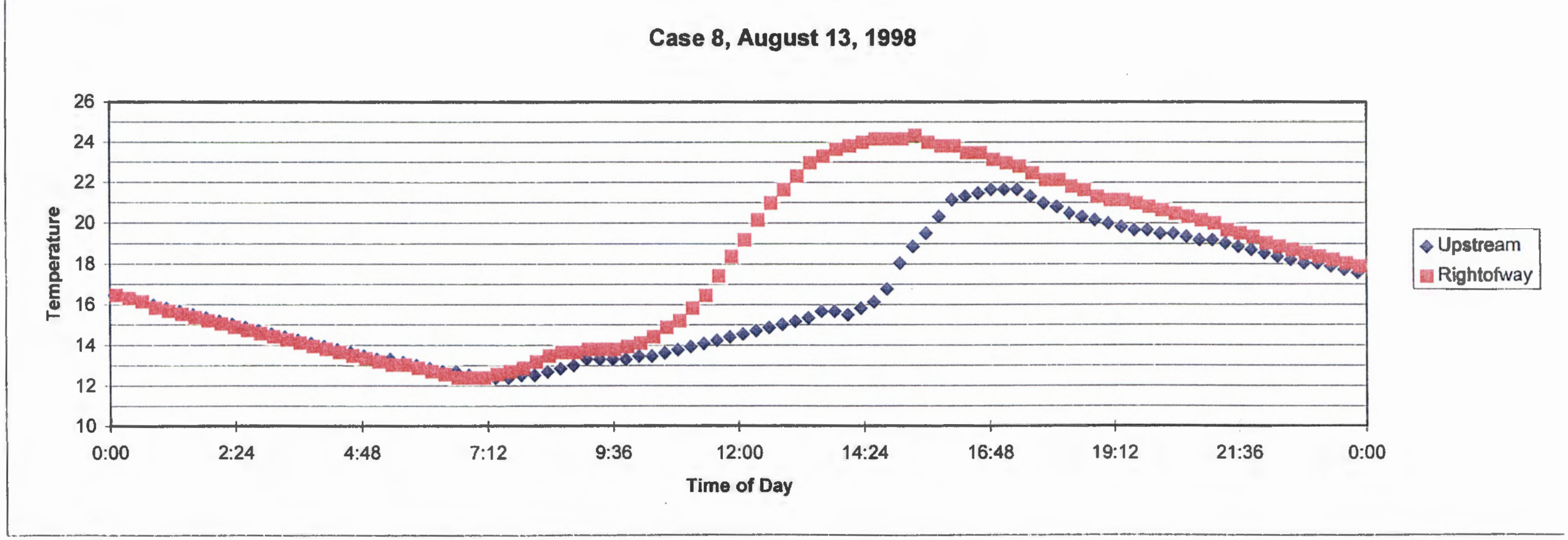
Windthrow

	Treated Section	Upstream Control Section	Downstream Section
Present	None	None	None
Type	N/A	N/A	N/A
Species	N/A	N/A	N/A
Distance From Stream	N/A	N/A	N/A
% riparian zone vegetation	N/A	N/A	N/A

Vegetation Management:

Observations: The non riparian sections of the Righofway, up to the edge of the gully, appear to have been managed aggressively, either through mowing or mowing and herbicide application. From the top of the gully on either bank it appears that the management strategy has been slashing vegetation as it becomes a problem. While the right bank provides little habitat for vegetation, due to the screef slope, the left bank provides ideal growing conditions.. The vegetation community shows significant diversity, with both tall growing coniferous vegetation and deciduous species present. The left bank also appears appears to be a part of a farmers' operation, which may prohibit routine cutting of trees. Upstream of the site it appears that selective removal has occurred within the last 30 years. However significant riparian community is still present along the shallow valley, through which the passes There are many pieces of large functioning LWD in the upstream reach, but it is much less common later in the stream. There is no potential LWD sources in the treated section.


Case 8, August 9-14, 1998
Temperature
24
22
20
18
16
14
12
10
36016
36017
36018
36019
36020
36021
36022
Date and Time
Upstream
Rightofway


Case 8, August 13, 1998
Temperature
26
24
22
20
18
16
14
12
10
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
21:36
0:00
Time of Day
Upstream
Rightofway

Case Number #9 **Location** @35km West of P.G., along Telachi Rd. **Stream Name** Sweden Creek

Direction of Flow North East **Orientation of Crossing** 45 degrees

General Information:

Date: Aug. 7/98 | Crew: JS, JM | Time: 11:00 am - 2:30 pm

Weather: Sunny, warm | General photograph roll ID and #'s: roll 2, 1-24, roll 3 1-12

Site Description:

Region of BC: Northern Interior | Biogeoclimatic Zone: Sub-Boreal Spruce

Transmission Line Id: 5L61 | Tower Numbers (as power flows): 18 / 5 to 19 / 1

Width of Rightofway: 100m | Stream segment length: 160 m

	n	s	e	w
sideslope angles	n	s	e10%	w 6%
Vertical distance calculated from nearest stream bankfull width to top of gully (m or N/A)	n	s	e 40 m	w 45 m

Landuse immediately upstream: Dormant

Predominant type of watershed land use: Agricultural, logging

Distance from closest tower to nearest stream bank full width: LEFT | RIGHT 65 m

Fish Present: Yes | Species utilizing stream: unknown

Comments: This site is composed of wide, single steel structure, 500 kV circuit Righofway, which passes across a small stream which traverses the bottom of very large and broad but gentle gully. Rather the stream transects the rolling hills on which the transmission facility is built. There is no riparian leave strip and no debris jam at the usptream ede of the ROW. The stream crosses approximately a 45 degree angle to the ROW with minimal meandering. The Righofway site is composed predominantly of red alder clumps, mixed shrub species and grasses. The old, out of commission crossing (discussed below) contributes significant fine sediments to the stream and may reduce the quality of downstream habitat. There is significant SWD downstream of the site There is no tall growing riparian vegetation leave strip, rather only young small trees, which provide no cover to the shallow stream.

Crossing:

Type: Ford (bridge) | Condition: Very Poor | Age: U/A | Specifications: 7m wide by 7m long

Comments: At the downstream edge of the Righofway a relatively new wood bridge, without timber cribbing, has been eroded and washed, resulting in a ford crossing. It appears a local farmer has used machinery to improve the ford. However this also exposed significant soils and continues to introduce significant volumes of fine grained sediments to the stream,. Fine sediments are very visible downstream of the crossing but not upstream. Much of the downstream substrate has been covered by a film of fine sediment. Thje right bank is much worse (more exposed soils) than the left.

Riparian Ecosystem Function 1 - Energy flow:

	Treated Section	*Upstream Control Section*	*Downstream Section*
Temperature (Diumal range)	11.50 - 21.00	12.00 - 20.50	11.50 - 19.50
Light (mean PPFD(micro mols)	69.50	51.33	34.33

Riparian Ecosystem 2 - Stream Hydrology:

	Treated Section	*Upstream Control Section*	*Downstream Section*
Vegetation Density	204,073 stems/ha (short (young) decidous stems)	28,512 stems/ha (deciduous), 2,183 (coniferous)	8,019 stems/ha (coniferous and decidous)
Vegetation Diversity	25% total: 40% cottonwood, 50% aspen, 10% spruce	60% of total: of that: 20% spruce, 20% cottonwood, 60% birch.	5% birch, 15% aspen, 20% cottonwood, 60% spruce.
Understory	75% of total: 40% red alder, 30%mixed berries, 30% Will\ow (heavy grass presence)	40% of total, of that: 20% mixed berries, 30% willow, 60% red alder.	10% mixed shrubs, 10% salal berries, 20% mixed berries, 20% red alder, 30% willow species.

Riparian Ecosystem Function 3 - Bank Stability:

Treated Section

Transect	1	2	3	Mean
Bankfull Width (Wb)	5.70	5.80	2.90	4.80
Mean Depth (d)	0.60	0.62	0.66	0.63
D60 (D)	0.20	0.19	0.20	0.20
Gradient (%)	1.00	1.00	1.50	1.17
D/Wb	0.04	0.03	0.07	0.05
D/d	0.33	0.31	0.30	0.31
(D/d)(D/Wb)	0.0117	0.0100	0.0209	0.01
Stream Type	RPc	RPc	RPc	RPc
Importance of LWD	Controlled			
Reach Disturbance	29 percent			

Upstream Control Section

Transect	1	2	3	Mean
Bankfull Width (Wb)	3.50	4.40	3.50	3.80
Mean Depth (d)	0.60	0.58	0.62	0.60
D60 (D)	0.18	0.16	0.17	0.17
Gradient (%)	1	0.50	1.50	1.00
D/Wb	0.05	0.05	0.05	0.05
D/d	0.30	0.30	0.30	0.30
(D/d)(D/Wb)	0.0154	0.02	0.02	0.02
Stream Type	RPc	RPc	RPc	RPc
Importance of LWD	Controlled			
Reach Disturbance	25 percent			

Downstream Section

Transect	1	2	3	4	Mean
Bankfull Width (Wb)	3.70	3.20	3.50	3.40	3.45
Mean Depth (d)	0.51	0.46	0.52	0.53	0.51
D60 (D)	0.16	0.17	0.18	0.12	0.16
Gradient (%)	1	1.50	0.00	1.00	0.88
D/Wb	0.04	0.05	0.05	0.04	0.05
D/d	0.31	0.37	0.35	0.23	0.31
(D/d)(D/Wb)	0.0136	0.0196	0.0178	0.0080	0.01
Stream Type	RPc	RPc	RPc	RPc	RPc
Importance of LWD	Controlled				
Reach Disturbance	35 percent				

Riparian Ecosystem Function 4 - Habitat Complexity

	Treated Section	*Upstream Control Section*	*Downstream Section*
Distribution of habitat (m)	44 percent pool, 56 percent riffle	43 percent pool, 57 percent riffle	47 percent pool, 53 percent riffle
Total Reach Length(Thalweg)	147.00	170.00	150.00
Volume of LWD (Pieces/m stream)	0.08	0.06	0.12

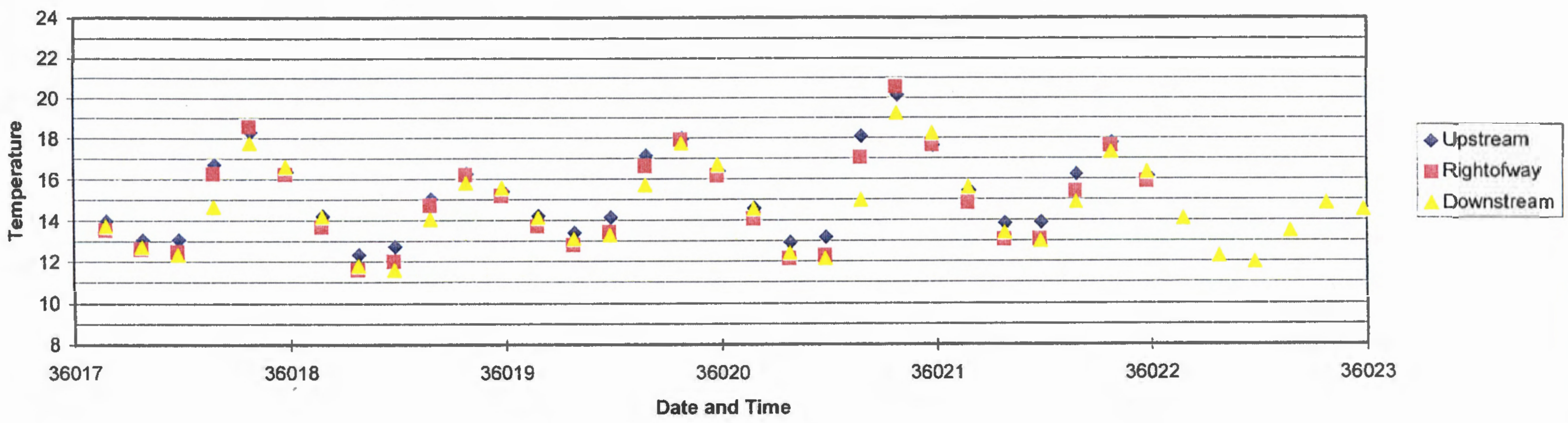
Windthrow

	Treated Section	*Upstream Control Section*	*Downstream Section*
Present	None	None	None
Type	None	None	None
Species	None	None	None
Distance From Stream	None	None	None
% riparian zone vegetation	None	None	None
Photographs roll ID and #'s	None	None	None

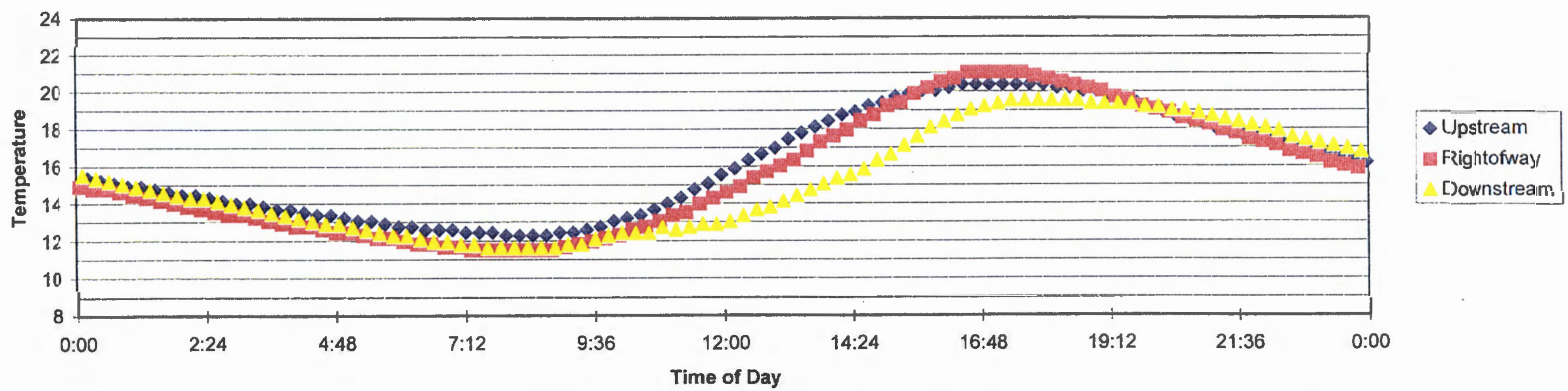
Vegetation Management:

Observations: It appears that vegetation has been slashed and mowed. The sides of the creek have been managed aggressively. There is minimal overhang for the stream, mostly grasses and very few individuals form tall species around the stream. The upstream section is not densely vegetated (a 2nd growth forest), appears as though selective logging may have occurred within the last 30 years. The downstream section very densely covered by spruce forest. It appears the land has been largely left undisturbed for a significant period of time. The vegetation managemnt at the site has resulted in multiple coppice red alder bushes and aspen stands (both single and multiple coppice), quite heavy in some spots persisit throughout the broad gully at the site.

Case 9, August 10-15, 1998



Case 9, August 13, 1998



Case Number #10 **Location** South of Quesnel B.C., off Zseidrich Road **Stream Name** South Sisters Creek

Direction of Flow West **Orientation of Crossing** 45 degrees

General Information:

Date: Aug.16/98
Crew: JS, JM
Time: 14:30 - 18:30
Weather: Cloudy,very warm
General photograph roll ID and #'s: 1, 1-24

Site Description:

Region of BC: Central Interior
Biogeoclimatic Zone: Suboreal Spruce
Transmission Line Id: 5L11/12
Tower Numbers (as power flows): 244 / 1 to 244 / 2
Width of rightofway: 300 m
Stream segment length: 314 m
sideslope angles: n 10% | s 20% | e | w
Vertical distance calculated from nearest stream bankfull width to top of gully (m or N/A): n N/A | s N/A | e | w
Landuse immediately upstream: Dormant
Predominant type of watershed land use: Grazing (cattle)
Distance from closest tower to nearest stream bank full width: LEFT | RIGHT 38 m
Fish Present: Yes
Species utilizing stream: unknown

Comments: This site is composed of a small intermittent stream which crosses a very wide Rightofway with 2 steel structure 500 kV's circuits. The stream was dry upon entering, showing predominant gravel, riffle-pool morphology. The The stream is located in a fairly deep gully with pole structures on top of the gully on the right and but only 1/2 way up the gully on the other. Banks exhibit some significant degradation from free range cattle grazing which is allowed by the farmer on the lower 1/3 of the Righofway. The farmer has also placed a road crossing on the bottom edge of the Rightofway. These stream sections were not factored into habitat. calculations. All procedures except for a diagram, and pool-riffle analysis, were completed on August 16/98. The remainder of the procedural tasks were completed in early fall 1999.

Crossing:

Type: Bridge
Condition: Good
Age: U/A
Specifications: U/A

Comments: The timber bridge, without cribbing, is located on the downstream edge of ROW and has been disturbed by cattle grazing.

Riparian Ecosystem Function 1 - Energy flow:

	Treated Section	*Upstream Control Section*	*Downstream Section*
Temperature (Diurnal range)	N/A	N/A	N/A
Light (mean PPFD)(micro mols)	53.92	61.67	92.42

Riparian Ecosystem 2 - Stream Hydrology:

	Treated Section	*Upstream Control Section*	*Downstream Section*
Vegetation Density	18,042 stems/ha	1,708 stems/ha	891 stems/ha
Vegetation Diversity	10% red alder, 10% cottonwood, 20% spruce, 50% aspen.	10% cottonwood, 20% birch, 30% aspen, 40% spruce.	10% cottonwood, 10%birch, 40% aspen, 40% spruce.
Understory	10% grasses, 10% red alder, 20% willow species, 20% mixed berries, 40% cow parsley.	10% brackenfern, 30% mixed berries, 30% cow parsley, 30% red alder.	5% brackenfern, 20% red alder, 20% willow species, 25% mixed berries, 30% cow parsley.

Riparian Ecosystem Function 3 - Bank Stability:

	Treated Section						*Upstream Control Section*						*Downstream Section*					
Transect	1	2	3	4	5	Mean	1	2	3	4	5	Mean	1	2	3	4	5	Mean
Bankfull Width (Wb)	3.60	3.00	2.80	3.00	4.40	3.36	3.00	3.00	3.40	2.80	4.00	3.24	3.00	2.30	2.30	3.10	2.40	2.62
Mean Depth (d)	0.50	0.45	0.49	0.48	0.49	0.48	0.55	0.49	0.40	0.71	0.55	0.54	0.59	0.50	0.32	0.47	0.58	0.49
D60 (D)	0.19	0.17	0.19	0.19	0.15	0.18	0.18	0.18	0.19	0.15	0.17	0.17	0.18	0.12	0.11	0.13	0.16	0.14
Gradient (%)	1.50	1.75	2.00	1.50	2.00	1.75	2.50	1.50	2.00	2.00	2.25	2.05	2.00	2.50	2.50	0.50	2.00	1.90
D/Wb	0.05	0.06	0.07	0.06	0.03	0.05	0.05	0.11	0.07	0.05	0.04	0.07	0.00	0.05	0.05	0.04	0.07	0.04
D/d	0.38	0.38	0.39	0.40	0.31	0.37	0.33	0.37	0.48	0.21	0.31	0.3380	0.31	0.24	0.34	0.28	0.28	0.2883
(D/d)(D/Wb)	0.0201	0.0214	0.0263	0.0251	0.0104	0.0203	0.0179	0.0420	0.0335	0.0113	0.0131	0.0236	0.0011	0.0125	0.0164	0.0116	0.0184	0.0120
Stream Type	RPg	RPg	RPg	RPg	RPg	RPg	RPc	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg	RPg
Importance of LWD	Controlled						Controlled						Controlled					
Reach Disturbance	19 percent						None						4 percent					

Riparian Ecosystem Function 4 - Habitat Complexity

	Treated Section	Upstream Control Section	Downstream Section
Distribution of habitat	19.5 percent pool,81.5 percent riffle	27 percent pool, 73 percent riffle	55 percent pool,45 percent riffle
Total Reach Length(Thalweg)	314 m	290 m	290 m
Volume of LWD (Pieces/m stream)	0.13	0.16	0.56

Windthrow

	Treated Section	Upstream Control Section	Downstream Section
Present	None	None	None
Type	N/A	N/A	N/A
Species	N/A	N/A	N/A
Distance From Stream	N/A	N/A	N/A
% riparian zone vegetation	N/A	N/A	N/A
Photographs roll ID and #'s	N/A	N/A	N/A

Vegetation Management:

Observations: The vegetation along this Righofway has been managed but it appears this involves slashing and/or mowing at long intervals. The vegetation on the Right bank is mixed and heavily composed of conifers. On the left bank there are very dense aspen patches, most with multiple coppices. As noted earlier the lower 1/3 of the Rightofway is used for free range cattle grazing. The riparian community through this section is often limited to a strip of vegetation alone the stream. In the upper section of the Righofway there is a fairly dense and diverse riparian zone. The upstream section has a mature and well developed riparian community. The area seems to have been untouched for over 60 to 70 years. The downstream section is younger, appears to be less than 40 years, and composed of a mixed species, with conifer emerging as dominant individuals.

Case Number #11 **Location** Elephant Ridge, 1/2 way between Chetwynd and Tumbler Ridge **Stream Name** No name

Direction of Flow South **Orientation of Crossing** Right Angle

General Information:

Date: Aug.17/98 Crew: JS, JM Time: 13:30-15:00

Weather: Sunny, warm General photograph roll ID and #'s: roll 2, 15-37

Site Description:

Region of BC: North Biogeoclimatic Zone: Northern White Spruce

Transmission Line Id: 2L12/13 Tower Numbers (as power flows): 88/ 3 to 88/ 4

Width of rightofway: 60m Stream segment length: 60 m sideslope angles: n | s | e 2% | w 4 %

Vertical distance calculated from nearest stream bankfull width to top of gully (m or N/A): n | s | N/A | N/A

Landuse immediately upstream: Logged, 25-50 years ago., riparian zone mature

Predominant type of watershed land use: Logging, however mostly unlogged.

Distance from closest tower to nearest stream bank full width: LEFT 58m RIGHT

Fish Present: No Species utilizing stream: N/A

Comments: This site is composed of a 2 pole wood structure and Righofway which passes along the front of Elephant Ridge on its way to Tumbler Ridge. The stream crossing site is small shallow creek which flows down the hillside and across the Righofway. No gully is present, rather the site, like the Righofway is a series of low rolling hills. There are numerous small alders (<2.5 m tall), which, because of the small size of the stream, do provide some overhang and cover. The site ends at the downstream edge of the Righofway because culverts are present, but then the gradient also increases to over 25%. There is a debris jam immediately upstream of the Righofway which appears to have occurred during construction.

Crossing:

Type: Culvert Condition: Good Age: N/A Specifications: 90cm culvert

Comments: The culvert is located at the downstream edge of the Righofway. The access road crosses over it. It is in good condition and sized properly for the site. Fish passage is not an issue given the extreme gradient of the downstream section.

Riparian Ecosystem Function 1 - Energy flow:

	Treated Section	Upstream Control Section
Temperature (Diurnal range)	N/A	7.5 - 11.0
Light (mean PPFD)(micro mols)	N/A	N/A

Riparian Ecosystem 2 - Stream Hydrology:

	Treated Section	Control Section
Vegetation Density	4,395 stems/ha	74,735 stems/ha
Vegetation Diversity	No tall growing present.	60% spruce (25-30yrs), 40% cottonwood. Sparsely vegetated above gully
Understory	5% cottonwood, 15% young spruce, 25% willow, 55% red alder.	5% spruce, 10% Pine, 15% berries, 70% red alder.

Riparian Ecosystem Function 3 - Bank Stability:

	Treated Section				Upstream Control Section			
Transect	1	2	3	Mean	1	2	3	Mean
Bankfull Width (Wb)	3.20	2.90	2.70	2.93	2.20	1.40	1.70	1.77
Mean Depth (d)	0.60	0.42	0.30	0.44	0.48	0.30	0.38	0.39
D60 (D)	0.16	0.11	0.12	0.13	0.12	0.16	0.12	0.13
Gradient (%)	6.00	6.00	5.00	5.67	9.00	8.00	5.00	7.33
D/Wb	0.05	0.04	0.04	0.04	0.05	0.11	0.07	0.08
D/d	0.27	0.27	0.27	0.27	0.25	0.53	0.32	0.37
(D/d)(D/Wb)	0.01	0.01	0.01	0.01	0.01	0.06	0.02	0.03
Stream Type	RPc	RPc	RPc	RPc	RPc	CPc	RPc	RPc
Importance of LWD	Controlled				Controlled			
Reach Disturbance	None				None			

Riparian Ecosystem Function 4 - Habitat Complexity

	Treated Section	*Upstream Control Section*
Distribution of habitat	13 percent pool, 87 percent riffle	25 percent pool,L39 75 percent riffle
Total Reach Length(Thalweg)	60.00	60.00
Volume of LWD (Pieces/m stream)	0.20	0.02

Windthrow

	Treated Section	*Upstream Control Section*
Present	None	None
Type	N/A	N/A
Species	N/A	N/A
Distance From Stream	N/A	N/A
% riparian zone vegetation	N/A	N/A
Photographs roll ID and #'s	N/A	N/A

Vegetation Management:

Observations: This Righofway, including the riparian zone has been heavily managed. The area appears to have been mowed in some areas but slashed in others. The remaining vegetation's composed of bundles of red alder and miscellaneous broad leaf shrubs, (predominantly willow species). The area is also part of test site where vegetation is cut at waist height so winter forage activity by ungulates keep tall growing species under control. The remaining vegetation is well away from tolerance limits.

Case Number #12 **Location** Along Elephant Ridge, 1/2 way between Chetwynd and Tumbler Ridge

Direction of Flow South **Stream Name** No name **Orientation of Crossing** Right Angle

General Information:

Date: Aug.17/98 | Crew: JS, JM | Time: 15:00 - 18:30

Weather: Sunny, warm | General photograph roll ID and #'s: Roll 3, 1-24

Site Description:

Region of BC: North | Biogeoclimatic Zone: Northern White Spruce

Transmission Line Id: 2L12/13 | Tower Numbers (as power flows): 85/ 6 to 85/ 2

Width of rightofway: 60m | Stream segment length: 72 m | sideslope angles: n | s | e N/A | w N/A

Vertical distance calculated from nearest stream bankfull width to top of gully (m or N/A): n | s | e N/A | w N/A

Landuse immediately upstream: Dormant

Predominant type of watershed land use: Logging, dormant

Distance from closest tower to nearest stream bank full width: LEFT | RIGHT 38 m

Fish Present: No | Species utilizing stream: N/A

Comments: This site is composed of a 2 pole wood structure and Righofway which passes along the front of Elephant Ridge on its way to Tumbler Ridge. The stream crossing site is a small shallow creek which flows down the hillside and across the Righofway. No gully is present, rather the site, like the Righofway is a series of low rolling hills. There are numerous small alders (<2.5 m tall) and willows, which do provide some overhang and cover. A beaver has created a dam which backs up the downstream edge of the ROW. Therefore this site is does not have a downstream section. There is a debris jam immediately upstream of the Righofway which appears to have occurred during construction. The vegetation along the Righofway is well away from tolerances and managed for ungulates.

Crossing:

Type: Ford | Condition: Good | Age: U/A | Specifications: N/A

Comments: The ford is not often used; it is heavily vegetated, and contains gravel.

Riparian Ecosystem Function 1 - Energy flow:

	Treated Section	Upstream Control Section
Temperature (Diurnal range)	9.50 - 18.25	9.50 - 15.00
Light (mean PPFD)(micro mols)	N/A	N/A

Riparian Ecosystem 2 - Stream Hydrology:

	Treated Section	Upstream Control Section
Vegetation Density	no tall trees species,	
Vegetation Diversity	40% red alder, 40% willow sp., 10% cottonwood, 10% aspen	100% spruce
Understory	30% Cow Parsely, 40% mixed berries, 20% grasses, 10% broad leaf shrub	50% red alder, 40% mixed berry, 10% willow sp.

Riparian Ecosystem Function 3 - Bank Stability:

Treated Section

Transect	1	2	3	Mean
Bankfull Width (Wb)	0.70	1.00	1.60	1.10
Mean Depth (d)	0.27	0.19	0.18	0.21
D60 (D)	0.12	0.06	0.08	0.09
Gradient (%)	5.50	4.00	3.75	4.42
D/Wb	0.17	0.06	0.05	0.09
D/d	0.44	0.44	0.44	0.44
(D/d)(D/Wb)	0.08	0.03	0.02	0.04
Stream Type	RPg	RPg	RPg	RPg
Importance of LWD	controlled			
Reach Disturbance	10 percent			

Upstream Control Section

Transect	1	2	Mean
Bankfull Width (Wb)	1.00	1.80	1.40
Mean Depth (d)	0.30	0.20	0.25
D60 (D)	0.10	0.06	0.08
Gradient (%)	4.00	6.50	5.25
D/Wb	0.10	0.03	0.07
D/d	0.33	0.30	0.32
(D/d)(D/Wb)	0.03	0.01	0.02
Stream Type	RPg	RPg	RPg
Importance of LWD	controlled		
Reach Disturbance	7.1 percent		

Riparian Ecosystem Function 4 - Habitat Complexity

	Treated Section	Upstream Control Section
Distribution of habitat (m)	26 percent pool/ 74 percent riffle	31 percent pool/ 69 percent riffle
Total Reach Length(Thalweg)	72.00	46.00
Volume of LWD (Pieces/m stream)	0.07	0.02

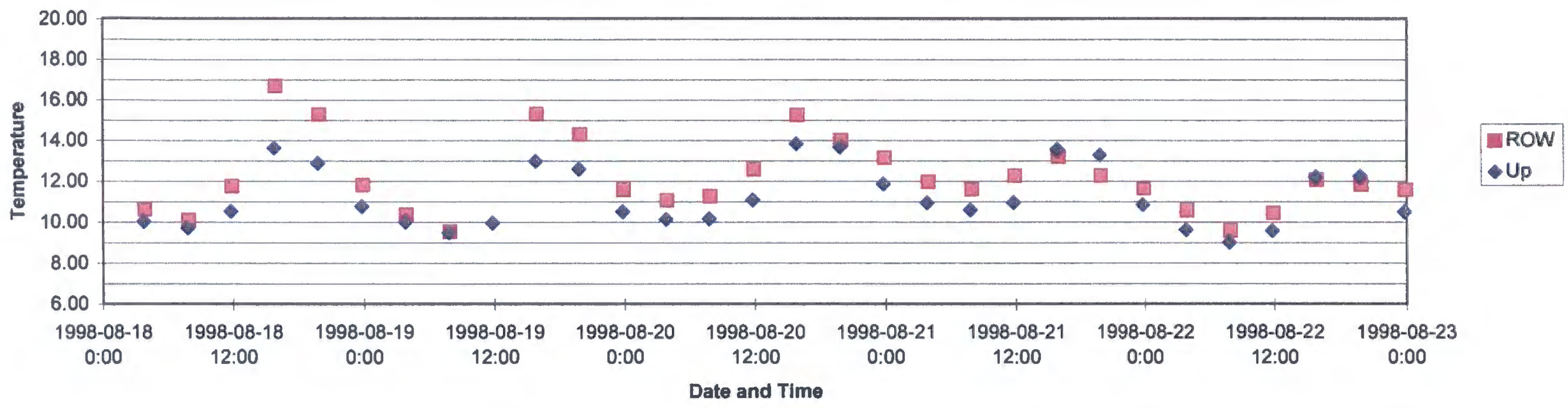
Windthrow

	Treated Section	Upstream Control Section
Present	None	None
Type	N/A	N/A
Species	N/A	N/A
Distance From Stream	N/A	N/A
% riparian zone vegetation	N/A	N/A
Photographs roll ID and #'s	N/A	N/A

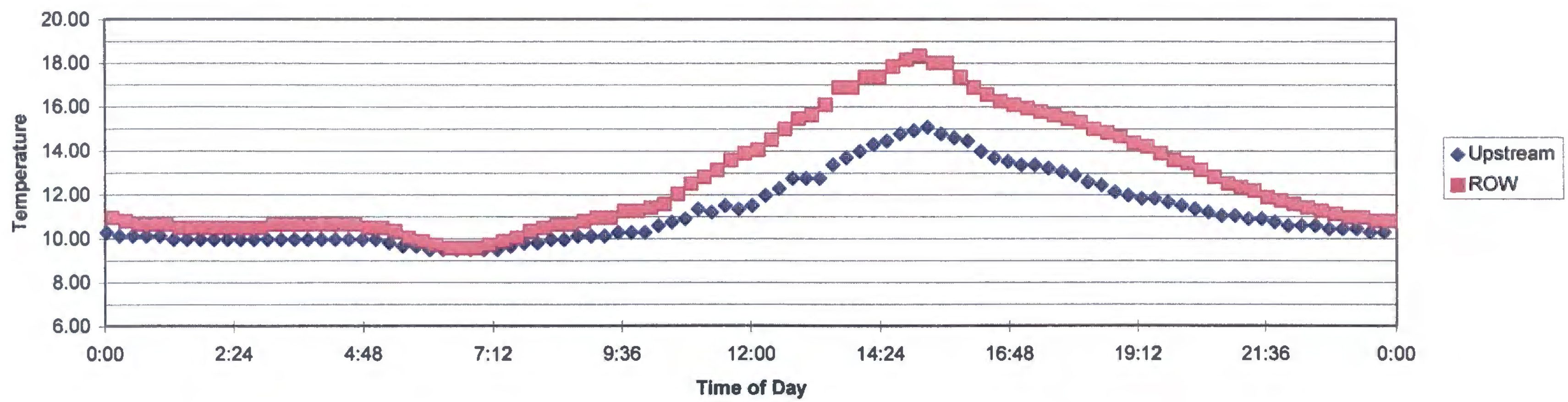
Vegetation Management:

Observations: This Righofway, including the riparian zone has been heavily managed. The area appears to have been mowed in some areas but slashed in others. The remaining vegetation's composed of bundles of red alder and miscellaneous broad leaf shrubs, (predominantly willow species). The area is also part of test situation where vegetation is cut at waist height so winter forage activity by ungulates keep tall growing species under control. The remaining vegetation is well away from tolerance limits.

Case 12, August 18-23, 1998



Case 12, August 18, 1998



Appendix 2

The Questionnaire Used in this Study.

Riparian Zone Management on Electric Transmission Rightofways
QUESTIONNAIRE
(BCHYDRO ROW MANAGEMNT STAFF)

Optional Information:
Respondent Name:
Job Title:
Daytime Telephone Number: (   ) -

I. Site Description

1) Are you familiar with the Rightofway (line ID) crossing of (stream name) near (location)?

____

2) What is the composition of the powerline (i.e. double, 238 kv, wood-pole structures)

____

3) What is the age of the transmission line?

____

4) Does heavy machinery pass across this site?

____

5) How is that accomplished (ford, bridge, culvert, other)?

____

II. Vegetation Management

What is the vegetation management cycle frequency, applied for this section of transmission line ()?

- 1 year __________
- 2 year __________
- 3 year __________
- 4 year __________
- 5 year __________
- 6 year __________
- 7 year __________
- 8 year __________
- 9 year __________
- 10 year __________
- 15 year __________
- 20 year __________
- other ______________________________

7) Which of the following methods does B.C.Hydro use to manage vegetation? along this Rightofway, at this site?

- broadcast herbicide application (aerial or ground spraying) ________
- selective herbicide application (i.e. baseline thinline, basal streamline or backpack foliar ________
- capsule injection ________
- non-selective mowing ________
- selective mowing ________
- high table mowing (cutting at waist level) ________
- topping ________
- selective hand cutting (i.e. chainsaw, brush saw, hand slash) ________
- forestry type operations (large scale cutting, clearing, widening) ________
- cut and treat (i.e. cover surface of fresh stump with herbicide) ________
- girdling ________
- controlled burning ________
- sheep grazing ________
- cattle grazing ________
- allelopathy ________
- other ____

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8) What is the goal of the vegetation maintenance program across this site?

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9) To your knowledge, does B.C.Hydro actively employ any form of Riparian Zone Management strategies or techniques along its Rightofways?

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10) To your knowledge have any special conditions or work plans been considered or applied at this stream-crossing site?

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____
____
____
____
____

11) What was the goal of any such conditions or work plans?

____
____
____
____
____
____

12) Do you anticipate applying any new or additional special conditions or work plans at this or other stream crossing sites in the future?

____
____
____
____
____
____

III. Other Factors

Are there other additional considerations, other than routine maintenance can require significant work at a stream crossing (i.e. outages, hardware maintenance, marking ball replacement etc.)

____
____
____
____
____

14) Do you anticipate applying any new or additional special conditions or work plans at this or other stream crossing sites in the future in conjunction with the items identified in the previous question (13)?

____
____
____

IV. Secondary uses

15) Are there any other work related activities that have been conducted at or near this site by members of the public, private landowners, municipal governments, First nations or other corporations/utilities including,

- tree farming ________
- gravel removal ________
- road construction ________
- landscape management ________
- livestock grazing ________
- forestry operations ________
- vegetation harvesting (salal, berries, etc.) ________
- trapping ________
- other ____

____

____

____

____

____

16) Are there any other recreation activities that are or have been conducted at or near this site including,

- snow mobiling ________
- hiking ________
- motor-cross ________
- 4*4 operation ________
- hunting ________
- fishing ________
- skiing ________
- nature walks ________
- other ____

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