Remedial agriculture:

Reconciling ecological restoration and agriculture in the design of a wetland complex

by

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Abstract

Reconciling human landscapes with wildlife needs can demand innovative solutions. Enhancing wildlife conservation in agricultural landscapes requires habitat restoration; returning marginal farmlands to wetlands in a way that remains productive for farmers can aid existing strategies. This study develops and explores the feasibility of an ecological design to rehabilitate wet, poor quality farmland into a wetland that can serve as wildlife habitat while producing a crop.

Research targets methods of biophysical site restoration that are feasible for farmers to initiate; identification of temperate wetland crops with potential to meet economic and ecological criteria; and parameters for meeting farmers' needs in terms of management and desirability. Scientific literature on wetland and restoration ecology is examined and integrated with agricultural studies and interview responses from landowners involved in alternative food production. Primary data collection for design development centers on coastal British Columbia, where competing land uses have degraded many former wetlands while the region's fertile soils support prolific, diversified farming. Qualitative, semi-structured interviews with key informants involved in local food production were conducted as part of a participative research process in order to get input and feedback throughout design development. A case study site was chosen in a seasonally flooded agricultural watershed outside of Duncan, B.C. A design is proposed that combines five habitat types with a naturalized cropping system.

Major findings include the potential use of many wild and native plants as crops, as a way to provide sufficient economic returns and maintain ecological sustainability. Current opportunities for wetland agriculture include niche marketing, added value products, agrotourism, and increasing sales through farm reputation. Possible deterrents include product marketing, and the unfamiliarity of the plants from a farming perspective, where levels of acceptable damage imposed by fluctuating water conditions, weed competition, and herbivory are undetermined.

Participant response was positive overall with regards to the design and preliminary results indicate that such a system could be feasible. Public interest and technical ability to create an agricultural wetland exist; developing creative marketing for such products in North America appears to be the primary challenge. The design is thus proposed as a long-term study to minimize risk for interested landowners. Redesigning human landscapes to include wild species is an important step towards a more sustainable society.

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1.0 Introduction: An alternative wetland restoration

Friction between humans and wildlife is ubiquitous. Competition over land use is a frequent point of contention: when humans occupy and utilize a tract of land, the habitat is often altered in a way that excludes non-domesticated species. Historical expansion of human populations into new environments led to two major waves of species extinctions in recorded history (Martin and Klein 1994; McNeely and Scherr 2001). As human populations continue to increase, more land is developed and wild species are edged out. One answer is to set aside tracts of land as protected wildlife habitat within a mosaic of human land uses. Restoring degraded habitats for wildlife use is an associated part of conservation. Yet, these solutions endorse the view that humans and wildlife are inherently different with separate needs and life requirements.

All living species must share the finite resources of the planet. Developing possibilities for humans and wildlife to thrive on the same land is critical for future sustainability. Food production is a common requirement for survival; it provides many people with a means of livelihood and also consumes much of the land and resource base. Agriculture as it is currently practiced is a primary cause of habitat destruction leading to the loss of wild biodiversity (Main et al. 1999). Many farmlands are located on former wetland sites, potentially valuable wildlife habitat. In spite of historical drainage work, many farms across Canada still contain marginal, poorly-drained farmland. Restoring these lands and taking them out of production can put conservationists and farmers at odds.

Reconciling the needs for human food production and wildlife habitat requires innovative solutions. Bridging the gap between restoration ecology and alternative agriculture can uncover new options for farmers and landowners. Rehabilitating habitat damaged by human use is the first step; moving beyond this stage can integrate human use with species habitat in a way that can be beneficial to both. Remedial agriculture can offer an alternative solution to wetland restoration on marginal farmland.

1.1 Sustainability, land use, and the biodiversity connection

Sustainability incorporates environmental, social, and economic considerations that strive to meet present needs without compromising future requirements (WCED 1987). From this three-pillared approach, a set of principles embodying key objectives have been outlined by Gibson (2002). These principles include integrity; sufficiency and opportunity; equity;

democracy and civility; precaution; and immediate and long-term integration (Gibson 2002). Strategies to increase the sustainability of existing systems should promote these principles. In the larger context, sustainability encompasses both human and non-human life forms. The fate of both depends on preserving a healthy and productive environment at all scales (Brown and Lomolino 1998, 624).

Land use, the manner in which humans employ the environment and its resources and the purposes for which it is employed (Turner et al. 2001, 86), has strong implications for sustainability as it impacts both humans and wild species. Land is often used for human production systems; this type of land use is linked to the earth's survival through conservation or destruction of species and habitats (van Mansvelt et al. 1998). Land use both shapes and is shaped by aspects of local ecology, social systems, and economic structures.

The ecological aspect of sustainability is usually addressed by scientific disciplines. Conservation biology focuses on the conservation and preservation of species and their habitat, and has a traditional emphasis on endangered species and unspoiled habitats (Brown and Lomolino 1998, 623). These areas, unaffected by human activity, are vital for the survival of wild species and are often protected in parks and reserves as "core" habitat (Noss 1994, 140). However, buffer zones that incorporate multiple uses are equally valuable and necessary (Noss 1994, 141): the 10% of the Earth's landscape set aside in protected reserves is insufficient for species protection unless the intervening habitats can be made hospitable for wildlife (McNeely and Scherr 2001). This intervening area must also support populations of local people using the resources.

Using agricultural land to preserve wild biodiversity is important, since most of the terrestrial land surface is taken up by agricultural land use alone (Gliessman 1998, 293). Privately owned lands must contribute to species conservation through greater habitat opportunities.

1.1.1 Role of biodiversity

Native species are essential to the healthy functioning of the ecological webs that support all life; they are also valued in and of themselves as well as for the many uses and enrichments they bring to human life (Beazley 2001, 20). There is a strong ecological and philosophical rationale behind the conservation of species, which necessitates conservation of their habitat requirements. One set of arguments related to species conservation targets the instrumental worth of biodiversity; another targets their intrinsic worth (Beazley 2001, 13). Rolston (1985) identifies four main instrumental reasons why all species are valuable: species act like rivets in anchoring life-support systems; they are valuable as sources of awe and wonder; they are useful for economic, medicinal, recreational, and other applications; and species are sacred on religious grounds. The other set of arguments for species conservation rest on the premise that all species have inherent value for the simple reason that they exist as the products and processes of evolution no matter what their perceived utility (Rolston 1985). Preservation of species preserves the formative evolutionary process. However, the most widely accepted argument for the preservation of biodiversity at the species level appears to be enlightened self-interest (Beazley 2001, 20). Species diversity creates a complex web of life forms that humans do not fully comprehend; a precautionary approach suggests that all species be protected since most of their individual roles in the planetary scheme are unknown (Beazley 2001, 20). As stated by Leopold (1949),

> "To keep every cog and wheel is the is the first precaution of intelligent tinkering."

Wild species are a vital component of the Earth's natural life-support system, whether or not they are valued intrinsically or instrumentally (WCED 1987, 13; Goodland 1995). Their protection is therefore important to both the principle of integrity and of precaution with respect to sustainability of the Earth as a whole.

Protection of wild species requires protection of habitat (McNeely and Scherr 2001); appropriate land use is thus paramount to the survival of biodiversity.

1.1.2 Importance of wetlands

Wetland ecosystems provide vital habitat for populations of fish, shellfish, mammals, and waterfowl (Mitsch and Gosselink 2000, 571). In North America, 80 percent of breeding bird populations and 50 percent of protected migratory birds depend on wetlands (Mitsch and Gosselink 2000, 575). Canada contains a quarter of the world's wetlands (Government of Canada 1991) which are home to one third of the country's currently identified endangered, threatened, or rare species (McLaughlin and Mineau 1995). Over a seventh of Canada's wetland resources has been lost to human development since 1800; agricultural drainage accounts for 85% of the known losses (Government of Canada 1991). In heavily populated areas, wetland losses are as high as 90%. Protecting and restoring these habitats can strengthen the state of Canadian biodiversity.

Many wetland species are migratory, and rely on adequate habitat from Texas to the Northwest Territories (Mitsch and Gosselink 2000, 583). Species require sufficient habitat to feed or rest throughout their range; land use in between conservation reserves can be designed to accomodate wetland species.

1.1.3 Agricultural impacts

Canadian wetland ecosystems are strongly affected by agricultural practices. Wetlands are drained to create new farmland or to irrigate existing fields (Daigle and Havinga 1996, 103; Innes et al. 2000; Wood et al. 2000), creating habitat changes that significantly shift species composition in the region (McLaughlin and Mineau 1995). Better land uses in agricultural wetland regions could mitigate impacts to wild species.

To promote wildlife conservation strategies in agricultural areas, it helps if landowners gain direct benefits. Tax incentives for donating land as conservation easements are the primary financial incentive currently available to landowners in Canada (Freedman et al. 2001). This type of incentive to conserve wetlands may be supplemented by strategies in which wetlands become assets for landowners as well as for the wildlife that inhabits them. Such strategies may succeed over the long-term if they are independent from funding whims and benefit local people.

Wetlands have potential for agricultural uses if left undrained: their connection to both freshwater and terrestrial systems make wetlands among the most productive ecosystems on Earth (Innes et al. 2000; Mitsch and Gosselink 2000, 20). In a freshwater marsh, primary productivity often reaches 6000 $g/m^2/y$ (Mitsch and Gosselink 2000, 401). This is higher than the productivity of many farm crops under intense cultivation (Hammer 1992, 85). If natural wetland productivity could be harnessed in a way that benefits the farmer or landowner, a more species-friendly land use system could result.

1.1.4 Combining land uses

Land use that integrates wild biodiversity conservation with human needs can have both philosophical and physical benefits that increase the integrity, and thus the sustainability, of human systems.

Mentally separating nature into useful and non-useful categories prompts a physical separation of land use between human society and nature. In agriculture, domestic species are valued while wild species are dismissed as weeds or pests (Sarre 1995, 31). The perceptual separation of humans from nature is repudiated by an approach that values working with nature as parts of the same system (Beazley 2001, 19; Sarre 1995, 36). A perceptual shift may help in generating viable conservation solutions for the long-term, especially on private lands where they are most needed (Freedman et al. 2001, 37). Private land used for agriculture covers 68 million hectares of the Canadian landscape, most of it concentrated in the south (Agriculture and Agri-Food Canada 2001).

The literature offers examples of cooperative approaches between human and wildlife needs. The field of reconciliation ecology is a growing discipline that involves shaping anthropogenic habitats to include wild species (Rosenzweig 2003). Reconciling humans and nature in a farm scheme can lead to mutual benefits.

Integrating wildlife into a farming scheme creates synergies that have many positive functions in an agricultural setting (McNeely and Scherr 2001; Minns et al. 2001). An agricultural system could take advantage of these synergies, so that while improvements in agriculture can help conserve wild species, the inclusion of wild species can improve the efficiency of food production and increase the integrity of the agroecosystem. For example, insect and bird species supported by natural vegetation often prey on crop pests (Soule 2002, 183; Gliessman 1998, 288; McLaughlin and Mineau 1995). Natural pest control can increase land health and lead to cost savings for the farmer.

Another interesting application of promoting biodiversity on farmscapes is the potential it opens up for innovative income-generating activities from nature-based enterprises. These may include the opportunity for local birdwatching outings or ecology education visits. Income generated from a small site-visit fee is independent from the quirks of weather, pests, and crop market swings (Soule 2002, 175).

Thus, both wildlife and landowners can potentially benefit from agricultural land uses that promote wild biodiversity, increasing the sustainability of human production systems. This premise is explored using wetland restoration of marginal farmland to increase habitat and produce a crop.

1.2 Research questions and objectives

My objective is to develop and explore the feasibility of a design to restore wet, poor quality farmland to a wetland that can both produce a crop and provide wildlife habitat. The research question is whether a restoration plan can be designed to provide both crop production and habitat, and what ecological, social, and economic parameters are needed to make the project feasible.

1.2.1 Design goals and system boundaries

In an operative sense, my study is targeted at small-scale farmers whose lands include poorly drained areas requiring heavy modifications to keep in production in conventional agriculture. This research attempts to provide an ecological design solution as a species-friendly alternative to conventional production.

The goals of the design are to create financially viable long-term wildlife conservation while improving farm ecological integrity, increasing environmental efficiencies, and introducing new market opportunities for farmers that incorporate wild biodiversity into their farm scheme.

The intention is to provide a cost-effective solution to reduce the difficult trade-offs farmers often face between maximizing profits and conserving biodiversity.

1.2.2 Research questions

The question I address is whether a viable system of agriculture can be coupled with wetland biodiversity conservation through methods of ecological design in a way that is feasible for a small farmer.

Focal elements include:

1. What is the simplest and most feasible way for a farmer to restore wetland structure and function to a drained site?
2. What wetland crops can provide sufficient economic returns to make the design desirable and ecologically sustainable?
3. What criteria would make the design desirable for farmers?
4. What are the current challenges and opportunities?

1.3 Thesis outline

This chapter introduces and explains the research topic; the following chapters discuss the research process, the findings, and a proposed design.

Chapter 2 reviews the current literature on the factors that contribute to biodiversity in agroecosystems. It also discusses advances in restoration ecology, ecological design, and alternative agriculture to put the research into context.

Chapter 3 explains the research design and methodology.

Chapter 4 presents the results of the primary research conducted through interviews with local food producers in coastal British Columbia.

Chapter 5 discusses the findings related to wetland restoration and suggests the most simple methods for farmers to restore wetland biophysical components to marginal land depending on the challenges of site-specific conditions.

Chapter 6 discusses the next set of findings involving the creation of cropping criteria and choice of wetland crops used in the design.

Chapter 7 describes a proposed design for a wetland complex integrating agriculture into the restored wetland. Physical layout, cropping, and management plans are included.

Chapter 8 provides an example of how the restoration design can be applied using a case study site near Duncan, B.C.

Chapter 9 concludes with a look at challenges, opportunities, and a preliminary monitoring plan as an opportunity for future research.

2.0 Literature review: Conflict, cooperation, and design for a sustainable future

Conflicts over land use are common when it comes to conserving biodiversity on private lands; new approaches advocate cooperation between landowners and conservationists in order to gain mutual benefits. This chapter discusses the definition and importance of biodiversity, as well as its changing relationship with agriculture. Wetlands have a critical role in promoting biodiversity, among other important functions and values in the landscape. There are strategies in place to give incentives to farmers and landowners to conserve wetlands on their properties; however, there are still funding issues associated with many of these strategies that may be a problem over the long term. The literature on sustainable design, including restoration ecology and ecological engineering, provides a foundation for creating a new system of land use that integrates production and conservation.

2.1 Biodiversity and agriculture

Biodiversity, in its most general sense, refers to all species of animals, plants, and microorganisms living within an ecosystem (Altieri 1999). This includes both wild and domesticated species. Biodiversity can be defined at different levels and scales. Levels include genetic, species, or ecosystem diversity (Swanton and Murphy 1996; Gliessman 1998, 230). Scales of diversity include alpha diversity, the number of species in a single area; beta diversity, the number of species from one location to the next in a landscape; and gamma diversity, the species diversity of a biogeographic region (Gliessman 1998, 231).

In an agroecosystem context, wild or natural biodiversity refers to wild native species that colonize the farming area from the surrounding environment (Altieri 1999). Historically, this natural biodiversity provided the foundation for all modern domestic biodiversity (Altieri 1999). The persistence of wild species in the agroecosystem depends on its management and structure. Four general characteristics determine the degree of biodiversity supported by a farm: the vegetation diversity both on- and off-farm, the crop permanence, the management intensity, and the isolation from other areas of natural vegetation (Altieri 1999; Mander et al. 1999). These characteristics vary depending on whether the farmer espouses a conventional or alternative perspective on agricultural production.

2.1.1 Conventional agriculture

Conventional or industrial model agriculture refers to a system of intensive production that depends on mechanical tillage along with inputs of fertilizers and pesticides to sustain a continuous rate of output (McLaughlin and Mineau 1995). The focus is on mechanical efficiency and short-term profitability (van Mansvelt et al. 1998; Mander et al. 1999). Conventional agriculture is higher yielding and less diverse than a natural system (Gliessman 1998, 299). Thus, conventional agroecosystems generally consist of even-aged monocultures: fields in which a single commodity is planted at the same time of year (Jordan 1998, 35). Traditionally, these crops are annual, since annual crops repond quickly to selective breeding and can produce a new, improved generation each year (Fern 2000, 2).

The emphasis on monocrop culture has resulted in the loss of natural capital, including biodiversity and fertile soils, and depletion of resources such as fossil fuels for chemical control and mechanization (van Mansvelt et al. 1998; Mander et al. 1999). Wild species are an important component of natural capital. Monocrop cultures tend to exclude wild species through loss, fragmentation, and pollution of native habitats (McLaughlin and Mineau 1995; Burel et al. 1998; Mander et al. 1999; Mannion 1999; McNeely and Scherr 2001). Cropped fields are inhospitable to most native species (McLaughlin and Mineau 1995). Fences and fields can erode vulnerable populations by breaking them into smaller units, separated by these barriers (McLaughlin and Mineau 1995). As fragmentation increases, patch size and isolation contribute to species loss (Burel et al. 1998).

Within the fields themselves, the lack of crop diversity can create further problems also leading to wild biodiversity loss. Growing extensive cultures of the same crop means that identical resources are drawn from the environment at the same time (Jordan 1998, 35). For example, competition for sunlight occurs when all leaves are at the same level and angle, while competition for nutrients and water occurs when the roots are all at the same depth (Jordan 1998, 36). This kind of intense competition quickly depletes the resource base. The system is thus extremely inefficient in an ecological sense: it under-utilizes some resources, while requiring subsides for others. Weeds can often out-compete crops in such situations, which then require chemical control (Jordan 1998, 36).

When efficiency is defined as net economic profit per farmer effort per unit time, mechanized agriculture is highly efficient (Jordan 1998, 6). A second definition of efficiency, however, highlights the energy component. This definition refers to the input/output ratio of energy use per tonne of crop produced (Swanton and Murphy 1996; Swanton et al. 1996). Using this definition, the efficiency of conventional agriculture is quite low despite high productivity because of the amount of inputs (fertilizers, pesticides, and mechanical energy) that are needed (Swanton and Murphy 1996; Altieri 1999). Continual inputs are necessary in conventional agriculture because food production is decoupled from natural ecosystem services (Swanton and Murphy 1996; Altieri 1999; Bergen et al. 2001). Energy subsidies from fossil fuels are externalized costs that may explain the difference in efficiency accounting between these two definitions (WCED 1987, 12).

Chemical agents added to fields in order to eliminate pests and weeds from crops also have a detrimental impact on wildlife populations (Altieri 1999; Kennedy and Mayer 2002). Conventional monoculture farms applying chemical nutrients and pest control agents possess significantly less biodiversity in terms of wild species than organic farms (McLaughlin and Mineau 1995; Burel et al. 1998; van Mansvelt et al. 1998; Mander et al. 1999).

The consequence of monoculture and its intensive management is that conventional agriculture relies heavily on inputs of energy and materials to maintain its high productivity (Gliessman 1998, 299), eliminating natural biodiversity, and therefore excluding itself from the benefits of ecological interactions (Jordan 1998, 35). Thus, while conventional agriculture is economically efficient in the short term, ecological inefficiencies prevent this kind of system from being sustainable. Maintaining natural capital in the form of biodiversity could therefore greatly improve the ecology of current agriculture.

2.1.2 Alternative agriculture

Most alternative agriculture systems are defined by broader goals than maximizing profit. Most alternative systems aim for greater system sustainability, producing the concept of sustainable agriculture. Sustainable agriculture represents one part of a greater goal: the sustainability of food systems at a global level. Human societal and ecological requirements are both components of true food systems sustainability, which includes all aspects of food production, distribution, and consumption (Gliessman 1998, 315). Production systems are the focus here, as these systems are most directly tied to use of the land and must deal with competing land uses such as wildlife protection. Sustainability in food production refers to the continued ability to produce a harvest from the land without compromising the ability of the system to renew itself (Gliessman 1998, 13). Thus, agriculture must not only yield a crop harvest but must maintain the land conditions that allow this yield to be produced over multiple seasons (Gliessman 1998, 315).

The Canadian definition of sustainable agriculture describes a way of producing and processing agricultural products in a manner that can be supported over the long term. It does not define a specific system or practice, but outlines a set of characteristics. The characteristics identified in this definition are described by Agriculture and Agri-Food Canada (2001):

> "Sustainable agriculture protects the natural resource base, prevents the degradation of soil, water, and air quality, and conserves biodiversity; contributes to the economic and social well-being of all Canadians; ensures a safe and high-quality supply of agricultural products; and safeguards the livelihood and well-being of agricultural and agri-food workers and their families."

Additions to this definition found in the literature include a minimal reliance on inputs from outside system boundaries; use of internal regulation to manage pests and diseases; and the ability to recover from disturbances such as crop harvesting (Gliessman 1998, 299).

Many subsets of sustainable agriculture are based on the idea of using natural ecosystems and principles of ecology to model productive agroecosystems (Beeman and Pritchard 2001, 117). Approaches to sustainable agriculture have taken many forms, drawing from different disciplines and creating innovative practices that can offer valuable lessons for this study.

Agroecology is an interdisciplinary, cooperative science that links the disciplines of agronomy and ecology in order to provide the knowledge and methods required to develop agricultural systems that are environmentally sound and economically productive (Gliessman 1998, 13). While this approach uses the methods and techniques of empirical science, local knowledge is also valued (Gliessman 1998, 13; Beeman and Pritchard 2001, 116). The general idea behind agroecological design is that the more structurally and functionally similar an agroecosystem is to the natural systems in its biogeographic area, the greater its sustainability (Gliessman 1998, 300).

Perennial polyculture refers to a combination of land stewardship and organic farming with scientific plant breeding to create a minimal-tillage polyculture (Beeman and Pritchard 2001, 116). Integrated weed management is another example of a systems approach to farming, where problems of soil erosion and chemical dependence are reduced through methods of conservation tillage and efficient, targeted herbicide use (Swanton and Murphy 1996). Both these systems tend to be more relevant to field crop agriculture rather than a system of wetland agriculture as explored by this research; they are mentioned only to emphasize the wide range of interest in alternative agricultural options. Other examples of alternative management approaches that work towards greater agricultural sustainability include bio-dynamic farming (Steiner 1984), holistic resource management (Savory 1988), organic farming (Wolf 1977), permaculture (Mollison 1988) and ecoagriculture (McNeely and Scherr 2001). The last three are particularly applicable to the current research directions.

Organic farming refers to methods that avoid the use of artificial herbicides, pesticides, and fertilizers in favour of naturally occurring chemicals such as green and animal manures (Beeman and Pritchard 2001, 116). Organic farming tends to follow the tenets of an agroecological approach, basing its philosophy on integrating food production into a natural landscape (van Mansvelt et al. 1998). Biodiversity tends to be greater on organic farms compared to conventional ones because of greater habitat diversity and reduced pollutants (van Mansvelt et al. 1998; Mander et al. 1999). The organic agriculture movement also incorporates support for small, family-owned farms and rejuvenation of rural communities (Beeman and Pritchard 2001, 120). As such, it explicitly incorporates a number of principles of sustainability into its objectives.

Permaculture, or permanent agriculture, has much more of a design-oriented basis than organic agriculture. Its mandate is to create agriculturally productive ecosystems with the diversity, stability, and resilience of natural ecosystems through observation and conscious design (Mollison 1988, ix). Thus, permaculture design tries to incorporate multiple functions. Maximizing diversity in terms of the number of species in a system is not enough; what is valued is the number of beneficial connections between these species (Mollison 1988, 32). Problems become solutions: a rocky outcrop blocking a row crop may provide shade for a small herb species, for example. Relationships and functional connections are important in creating a permanent system. As a system of land use, permaculture is intended to re-design currently settled and agricultural lands, not expand the area of cultivated land (Mollison 1988, 6). In terms of management and social systems, permaculture emphasizes self-sufficiency as well as small-scale technology requiring very little energy and low maintenance (Mollison 1988, ix; Beeman and Pritchard 2001, 116). Permaculture is also a philosophy, extending ethical responsibility to the land and other species (Mollison 1988, 3). Mollison (1988) also argues that a system of permanent agriculture, coming from a cooperative integration of landscape and human production, is necessary to the development of a stable social order (Mollison 1988, 6). Thus, sustainability is addressed in the permaculture philosophy.

Ecoagriculture is a more recent branch of alternative agriculture. The term refers to a system of land use management where overall goals relate to both agricultural production and wild species conservation (McNeely and Scherr 2001). The objective is to actually increase agricultural production, farmer income, and wildlife conservation simultaneously; not simply to have them coexist (McNeely and Scherr 2001). The approach links different initiatives worldwide that seek improved farming technologies, land management practices, institutions and policies in order to meet the combined goal (McNeely and Scherr 2001). A unified strategy of land use management to produce food and protect wildlife is highly advocated in this body of literature.

Management techniques are similar in many of these approaches. A common goal is to attract wild biodiversity in order to make use of beneficial interactions. Biodiversity in crops, insects, and soil microorganisms is essential for ecosystem services highly valuable for agricultural production such as nutrient recycling, microclimate control, hydrological regulation, pest control, pollination, and chemical detoxification (Stinner 1997; Gliessman 1998, 234; Altieri 1999). Lower management intensity and greater proportions of semi-natural farm habitat (eg. hedgerows) increase on-farm biodiversity (Burel et al. 1998; van Mansvelt et al. 1998).

Often, models of sustainable agriculture place an emphasis on small farmers and on-site landowners. When corporate and contract farms dominate a rural area, rural communities tend to degenerate, eroding place-based knowledge and connection of people to the land (Gliessman 1998, 10). Local control over modes of production is lost as industrial-scale agriculture takes over a landscape. On-site landowners tend to have a greater stake in the care of land and proper land stewardship (Beeman and Pritchard 2001, 166). Developing sustainable farming systems that are feasible for a small farmer could foster more sustainable land uses in rural environments.

2.1.3 Role of wetlands

Many of North America's fauna species spend part of their life cycle in wetland environments. Wetlands are defined by three main components: a) presence of water at surface or within the root zone; b) unique soils produced by anaerobic conditions; and c) vegetation adapted to the wet conditions (Mitsch and Gosselink 2000, 28). Wetland plants are defined as plants able to grow in an area of periodic flooding, inundated for more than five days during the growing season to a level of usually less than two metres (Hammer 1992, 33).

There are many types of wetlands in Canada: bogs, fens, swamps, marshes, and shallow open water wetlands are the broad classification based on vegetation, water chemistry, and hydrology (NWWG 1987). While different wetland types offer different habitats, all exhibit common anoxic biochemical processes (Mitsch and Gosselink 2000, 20). Inland freshwater marshes are particularly valuable as islands of wildlife habitat in farmscapes (Figure 2.1) (Mitsch and Gosselink 2000, 377).

Figure 2.1. Small unmanaged marsh created by beaver activity on a homestead in British Columbia.

The Government of Canada (1991) has identified a number of ecological and socio-economic functions performed by wetlands. These include:

- hydrological mediation (water purification, storage, flood reduction, groundwater recharge),
- habitat provision (waterfowl, mammals, reptiles, amphibians, fish, flora; many rare and endangered species),
- geochemical cycling (carbon storage, pollutant sinks, nutrient source, soil conservation),
- economic value (hunting, fishing, peat source, forest and agricultural products), and
- aesthetic and scientific value (tourism, recreation, natural heritage, research).

2.1.4 Current on-farm conservation strategies

Historically, there have been limited incentives for farmers to conserve marginal wetlands along crop fields as it is more profitable to drain and crop the whole land area (Mannion

1999). Drained wetlands create fertile farmland because of their typically high organic matter content, high nutrient availability, and easily cultivated land (Reddy and Gale 1994; Kennedy and Mayer 2002).

The Canadian government has a national policy in place on wetland conservation. “No net loss” is the objective of the policy (Government of Canada 1991). One of the goals identified by the Federal Government is the “recognition of sound, sustainable management practices in sectors such as forestry and agriculture that make a positive contribution to wetlands conservation while also achieving wise use of wetland resources” (Government of Canada 1991). The U.S. has taken this concept further in that “cropped wetlands” are given wetland status. These areas are wetlands that produce crops for part of the year, but serve wetland functions during the other seasons (Mitsch and Jorgensen 2004, 167).

Different federal, provincial, and municipal laws affect wetland conservation in British Columbia; the province does not have one overriding law or policy in place. The major provincial laws with reference to wetlands conservation include the *Water Act*, the *Wildlife Act*, the *Land Act,* the *Waste Management Act,* and the *Environmental Assessment Act* (Nowlan and Jeffries 1996).

One strategy that has been relatively successful in the U.S. for addressing waterfowl conservation is the Conservation Reserve Program (CRP), an initiative created by Congress in association with Ducks Unlimited and the U.S. Fish and Wildlife Service (Ducks Unlimited 2002). This program offered financial incentives to farmers who agree to retire marginal farmlands from production for a period of 10 years. The program was extremely successful in recruiting participants and in increasing the abundance of nesting waterfowl across the United States and into Canada (Ducks Unlimited 2002). Between 1986 and 1990, farmers enrolled 8.2 million acres of cropland in the north-central states; spring survey counts of nesting waterfowl increased by 40% by 1995 (Ducks Unlimited 2002). In 1995, however, U.S. farm policy was reviewed and the funding was initially allocated to other programs. In this instance, conservation groups and sportsmen did put together enough lobbying power to extend the program for another seven years (Ducks Unlimited 2002). Although the program continues to be successful in terms of conservation, the U.S. Department of Agriculture (USDA) stopped enrollment for 2002 despite continuing appeals by the same lobby groups. The success of programs dependent on inconstant sources of funding is never assured. Thus, this kind of conservation initiative may be unsustainable as it relies on outside financial subsidy.

2.2 Sustainability by design: Integrating ecology and engineering

Integrity is one of the main principles of sustainability (Gibson 2002) promoted by including biodiversity in a designed landscape such as an agroecosystem. While the concept of ecological integrity is good in theory, it is extremely difficult to measure in practice. Maintaining ecological integrity in a system of agricultural production may be best defined by the presence of elements that improve the health, resiliency, and self-organizational capacity of the land.

In operational terms, health is improved by maintaining natural capital in the form of biodiversity in crops, insects, and soil microorganisms in order to support the functioning of ecological interactions. Effects on surrounding ecosystems are another aspect related to overall ecosystem health (UNEP 2002). A sustainable agriculture should ideally have minimal to beneficial impact on its surroundings. Protecting ecosystem health is positively correlated with the improvement of ecosystem services: each leads to improvements in the other. Improving the health of the land increases the opportunity to take advantage of ecosystem services, while conserving natural ecosystem structure and function is necessary to maintaining ecological health in agricultural environments (UNEP 2002).

Ecosystem resiliency, the ability of the system to rebound after a disturbance, is also enhanced by crop and microorganism diversity (Swanton and Murphy 1996; Altieri 1999; Bergen 2001). Conserving wild species as part of an agricultural scheme adds to increased biodiversity, which tends to increase the resiliency of ecosystems. Biodiversity also provides the foundation from which the self-organizational capacity of the ecosystem is built (Kay and Schneider 1994; Lister and Kay 2000, 5).

Sustainable design takes many forms, all in an attempt to create ecosystems with greater integrity. The literature on sustainable design theories has applications for the current research: design that can restore habitat in wet marginal farmlands while integrating human and wildlife uses. The body of literature on restoration ecology connects theoretical ecology to applied problems; there have been many recent advances in wetland restoration in particular.

2.2.1 Restoration ecology

Broadly defined, ecosystem restoration is the process of re-creating an ecological community (Keddy 1999). Judging the ecological fidelity of a restoration project depends on three criteria: structural replication, functional success and durability (Higgs 1997). Direct benefits of ecological restoration include the recovery of the health and biodiversity of the ecosystem (Havinga 1999).

The term "restoration" typically refers to human action that returns a disturbed or anthropogenically altered ecosystem to a previously existing state (Mitsch and Jorgensen 2004, 165). Wetland restoration is different than wetland creation, whereby an upland or permanent water site is changed to a wetland by human effort (Mitsch and Jorgensen 2004, 165). When one or more functions of an existing wetland are increased, the process is known as wetland enhancement (Mitsch and Jorgensen 2004, 166). Successful restoration requires knowledge of natural wetland functions and processes (Mitsch and Jorgensen 2004, 163).

In a farmscape, the areas with the greatest potential for restoration or conversion to more ecological farming practices are marginal lands under low-intensity production (Mander et al. 1999). Restoration can be simple; sometimes plugging drainage systems on farmland can be enough to raise water levels and revive an old wetland (Mitsch and Jorgensen 2004, 163). Even land under cultivation for many years can often retain a seed bank that can germinate once the appropriate hydrology is resumed (Hammer 1992, 105). For a freshwater marsh the regeneration process can take from 3 to 5 years; a forested swamp may take more than 50 years to regenerate (Hammer 1992, 105).

There are four major vegetation types and growth forms for wetland plant communities depending on local conditions: wooded wetlands, emergent marsh, wet meadows, and aquatics (Keddy 2000, 86). Most shrubs and trees that inhabit wooded wetlands can withstand flooding when dormant, but are less tolerant of prolonged floods during the growing season (Hammer 1992, 195). Emergents typically grow in marshes where water levels fluctuate between 5 to 30 cm in depth, obtaining their nutrients from the substrate, and often utilizing the C_4 pathway for metabolism for greater efficiency in their use of carbon dioxide under anoxic conditions (Hammer 1992, 34; Mitsch and Gosselink 2000, 222). Wet meadows are characterized by high levels of disturbance which promote the development of ruderal strategists (Keddy 2000). Aquatics can be free floating, floating-leaved, or submergent. Productivity of aquatics is extremely variable: free-floating plants such as duckweed often have extremely high productivities, while submergent plants can have very little (Hammer 1992, 34).

Common plants for restoration projects in North America include cattails (*Typha* spp.), sedges (*Carex* spp., *Scirpus* spp., and *Schoenoplectus* spp.), water lilies (*Nymphaea* spp.), and spatterdock (*Nuphar* spp.). Mainly emergent and floating plants are used, as the propagation of submergent plants is often made difficult because of turbidity and competition with algae during early wetland development (Mitsch and Jorgensen 2004, 185). Plants can be seeded or transplanted in the form of roots, rhizomes, tubers, seedlings, or mature plants; in some cases, the existing seedbank is relied on for self-propagation once the original hydrology is re-established (Mitsch and Jorgensen 2004, 189). Since *Typha* species are rapid colonizers and tend to form a monoculture habitat, different planting strategies exist to compete with these dominants. Planting marshes at sufficient density to provide effective competition and adequate seed source, approximately 2000 to 5000 plants per hectare, is suggested (Brown 1987). Planting whole plants, rhizomes, and tubers has been more successful than seeding, for emergent plants (Mitsch and Jorgensen 2004, 190). Planting in the fall and spring can both be successful, but spring is often recommended because of the damage done to young plants by grazers and migratory animals over the winter (Mitsch and Jorgensen 2004, 190).

Disturbance is critical to wetland establishment, and is equally important to many wildlife species (Hammer 1992, 65; Mitsch and Gosselink 2000, 146). Many species have coevolved with wetland cycles to take advantage of seasonal hydrology and the appearance or disappearance of certain plants (Middleton 1999, 49). Concurrent with recognizing the critical role of disturbance, there have been many advances in the field of wetland restoration ecology. One of these is in the development of a series of assembly and response rules for predicting the effect of key environmental factors on species composition in a community (Keddy 1992). According to this theory, restoration projects all contain three components: the initial environmental conditions, a pool of available species, and a list of key factors that can be manipulated (Keddy 1999). Species composition in a specific habitat is governed by a set of filters, which sieve out all species lacking certain combinations of traits (Keddy 1992). The major filters controlling community composition in wetlands include water levels, fertility, disturbance, salinity, competition, herbivory and burial (Keddy 1999). Different species can tolerate different filters because of their unique life history traits (Keddy 1999). Assembly and response rules predict how a given set of species will respond to different filters. With this idea in mind, using different filters should be able to create different communities from within a given species pool in a manner similar to natural selection (Keddy 1992; Keddy 1999).

Creating a sustainable agricultural system from previously degraded or drained land requires more design work than emphasized by restoration ecology, however. The process for creating a design that uses natural ecosystems as templates for human systems is described by ecological design methodology.

2.2.2 Ecological design

Ecological design is a relatively new discipline of engineering that uses ecological science as its base. Ecological engineering refers to "the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both" (Mitsch and Jorgensen 2004, 23).

Ecological design uses principles of ecology to create the integrity needed for sustainable systems (Bergen et al. 2001). Ecological design can be used for human industrial or production systems, but it also has wide ranging applications for conservation biology (Brown and Lomolino 1998, 623). The creation or restoration of specific habitat types responds to this latter goal.

An important objective of ecological design is to harness the self-design or self-organizational capacity of ecosystems (Mitsch and Jorgensen 2004, 30). Once the initial components or structure are created, nature is allowed to determine the specific composition best suited to the conditions (Bergen et al. 2001). Maintaining the state of the ecosystem is therefore not dependent on human input of materials or energy (Bergen et al. 2001). Thus, the discipline is suited to the design of sustainable agroecosystems.

There are two main approaches to ecological design: top-down, or bottom-up. Both are used with effective results, although the bottom-up model tends to be the one most tied to conventional disciplinary science and mechanistic philosophies (Jordan 1998, 99).

In the bottom-up approach, ecosystem components and their interactions with each other are analyzed. A model is then conceptualized that can use these interactions as a basis for designing resource production systems (Jordan 1998, 31). Interactions between system components determine the overall performance of the system. Interactions can take place at the level of the individual, species, or functional group (Jordan 1998, 32). Ecosystems incorporate both positive and negative interactions; agricultural ecosystems are no exception. Mutualisms, interactions that profit both components, can include benefits for nutrition and digestion in the case of symbiotic bacteria; protection; pollination; and seed dispersal (Boucher 1985). Negative interactions can also be useful in an agricultural context. These interactions can inhibit weeds, invasive species, or insect and disease pests (Jordan 1998, 39). Plant competition for resources is a major factor in wetlands. Wetland communities are often naturally dominated by only a few species with high competitive ability (Keddy et al. 1998).

Knowledge of the abilities of different plants to interact with other species is integral to the bottom-up approach to ecological design.

In the top-down approach, an ecosystem that appears to be sustainable is used as a model for creating a production system (Jordan 1998, 99). An existing system is then modified to take better advantage of natural ecosystem services, even though the specific functions and interactions are not necessarily known (Jordan 1998, 99). Using natural ecosystems as analogues is common in ecological design (Altieri 1999). An example of a popular ecosystem analogue for food production is an agroforest: a multi-storey stratified mixture of planted trees, shrubs, and crops that mimics the structure of a natural forest (Jordan 1998, 65; McNeely and Scherr 2001). Engineering and ecology can thus work together in sustainable land use design.

2.3 Integrated land use: Wetlands and agriculture

There is opportunity for wetlands to be a prime example of a combined human-wildlife land use option.

> "Wetlands have a huge potential for providing food crops for people whilst remaining an absolute haven for wildlife." (Fern 2000, 123)

Current consumptive wetland uses in Canada include food production, peat harvesting for horticulture, forestry, and recreational hunting, trapping and fishing (Kennedy and Mayer 2002).

2.3.1 Wetland agriculture: Past and present

Throughout history there are examples of many cultures that have learned to live with wetlands and even benefit economically from them. Examples of cultures that sustained themselves on wetland agriculture include the ancient Babylonians, Egyptians, Aztecs, and Mayans (Mitsch and Gosselink 2000, 4). Systems of raised fields alternating with canals seem to appear cross-culturally in the literature. These systems once covered large areas of Venezuela, Columbia, Ecuador, Bolivia, and Peru (Erickson 1998, 37) and also appear in parts of Africa (McNeely and Scherr 2001). Raised fields systems were used in pre-Hispanic times as a method of agriculture in the Altiplano region of Bolivia and Peru. In these systems, potatoes were grown on raised platforms built up from material excavated from ditches to each side (Sanchez de Lozada et al. 1998). These ditches naturally filled with water, creating a matrix of canals 1.6 to 4.5 m in width alternating with platforms 1.2 m high and 2 to 20 m wide (Sanchez de Lozada et al. 1998). Another example occurs in the state of Tlaxcala in Mexico, where traditional cropping systems were designed to take advantage of seasonally flooded land without artificial drainage. Here, the cropping system is called *zanjas*, and refers to a series of platforms or *camellones* constructed from adjacent soil simultaneously creating a set of ditches (Gliessman 1998, 78). Annual crops such as corn, beans, squash, vegetables, and alfalfa are grown on the raised platforms. The canals then provide a source of water during the dry season, as well as a nutrient reservoir and source of organic matter (Gliessman 1998, 78). It is possible that lessons from these traditional systems may be applicable to modern designs.

Even now there are wetland crops with economic value. Some current economic products of wetlands include wild rice, blueberries, honey, nuts, timber, and reeds for thatch and fencing (Hammer 1992, 85; Mitsch and Gosselink 2000). In Canada, wild rice, cranberries, and blueberries are the primary direct agricultural wetland uses (Kennedy and Mayer 2002).

In other areas, wetland crops are proposed as an ecological solution to landscape degradation. Currently only tropical wetland crops have been examined. The Yangtze river valley is one case where wetlands were diked and drained for agriculture, yet crops still suffer damage from excessive water loads (Mitsch and Gosselink 2000, 67). A proposed ecological solution here is to convert wet areas from rice to other native wetland crops like lotus, *Nelumbo nucifera*, and wild rice stem, *Zizania latifolia* (Mitsch and Gosselink 2000, 67).

The Florida Everglades is another area where the potential for growing wetland crops is being explored (Snyder and Deren 1999). Crops currently being tested for their ecological and economic potential include taro (*Colocasia esculenta*), lotus (*Nelumbo nucifera*), Chinese waterchestnuts (*Eleocharis dulcis*), water spinach (*Ipomoea aquatica*), watercress (*Nasturtium officinale*), water celery (*Oenanthe javanica*) as well as certain cultivars of rice (*Oryza sativa*) (Snyder and Deren 1999). Taro can also provide a high energy fuel for biomass cropping. Other crops for biomass energy have been suggested, including alemangrass and flood-tolerant sugarcane (Porter et al. 1991).

2.3.2 Wetland plant structure: Designing an agricultural wetland

In agroforestry, the cropping pattern attempts to mimic the structure of a natural forest. The same principle may be applied to wetland farming, although wetlands do not often appear in the literature as sites for sustainable agriculture as do other ecosystem analogues such as agroforests.

The strategy follows a top-down design approach. The function and structure of a natural ecosystem is examined and mimicked accordingly, using plants that produce a useable crop. Similar to forests, light gradients are important in determining species composition in wetlands; disturbance and gap creation are critical processes (Boutin and Keddy 1993). However, unlike forests, maintaining a continual disturbance regime is critical (Middleton 1999).

Wetland species guilds based on functional classification rather than taxonomic relationships have been developed for wetland plants (Boutin and Keddy 1993). This scheme uses indicators of plant performance in the areas of nutrient uptake ability, interactions with other plants, and ability to withstand agents of disturbance (Boutin and Keddy 1993). Forty-three wetland species were tested against these indicators and grouped into seven species guilds, or groups of functionally similar species (Boutin and Keddy 1993). These groups include members of the main families of emergent wetland plants: the Poaceae (grasses), Cyperaceae (sedges), Juncaceae (rushes), and Typhaceae (cattail) (Cronk and Fennessy 2001, 7).

Wetland plants tend to follow one of several survival strategies: ruderal, stress-tolerance, or competitive (Grime 1977; Middleton 1999; Cronk and Fennessy 2001, 258). Ruderals are gap-colonizers (Boutin and Keddy 1993), using high rates of reproduction, dispersal, and quick growth rates to survive (Grime 1979; Cronk and Fennessy 2001, 258). These are mainly annual plants. Stress-tolerators usually have lower growth rates, but possess adaptations that enable them to survive in stressful habitats with low resource availability and low productivity (Grime 1979; Cronk and Fennessy 2001, 258). Some of these plants are biomass storers, storing carbohydrate reserves in large rhizomes or herbaceous parts (Cronk and Fennessy 2001, 258). Blueberry is an example of a stress-tolerator (Cronk and Fennessy 2001, 258). Competitors are the third major functional plant type; these plants put all their energy into high growth rates, outcompeting other plants in terms of resource capture but having low reproductive ability (Cronk and Fennessy 2001, 258). These plants dominate undisturbed, productive habitats. Examples include cattail, *Typha latifolia*, and reed canary grass, *Phalaris arundinacea* (Cronk and Fennessy 2001, 258). Generally, the less disturbance there is, the more clonal dominants will occur in the wetland (Boutin and Keddy 1993). With increasing human activity, recreational development, grazing, or fluctuating water levels, the more ruderals will colonize the gaps (Boutin and Keddy 1993).

Crops chosen for planting should be compatible with local hydrological cycles in order to make an agricultural venture sustainable and economically viable (Porter et al. 1991).

2.3.3 Desirability for farmers

The persistence of conventional agriculture suggests that there are barriers to the alternatives. Financial, technical, and attitudinal barriers all limit the implementation of alternative agriculture models (Beeman and Pritchard 2001, 164).

Ecological economics can help determine whether a design project makes financial sense (Mitsch and Jorgensen 2004, 38). A significant barrier to conversion is that sustainable agroecosystem models show a somewhat lower and more variable yield than conventional systems (Gliessman 1998, 300). For corporations looking to maximize profit, and for small farmers trying to make ends meet, this may be a significant short-term barrier. Small farmers are often unwilling or financially unable to test different options because debt requires them to maximize their short-term income (Beeman and Pritchard 2001, 5). Economic pressure exerts a strong impact, even though the advantages accrued through reduced dependence on external inputs and the corresponding reduction in environmental impacts usually far offset the initially lower yields (Gliessman 1998, 300).

Using natural ecosystem services to produce crops is often intensive in labour, information, and understanding of natural ecology (Jordan 1998, 29). Environmental conditions are so complex to mimic that often the simplest factor can determine the success of the system (Shuwen et al. 2001). Over-design is described as a primary cause of failure in ecological design projects, especially with respect to wetland creation and restoration (Shuwen et al. 2001). Thus, technical difficulties can be intimidating, creating a barrier for many farmers.

There are also some attitudinal barriers. A technocratic outlook, in which humans are viewed as creating the conditions for ecosystems, can be a barrier to learning from the land (Jorgensen and Nielsen 1996). Humans, their activities, and even their economic systems are an integrated part of the natural world that must accommodate the ecological system rather than the other way around (Brown and Lomolino 1998, 624; Jordan 1998, 29). In addition, human resistance to change also causes a delay in accepting innovations that challenge the dominant development paradigm. New ideas are often dismissed. This human tendency can be a healthy scepticism, or it can be a simple unwillingness to change. Alternative approaches to agriculture have usually experienced resistance before becoming more accepted. Integrated pest management, no-till systems, and environmental farm planning were all considered radical when first initiated, and now are relatively common.

To get around some of these barriers and make alternative agriculture acceptable to farmers, a systems approach to agronomic research includes farmer stakeholders as experts in the development of innovative solutions (Kropff et al. 2001).

If the benefits of including biodiversity in an agricultural design are sufficiently advertised, the opportunities may be significant enough to overcome these barriers.

3.0 METHODOLOGY: A PARTICIPATIVE PROCESS OF DESIGN

This research is approached as an exploratory study to assess whether integrated wetland agriculture may be a feasible restoration alternative for farmers wishing to improve farm habitat.

3.1 CONCEPTUAL FRAMEWORK

The theoretical approach behind my conceptual framework has its foundations in ecological design. Pastorok et al. (1997) give an outline of a recommended ecological design model adapted for use in the current research (Figure 3.1). The design process begins by defining goals, followed by identifying a set of design parameters. Potential design ideas are then proposed and evaluated according to selected criteria, in this case, feasibility. Finally, a recommendation for an ecological design is the end product. The design is then ready for modeling or pilot testing at this stage.

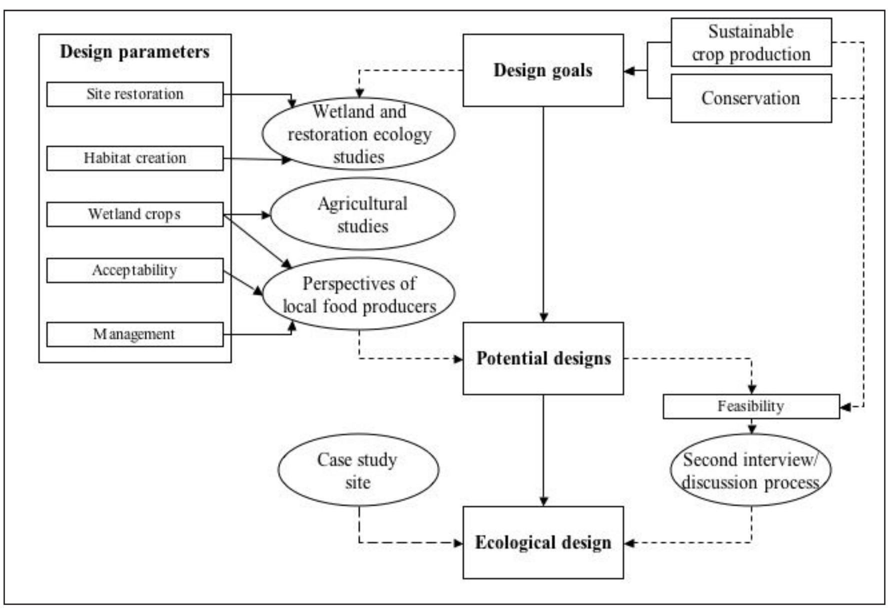

Figure 3.1. Conceptual framework for the ecological design process.

Design goals: Production and conservation

The objectives of the design are twofold: create a more sustainable agroecosystem out of wet marginal farmland, and promote the conservation of wild species within the same area.

Design parameters: Identifying specific research targets

To achieve the goals, a set of design parameters were defined and targeted by the research questions. The choice of parameters attempts to cover a range of key components: restoring the biophysical aspects of a wetland, creating habitat on the site, identifiying potential wetland crops, meeting the needs of local farmers, and developing management techniques. The research into creating an integrated wetland agriculture is drawn from a combination of three sources, with a case study site used as a physical example.

The first source of knowledge is scientific literature: ecological studies of natural wetlands and restoration ecology. Learning from nature is a key component of sustainable agriculture design (Gliessman 1998, 27). The intent is to take advantage of the self-design capacity of natural ecosystems learned from recent wetland studies to avoid problems of over-design in a agricultural setting. Restoration ecology provides examples of applications of wetland ecological research. Learning from others' experiences in agricultural wetland restoration is valuable.

The second body of literature examined is agricultural studies, including traditional agriculture and North American ethnobotany along with modern techniques. Ancient and indigenous systems can provide lessons for design structure, successful farming functions, and useful plants. Modern studies give context and relevance to the crops examined for use.

The third source of research is an interview process exploring current practices among local food producers, including permaculture growers, experimental farmers, and industry experts. This idea builds on a systems approach to agronomic research that includes farmer stakeholders as experts in the development of innovative sustainable solutions (Kropff et al. 2001).

A preliminary set of designs is then created based on the research into design parameters.

Evaluation criteria

The design ideas are assessed with respect to their technical and ecological feasibility. Using a case study site helps to define the variables and set real-world boundaries for a possible design. The social and economic feasibility of the design ideas are gauged through a second discussion with local food producers.

3.1.1 Assumptions

The research model represents a predominantly top-down approach to understanding natural functions. An assumption of this approach is that using a holistic rather than a reductionist approach to problem-solving is most successful for agroecosystem design and management. Problems are treated as part of a larger unit rather than dealing with them individually. Reductionist strategies tend to experience difficulties in ecological disciplines because of the complexity of unknown interactions (Keddy 1992). A holistic perspective is usually advocated in agroecology, organic farming, and permaculture design (Beeman and Pritchard 2001, 103; Gliessman 1998, 311).

The design framework also emphasizes the importance of the local farming community in determining the acceptability of a design. The idea is that that theory will never be useful if it is unacceptable to the people for whom it is intended.

3.2 Scope and boundaries

Although the social and economic aspects of the design remain very much a priority, they are only addressed here through the question of feasibility. The major focus is on the ecological components of the design. The assumption is made that sound ecology is necessary as a foundation for sustainability. Environmental sustainability, the promotion of life-support systems, has been described as a necessary prerequisite for social and economic sustainability (Goodland 1995). Since this research is exploratory in nature, the first priority appears to be the ecological basis. Further study will explore other socio-economic implications or improvements to the design and its implementation.

3.3 Research methods

The research approach is exploratory, and combines an intensive literature review and interview process to obtain data from:

a) wetland ecology,
b) restoration ecology,
c) traditional knowledge of wetland agriculture, and
d) current farming methods, including alternative practices producing low-technology crops.

Triangulation was used between the literature, interviews, and case study site to inform a design.

Primary data collection focused on coastal British Columbia, in the Pacific Maritime ecozone. This mild and wet region, encompassing the mainland Pacific coast and offshore islands, is the province's agricultural hotspot (FarmFolk/CityFolk 1999; McRae et al. 2000).

South coastal British Columbia was chosen as a site for data collection for a variety of reasons. First, the high soil fertility in the valleys along with the wealth of native biodiversity concentrated along the coast creates heavy competition for land resources (McRae et al. 2000). As part of the Pacific flyway, the agricultural land within this region contributes significantly to wildlife habitat; however, farmers have expressed concern about the costs incurred in maintaining habitat (GRVD 1999). British Columbia has the highest rate of habitat loss because of agriculture of any province (McRae et al. 2000). With agriculture's contribution to the province's GDP on the increase, working with farmers to conserve wildlife habitat in agricultural areas is identified as a key challenge for moving towards agricultural sustainability in the province (McRae et al. 2000). The competition for land use creates the type of situation where remedial agriculture may be successful.

Second, the area has a rich legacy of wetlands, and many of the current farms are sustained by previously hydric soils. This creates a land base with ample marginal farmland amenable to wetland restoration. An estimated 50% of wetland area has been converted to agricultural use in the Greater Vancouver area: this is consistent with what has occurred across Canada (Nowlan and Jeffries 1996). Because of the mild climate in the coastal area, wetlands are particularly important for providing waterfowl habitat all year around (Nowlan and Jeffries 1996). However, the province has little statutory legal protection for wetlands and no official written policy for wetlands protection like the ones provided by the federal government or the provinces of Alberta and Ontario (Nowlan and Jeffries 1996).

Third, the region is recognized for innovative and diversified farming techniques. British Columbia is a world leader in integrated pest management (IPM) (FarmFold/CityFolk Society 1999), and has the highest percentage of organic farms in Canada at 1.6% (Statistics Canada 2001). Permaculture has taken a stronger foothold in British Columbia than in other provinces; this alternative farming strategy is mentioned in policy recommendations for the future of British Columbia agriculture (FarmFolk/CityFolk 1999). The diversity of farm products and practices is evident in the proportion of crops categorized as "other" by Agriculture and Agri-Food Canada: 25% of farm receipts are derived from alternative and specialty crops, higher than any other province (McRae et al. 2000). Diversified farming means that producers have more experience with different products, and may have more varied experience from which to draw during interviews.

Gathering data from local food producers within this region may provide new and valuable insights to help initiate design ideas. Qualitative, semi-structured interviews with key informants involved in local food production were conducted as part of a participative research process, in order to get their input and feedback throughout the design process.

3.2.1 Interviews: Learning from experience and gauging initial interest

A series of semi-structured interviews were conducted in coastal British Columbia during the summer of 2003. Key informant interviews explored the experiences, opinions, and suggestions of participants with respect to integrating wetland restoration with alternative agriculture. Participants included those involved in local food production with an interest in experimental agriculture.

Since the research approach is exploratory, the sample of farmers interviewed was strategic rather than representative. The intent was to direct the questions to coastal British Columbians with experience in innovative farming and/or with experience dealing with flooded farm conditions. From this conceptual sampling universe, subgroups were identified based on the producers' position and relationship to agriculture:

Table 3.1. A breakdown of study participants by subgroup and geographical area.

Producer subgroup	Geographical location	Number of participants	Total
Organic farmers	Fraser Valley	9	15
	Cowichan Valley	2	
	Sunshine Coast	3	
	Cortes Island	1	
Conventional (industrial model) farmers	Fraser Valley	3	3
Permaculture farmers	Sunshine Coast	1	3
	Cortes Island	2	
Agricultural consultants/ Government extension workers	Fraser Valley	1	3
	Cowichan Valley	2	
TOTAL			24

a) organic farmers,

b) conventional (industrial model) farmers,

c) permaculture farmers, and

d) agricultural consultants and government extension workers.

Key informants from each of these subgroups were targeted using a snowball sampling procedure: head members of organizations representing these groups were contacted, which led to suggestions of other individuals considered leaders among their peers. To try to minimize sampling bias and increase diversity of participants, more than one organization was contacted for each subgroup. Organic farmers included both small-scale/hobby farmers as well as those running commercial-scale operations. Conventional farmers were defined as producers using chemical means of pest and weed control although they were not conventional in the true sense of the word: these participants were innovators in areas other than organic methods (eg. alternative crops). Four locations within coastal British Columbia were targeted: the Fraser Valley on the lower mainland, the Cowichan Valley (including Duncan) on the east coast of Vancouver Island, the Sunshine Coast just north of Greater Vancouver, and Cortes Island, one of the northern Gulf Islands. The participants involved in the study are categorized in Table 3.1.

Results from these interviews cannot be considered generally applicable to all producers in coastal British Columbia; what they do is give an initial indication of the ideas that

Table 3.2. Format for questions asked to study participants during the interviews.

INTERVIEW I	**INTERVIEW II**
General	*Crop Choices*
1. How do you define "success" in your growing practices and what sort of indicators do you use to measure it?	1. In each category, could you pick out a few plants that you might consider for cropping? Why? Any additions to this list?
2. What kinds of wildlife, if any, do you observe on your lands?	
3. How much available labour do you usually plan for in a season?	*Design systems*
4. Where do you tend to go to find out about new innovations in alternative crop systems?	2. Which of these design priorities(footnote) would you find most applicable? Why? Any alternative ideas?
Crop Choices	
5. When you make a decision about which crops you will plant, what elements most influence your decision?	*Manipulation and water control*
6. With which crops or crop combinations have you had the greatest success, and under what physical conditions did this take place?	3. Given these filters, which do you feel would be easiest to manipulate?
7. How widely applicable do you think such farming successes are?	4. For water control, would you rather use a small portable pump or a pipe system?
8. Could you recommend any crops that grow well in poorly drained soils that also provide high economic returns?	
Nutrients	*Flexibility and self-organization*
9. What is your biggest limitation with respect to soil fertility?	5. Where on this scale(footnote) do you see yourself? What do you consider ideal?
10. What methods have you found most successful in increasing nutrient recycling and improving soil fertility?	
11. Given your experience, how would you improve the availability of soil nutrients in an area of poorly drained land?	
Pests	*Implementation and barriers*
12. What is your greatest pest problem?	6. What would make you want to try such a system?
13. Do pest problems change from season to season, and how do you adapt?	7. What are the major barriers you can foresee?
14. In your experience, what kind of pest management techniques do you find most effective?	8. Is there anything else you would like to see in this kind of system?
15. How would you recommend dealing with the kinds of pests you would expect in a poorly drained land area?	

experienced farming innovators consider feasible possibilities in terms of a restoration and cropping design.

Two sets of personal interviews were undertaken. The first involved general questions regarding opinions on farming, wildlife, and crop choices as well as more technical questions regarding their expertise with nutrient cycling and pest management (Table 3.2). Not all questions were applicable to each participant, but participants responded according to their own practices and expertise. The second interview took place after data from the first interview sessions was compiled and compared to literature notes to create potential design ideas. This second interview assessed participants' responses to the design ideas (Table 3.2).

3.2.2 Case study: Application to actual site conditions

A case study for a theoretical design location was chosen by participant solicitation in a seasonally flooded agricultural watershed outside of Duncan, within the Cowichan Valley on Vancouver Island. The Somenos Basin watershed has a strong agricultural heritage, with equally strong biodiversity value; major income sources for the area include both agriculture and wildlife viewing, an uncommon combination (Madrone Consultants 2001). Small-scale agriculture dominates the valley. The area was recommended by a government agrologist looking for new options for farmers in the basin, who were losing farming capability due to increasing seasonal flooding and had experienced difficulty getting any help with the situation (Tattam, personal communication, 2003). The design work is based on the conditions at this site, but is intended to be modifiable to other sites.

The study site was previously covered by a wet meadow and marsh complex before drainage for agriculture at the turn of the century. The primary water sources are winter storm precipitation and runoff, as well as flooding coming from the backwatering of a creek during winter and spring. Flooding increased on farmlands in recent years, denying farmers access to parts of their land often until early summer.

Vegetation surveys indicate a range of wetland types in the region. There are tree and shrub riparian areas, willow/shrub areas, and seasonally flooded agricultural fields with a mixture of coarse grasses (Madrone Consultants Ltd. 2001). Vegetation growing in the streams includes reed canary grass (*Phalaris arundinadea*), sedges (*Carex* spp.), iris (*Iris pseudacorus*), and smartweed (*Polygonum* spp.) (Lanark Consultants Ltd. and Burns 1999). Willow-shrub wetlands are succeeding many of the marsh areas, reducing habitat for Great Blue Herons, wintering swans, geese, and ducks (Madrone Consultants Ltd. 2001). Overall declining biodiversity in the area has been recently identified as a management issue by the Somenos Steering Committee, a group of stakeholders established to guide watershed planning in the region, because of the increase in human impacts on natural habitat. At the same time, demands by landowners for action regarding the high seasonal flooding levels are increasing.

3.2.3 Data analysis and design creation

Data analysis was an iterative process, with results from early stages of data collection guiding further searches (Neuman 2000, 419). Analysis consisted of organizing interview responses and literature findings into conceptual categories, and comparing evidence to find areas of convergence from which elements of the design were drawn. Alternative designs were proposed based on the collected evidence.

Participants' choices of design from among the alternatives, examined in the second round of interviews, were then assessed and compared with design literature. Where the data converged, a design option was recommended. The reasons behind the selection or rejection of alternative cropping systems were recorded and used to improve the design throughout the process.

The literature on wetland and restoration ecology studies was used to develop a method for restoring marginal farmland in the most simple way feasible, according to the criteria of importance defined by study participants. A general step-by-step restoration programme is recommended, with guidelines on how to modify the general restoration work to a specific site. The case study site is used to demonstrate the process.

Examination of agricultural and ethnobotanical studies revealed several temperate wetland plants with economical potential as food crops. Government industry documents were also compared to assess the kind of crops to gain an economic foothold in the current agriculture industry in British Columbia. Crops found in the literature were compared in discussion with study participants to assess the initial level of acceptability in the farm community. A set of criteria was developed to choose a final crop selection for the design, and potential crops screened using these indicators.

A design for a wetland complex, a management scheme, and initial monitoring plan for pilot testing is the resulting product. Methods for possible site-specific modifications are also given in order to make the design ideas more generally applicable. Future research needs and possible visions and opportunities for this restoration alternative are outlined.

4.0 Results: Interviews with local food producers in coastal British Columbia

Thoughts on farming, especially innovative farming practices, can vary widely. Ideas expressed in literature will only have practical application if they meet the needs and values of those immersed in the business. The experiences, opinions, and suggestions for integrated wetland agriculture shared by key informants from coastal British Columbia are described here.

Twenty-four producers partcipated in the first round of interviews. Ten of these were able to continue with a follow-up discussion after design work was started; the others were unable to schedule a second interview because of demanding summer farming schedules. The limited availability of farmers combined with the travelling distance between farms made it impossible to meet with all producers a second time during the research term.

***Box 4.1**. A diverse group: Profiling innovative farmers in B.C.*

Meeting and talking with local food producers during this study provided valuable insights into the industry – the motivations driving participants to alternative products and wildlife-friendly farming methods were as diverse as the farms themselves.

One self-taught farming couple derives their entire income from a 2-1/2 acre organic produce farm, supporting a family of four while setting aside their additional land for wildlife. Another man grows and markets wild herbal salads while selling BMW parts as additional income. One farmer built up a prolific multi-farm business operation based on organically fed livestock, in response to high chemical spraying a decade earlier that left many of the farms barren of wildlife. Now, he describes seeing birds again that he remembers as a child. On the other end of the captial spectrum, a group of growers initiated a farming cooperative in order to afford a piece of land and deal with the capital costs of starting farming. One of them describes some of the most rewarding moments as when customers express their appreciation for their ecological farming practices, and thank him for doing what he does.

While some farmers are motivated to cash in on the growing alternative and organic markets, another told me that farming is "more heart than pocketbook". Some run their operations as a protest against large company takeovers and imported foods. Picking cattail shoots and drinking iris coffee with one farmer led to a discussion of the nutritional motivations behind alternative produce.

Despite evading a common profile, there were similarities. Most farmers spoken with had all persevered with their goals through difficult times. And all had one thing in common: a different view of agriculture than an industrial, monocultural model.

The number of participants answering any given question varied, since some questions were outside of their expertise. Therefore, the variation in participant numbers in the following results is due to those who responded "I don't know" to the posed question.

4.1 Interviews

General experience and opinions were discussed during the first interview session. Converging opinions and main themes arising from the interviews were explored. For simplicity, “participants” will be used to refer to the local food producers interviewed in this study.

4.1.1 On the interpretation of success in farming

Interpretation of success in growing practices defines what a producer will grow, and helps to identify what criteria are important when making on-farm choices. Elements that make a design desirable for farmers in the region may be drawn from characterizing a successful operation.

In speaking with participants, financial viability was mentioned most often as a component of a successful farm, followed by ecological sustainability (Figure 4.1).

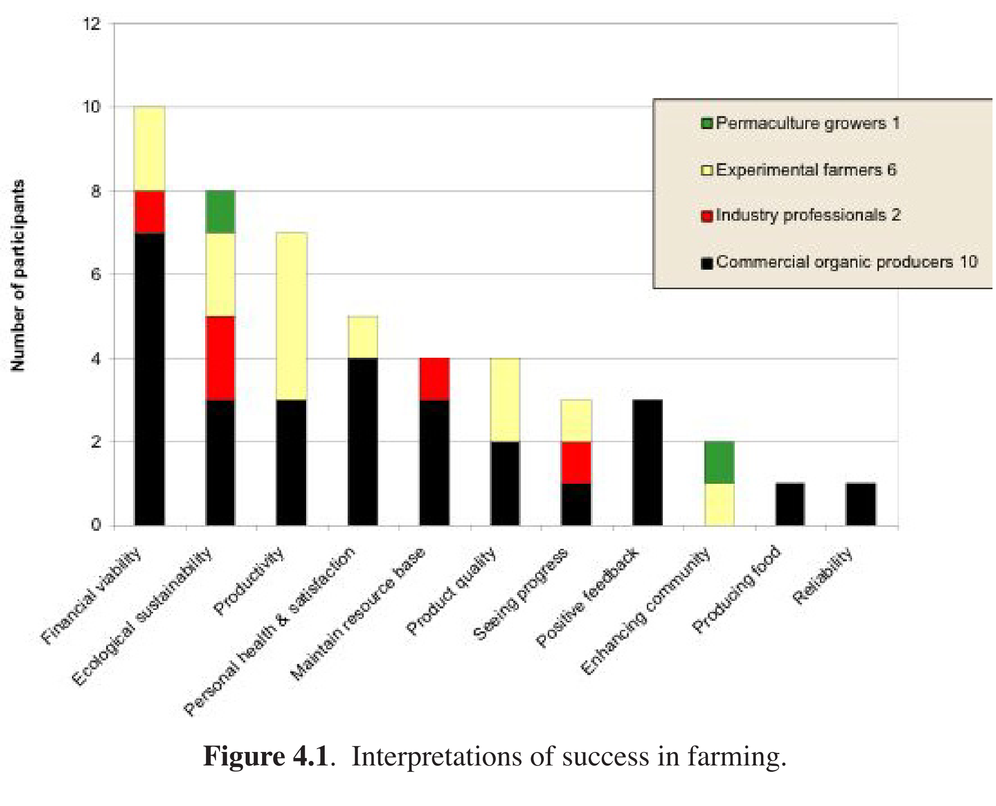

Figure 4.1. Interpretations of success in farming.

4.1.2 On crop choices

Participants were asked to discuss the factors they considered when making a decision about which crops to grow. Market demand and labour requirements were mentioned most often (Figure 4.2). While ecological sustainability was important to many farmers as an element of success, only two farmers identified ecological considerations among their criteria for crop choices. Physical limitations, including the land base as well as equipment needs were also often considered when planning crops. Growing new, innovative crops was mentioned to an equal extent as growing familiar crops within one's comfort zone. Maximizing profit and minimizing risk were also important to farmers.

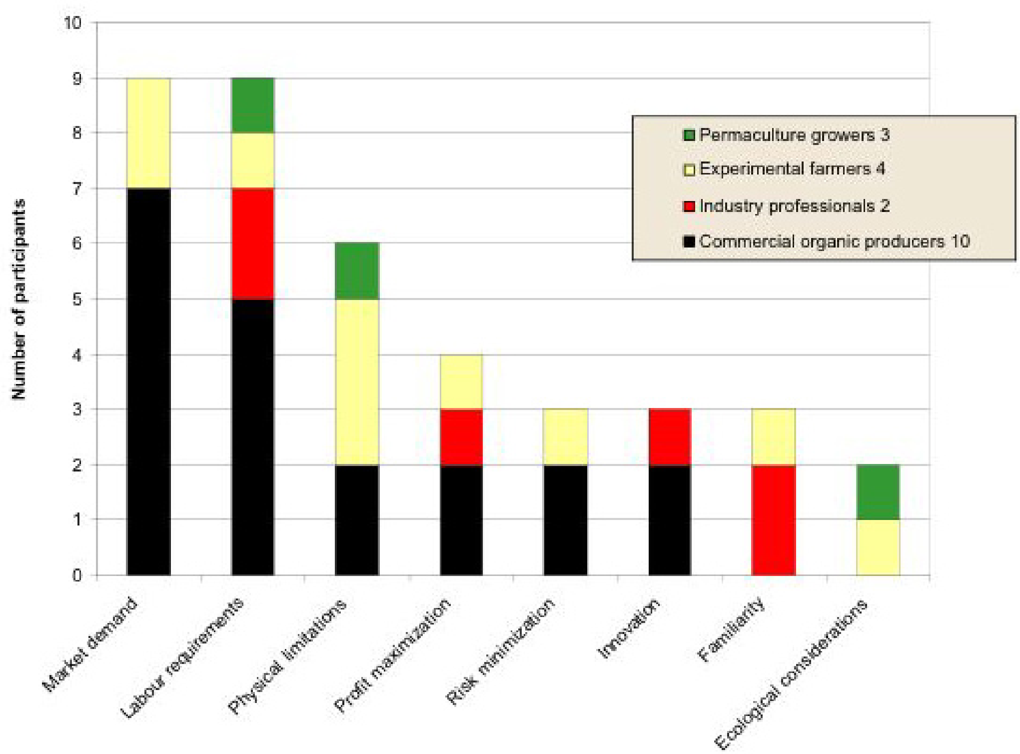

Figure 4.2. Factors influencing production choices.

To give a general idea of the crops currently grown in coastal British Columbia, the most successful crops described by participants were profiled (Figure 4.3). Vegetables, fruits and berries were the most successful crops produced by participants in this region. One unanticipated finding was the mention of four types of wild plant species as commercially successful crops, described by two participants.

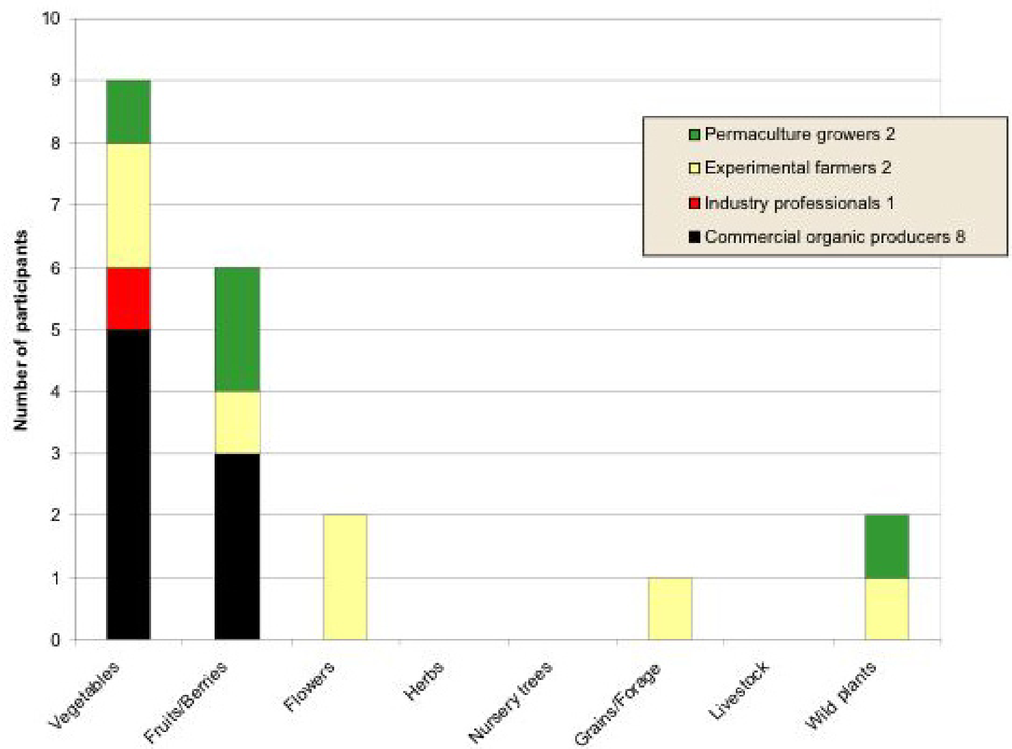

Figure 4.3. Successful crops.

A breakdown of the categories into specific crops is given in Figure 4.4, showing the proportion of participants that identified the crops as successful. Salad mixes were described as successful by five participants, carrots and strawberries by four, and beans, potatoes and squash by three different participants. The category “Other” is separated out in order to view the wild native species mentioned.

Based on their personal knowledge and experience, participants were asked to suggest possible crops for growing in a wetland setting. Results varied from the successful crops described previously. Different types of vegetables were still mentioned by most participants, again followed by types of fruit and berries (Figure 4.5). A greater number of alternative crops were now identified: herbs, flowers, nursery trees, grains and forage, and aquatic livestock. Now, seven of ten remaining participants identified 18 species of wild plants as potential crops. This is a large proportion of the 42 potential wetland crops suggested during the interviews. A breakdown of the crop categories by species is given in Figure 4.6.

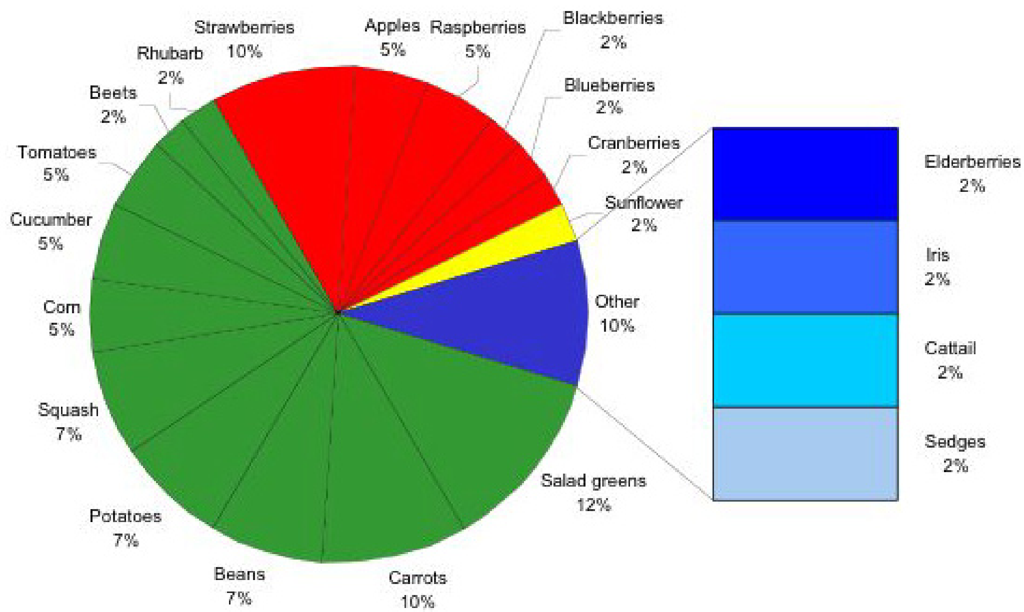

Figure 4.4. Proportional representation of successful crops.

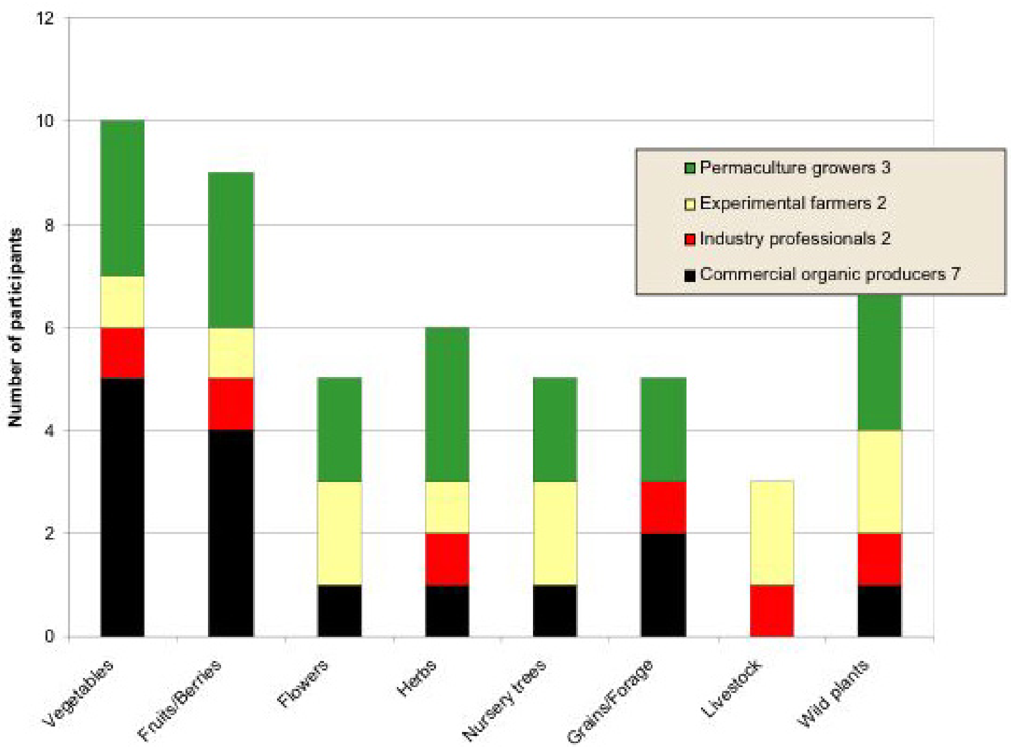

Figure 4.5. Suggested wetland crops.

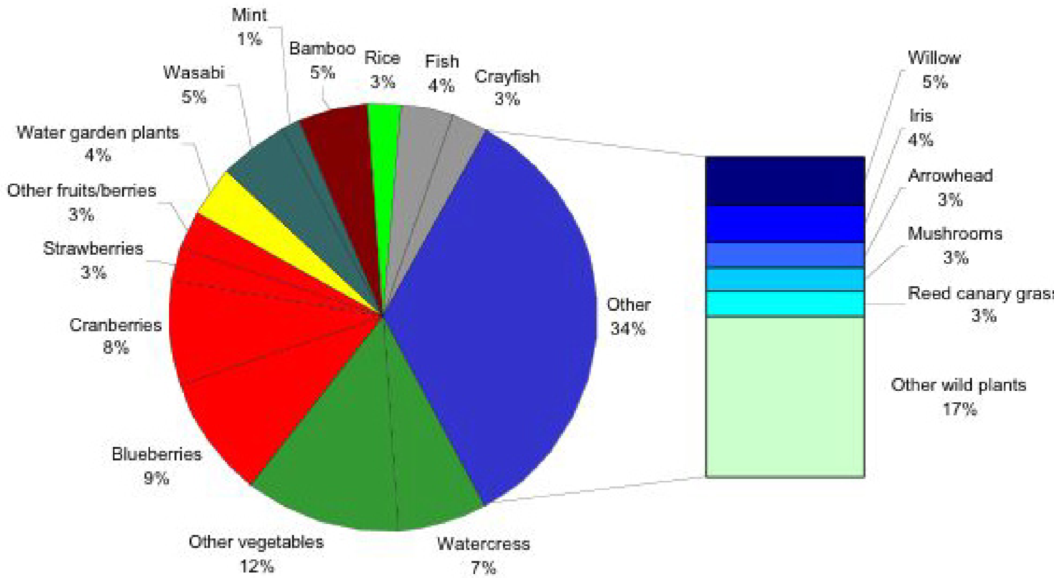

Figure 4.6. Proportional representation of suggested wetland crops.

The category "Other vegetables" (Figure 4.6) are those mentioned by a single participant. These include beets, carrots, celery, corn, kale, leeks, onions, squash, and water chestnuts. "Other fruit" include pears and raspberries, each mentioned by one participant. Thirteen "other wild plants" were suggested during the interviews: alder, arrowroot, aquatic mint, cattail, dawn redwood, Gunnera, Juneberry, lily, Pacific crab apple, poplar, rowanberry, wild herbs, and wild rice. These crops are all worth consideration; their denotation as "other" only means that the suggestion was not repeated by another participant during the interviews.

4.1.3 On management of farm problems

Weeds were discussed most often among the farmers interviewed as being their main problem on the farm (Figure 4.7). Insect pests were mentioned next. Both flooding and marketing were also notable among the problems discussed. In some cases, however, flooding was considered beneficial as it got rid of many insect pests.

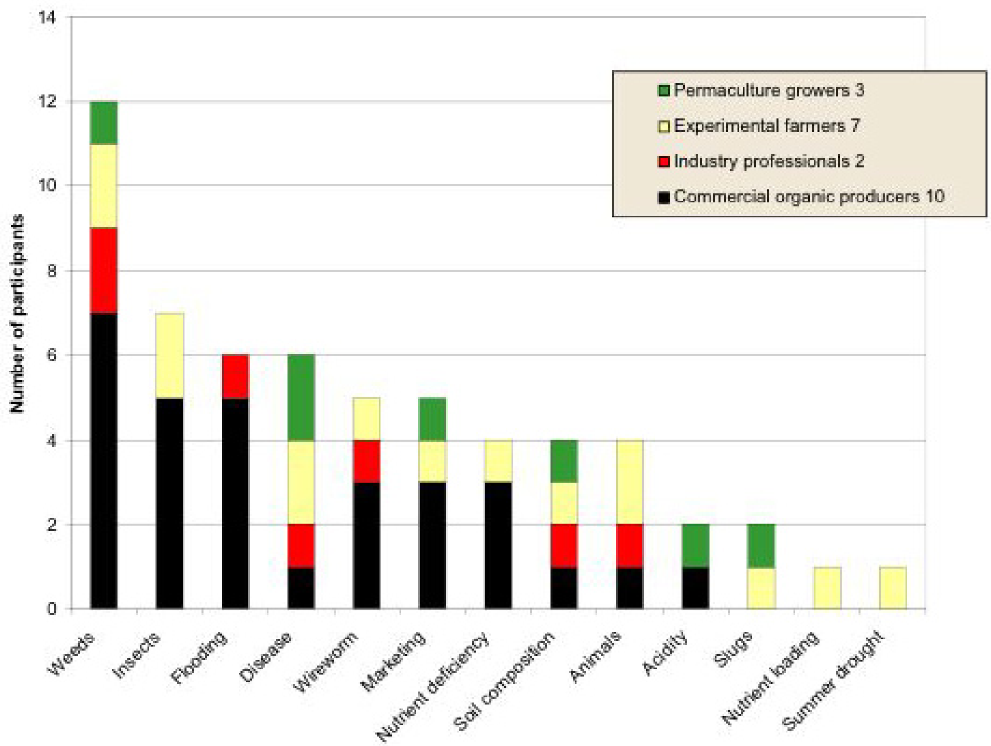

Figure 4.7. Primary difficulties experienced by farmers.

Marketing appeared to be a significant challenge, according to some farmers. As described by one farmer,

> "If you can't sell [a crop], and you can't sell it at a profit, then you're not going to last doing it." (Switzer, personal communication, 2003).

Since market demand has a significant impact on crop choices (Figure 4.2), marketing strategies were examined further. Here, direct farm sales appeared to be the most popular means of selling products, followed by farmers' markets, wholesale marketing, and restaurants (Figure 4.8). Direct farm sales appeared to be popular because there is no need to find a processor, which increases a farmer's margin of profit (Tattam, personal communication, 2003).

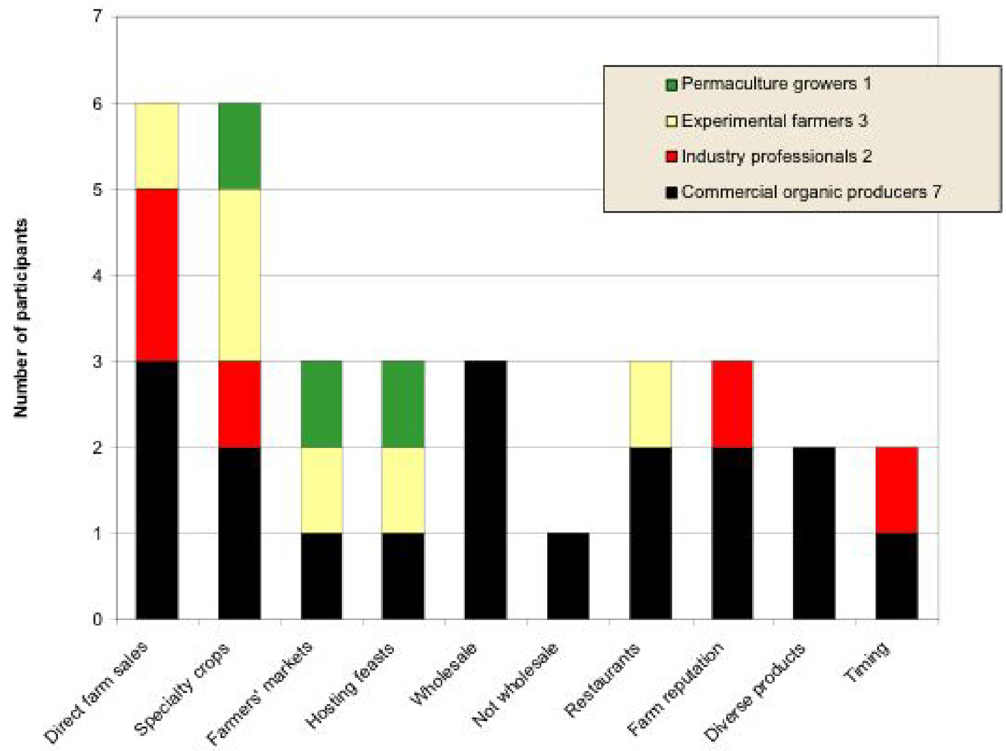

Figure 4.8. Preferred markets and marketing strategies.

Direct farm sales and farmers' markets both seemed to attract a certain strategy: growing specialty crops, and a diversity of products. Growing specialty crops fills niche markets, which is where many local producers found their marketing edge (Figure 4.8). Certified organic is just one area in which producers found a growing demand. Adding value to a crop was one way mentioned to increase the profit margin.

Farm reputation was brought up by a few farmers. Customer reviews and people coming back to the farm appeared to be a significant part of a farmer's marketing success. Professionals in the business recognized the increase in public perception regarding farm environmental practices (Tattam, personal communication, 2003). The farm community started to take advantage of the fact that how they're perceived by consumers has a major impact on their bottom line (Haddow, personal communication, 2003). Especially on Vancouver Island, consumers are more concious of buying local, and producing Island product while protecting the resource base (Haddow, personal communication, 2003). Three farmers mentioned that they host feasts as a means of advertising product and increasing farm reputation.

4.1.4 Wildlife and attitudes towards wild species

When asked about the kinds of wildlife they experienced on their farms, more bird species were mentioned than any other. More species were described as being a problem to farm operations than beneficial, although most were neutral (Table 4.1). All rodents described tended to cause problems, while the greater proportion of beneficial species described were birds and invertebrates.

Table 4.1. Wildlife described by farmers in coastal British Columbia.

	Beneficial	Problematic	Neutral
Birds	crows	crows	blackbirds
	kildeer	geese	ducks
	swallows	jays	eagles
		robins	finches
		starlings	herons
		Trumpeter swans	lazuli bunting
			owls
			pheasants
			ravens
			vultures
			woodpeckers
Mammals	coyotes	coyotes	bears
	feral cats	deer	cougars
		rabbits	opossum
		raccoons	skunks
			wolves
Rodents		beaver	
		mice	
		muskrat	
		squirrels	
		voles	
Invertebrates	bees		hornets
	butterflies		yellow jackets
	spiders		
Reptiles/Amphibians	snakes		frogs
			tree frogs
Fish			trout

4.2 Follow-up discussions on design issues

Follow-up discussions were conducted with ten participants to gauge levels of interest in different design ideas, opportunities, and challenges. Some preliminary design structures and crop ideas were sketched out and handed to the participants for comment. For the discussions, a preliminary design based on a system of raised beds and canals that demonstrates a full range of wetland habitats was presented. Four sketches were shown, using the same structure but each geared towards a different priority: aquaculture, agrotourism, native wild plants, and water quality control. Discussions included the relative merits of different crops; choice of priority for the design; thoughts on system manipulation and water control; and desired levels of flexibility and self-organization in such a system.

4.2.1 Crop selection

Crop ideas originated both from participant suggestions made during the interview sessions, as well as ideas in the literature. Crops were grouped into categories based on their ecological position on a wetland gradient, and participants were asked to discuss which crops they would be willing to grow under each category. The structure of the discussion design showing the different habitat categories is given in Figure 4.9. Preferred crops included mints; iris; watercress; sedges; salad blends; blueberries; and mulberry (Figure 4.9). Comments on the crop choices are given in further detail in Tables 4.2 to 4.9.

Crops for discussion were chosen from the most popular wetland crop suggestions. Thus, mint was offered as a possible bank plant (Table 4.2), iris for damp to muddy soil (Table 4.3), and watercress, sedges and cattail for shallow water areas (Table 4.4). Other wild plants that came up during the interviews as possible crops were mentioned for further comment in the follow-up discussions as well. These included arrowroot for the bank plants, cattail, Juneberries, Pacific crab apple, rowanberry, wild rice, and nursery plants. Alfalfa and clover appeared as bank crops in the permaculture literature, so were included for discussion (Table 4.2). The use of millet and mulberry also came from the permaculture literature; these two were looked upon favourably by participants.

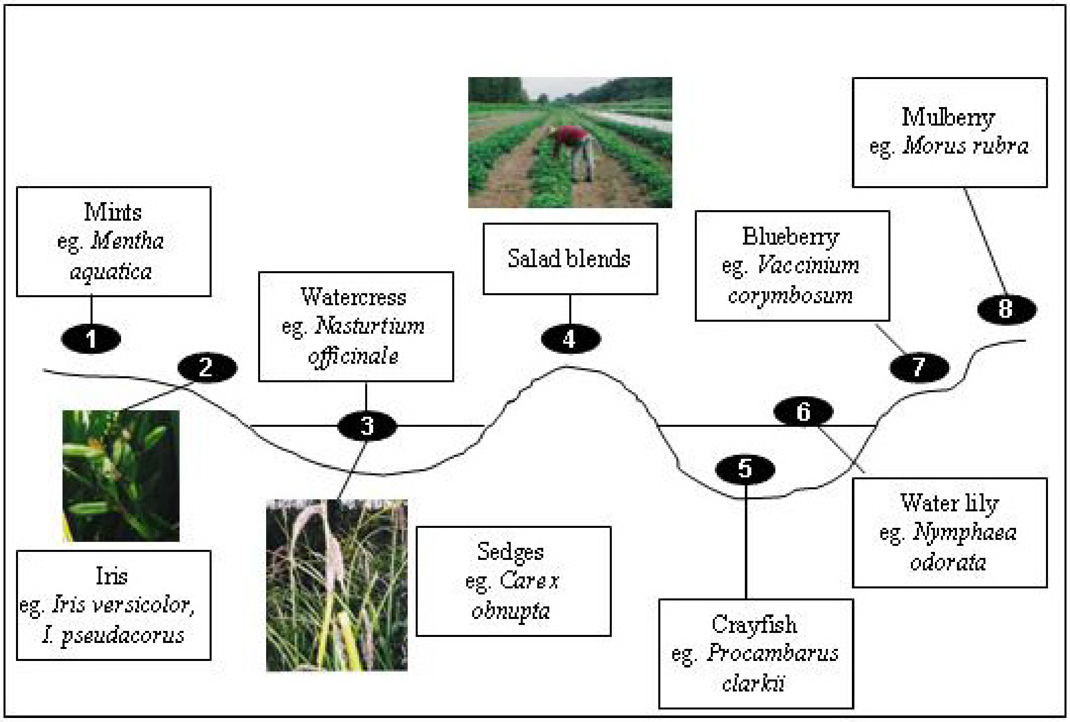

Figure 4.9. Preferred crops for different wetland niches as discussed in follow-up interviews.

The most favoured crops during the discussions tended to be those suggested by other participants rather than the permaculture or wild plants found in the literature. Overall, the crops most likely for participants to grow in their wet areas were:

1. blueberries (Table 4.8),
2. salad blends (Table 4.5) and wild iris (Table 4.3),
3. mints (Table 4.2), watercress (Table 4.4), sedges (Table 4.4), crayfish (Table 4.6), and mulberry (Table 4.9).

Often, participants were unfamiliar with the crop being suggested and did not comment on all possibilities. The crops favoured by participants therefore fall within their comfort range or range of experience. Of these wetland crops, four were also mentioned as being particularly successful for some farmers: salad blends, blueberries, iris, and sedges (Figure 4.4). All of the most favoured crops apart from mulberry came from suggestions during previous interviews.

Table 4.2. Groundcover and short bank plants.

Crop species	Participants who would try it		Participants who would avoid it	
Mints*	3	good market, especially for specialty mints act as weed competition can have added value eg. aromatic soaps	1	small to tiny market niche
Alfalfa	1	can sell sprouts	1	unknown market
Arrowroot*	1	no comments	1	unfamiliar crop
Clover	1	good nitrogen fixer	2	market slim to none
Other	1	herbs - good for marketing directly to restaurants		

*denotes those crops suggested by participants in previous interviews; the others are added from the literature

Table 4.3. Crops for mudflats and low seasonal flooding.

Crop species	Participants who would try it		Participants who would avoid it	
Blue iris*	4	familiar good sales at markets, especially Oriental markets		
Yellow iris*	4	could sell ground seed for coffee		
Reed canary grass*	3	medium market value		
Millet	2	small market exists	1	becomes a weed
Sweetflag		no comment		

Table 4.4. Crops for shallow water.

Crop species	Participants who would try it		Participants who would avoid it	
Watercress*	4	good market good commercial crop easy to harvest with planks	1	can be invasive, needs containment prone to weeds
Sedges*	3	can be used as mulch small market niche *Carex obnupta* makes a good grain crop		
Cattail*	2	shoot tips are excellent, restaurant fare small market niche		
Duckweed	2	comes in by itself small market niche	1	not good for anything
Smartweed	2	can sell as a spice, as a packaged condiment small market exists	1	no commercial value
Bulrush	1	tiny market niche		
Common reed	1	tiny market niche		
Water chestnut*	1	no comments	2	not hardy poor market
Wasabi*	1	high-end market	1	a fad crop
Wild rice*	1	winters not cold enough for it to become invasive	4	higher labour higher harvesting and processing costs requires diking and soil disturbance price dropped can clog channels, cover spawning grounds
Arrowhead		no comment		

Arrowhead and wasabi got surprisingly little positive comments during the discussions (Table 4.4), given the enthusiasm with which they were described during the previous interviews. Both these crops were more strongly endorsed by participants from the permaculture community, however, who did not participate in the follow-up discussions.

Table 4.5. Crops for raised beds.

Crop species	Participants who would try it		Participants who would avoid it	
Salad mix*	4	strong market for both direct farm marketing and wholesale		
Nursery trees*	3	good market for poplars, willows, dogwood, nursery pond plants		
Rhubarb*	3	good market likes water, can stay in ground for many years		
Squash*	3	small market but needs few inputs		
Beans*	2	strong market	1	too much tilling and soil disturbance
Carrots*	2	good market		
Cucumber*	2	strong high-end market likes lots of water		
Cut flowers*	2	Gunnera, hostas, water plants popular good for direct farm marketing		
Potatoes*	2	good market	1	too much tilling and disturbance
Strawberries*	2	strong market few equipment needs	1	may rot in winter
Other	1	Nasturtium - makes a good spice		

The aquaculture and floating/submergent plant categories received few positive responses (Table 4.6; Table 4.7). Generally this was due to the lack of constant water year-round, which would allow development of such crops.

Table 4.6. Aquaculture.

Crop species	Participants who would try it		Participants who would avoid it	
Crayfish*	4	small market niche, good Swedish market		
Tilapia*	3	small experimental market not a problem if they escape into the environment		
Rainbow trout*	2	few requirements small to medium market		
Mussels	1	small Vancouver Island market	1	need very specific environment
Gambusia		no comments		

Table 4.7. Floating and submergent crops.

Crop species	Participants who would try it		Participants who would avoid it	
Water lily	1	can cook and eat seeds like popcorn	1	not enough deep water in summer
Coontail		no comments		
Spatterdock		no comments		
Water lotus		no comments		
Water milfoil		no comments		
Gambusia		no comments		

Table 4.8. Shrubs and medium-size bank plants.

Crop species	Participants who would try it		Participants who would avoid it	
Blueberry*	5	high resistance to flooding likes acid, organic soils strong market		
Raspberry*	3	strong to medium market	1	risky because of root rot problem
Jerusalem artichoke	2	grow alright in a marsh	2	can be a weed small to tiny market
Other	2	blackberry - grows everywhere; easy to harvest		
Elderberry*	1		1	none to tiny market
Rowanberry*	1			
Salmonberry	1		3	easy to pick in the wild; flooded market
Juneberry*			1	unfamiliar

Table 4.9. Trees and tall bank plants.

Crop species	Participants who would try it		Participants who would avoid it	
Mulberry	3	could market in area		
Bamboo*	3	grows well some varieties are edible	4	unfamiliar tiny market niche possible invasive
Pacific crab apple*	2	grows well can graft marketable apples to root stalk	1	small to tiny market niche

4.2.2 Comments on design structure and priorities

Four participants commented favourably on the idea of using a raised bed structure within a wetland setting. Having a small raised area would allow them to grow vegetable crops such as salad mixes earlier in the spring or keep berry bushes from growing rampant. Two of these participants also advocated using the silt from the bottom of the wetland channel to fertilize higher beds. Some cautions about the practical aspects of raised beds were brought up: the beds sink over time, and the ditches must be wide enough to accomodate a stable slope. The difficulties of weeds in water farming were also discussed by one participant.

The relative merits and challenges of approaching wetland farming from different angles were also discussed (Table 4.10).

Table 4.10. Comments on design priorities for an agricultural wetland.

	High priority		Low priority	
Agrotourism	3	a growing industry creates awareness improves farm reputation	1	can undermine farming as food production
Aquaculture	2	can be low-maintenance if they have proper habitat	2	need lots of space; high expertise; constant water levels and temperature lots of aquaculture already
Native plants	2	closest to reality; just needs marketing		
Water quality control	1	important to most commercial farmers		

4.2.3 System manipulation and water controls

Different management schemes were discussed that involved using environmental filters (Keddy 1999) rather than manual labour to modify crop communities. Participant responses on the ease of manipulating environmental filters showed that water levels may be the simplest to manipulate, followed by disturbance and fertility (Table 4.11).

4.2.4 Flexibility and self-organization

Participants were asked to comment on their position regarding the importance of predictability over flexibility in growing a crop. Their position on a scale of crop predictability was discussed (Figure 4.10).

Table 4.11. Comments on ease of management schemes for controlled disturbance on a farm wetland.

	Easy		Difficult	
Water levels	4	easy to put in drainage or raise a bed can use dams or irrigation flooding also kills many pests	3	too many variables carries over beyond farm limits fisheries limitations can be expensive
Disturbance	3	easy to bulldoze or cultivate	2	difficult if water table is high disruptive to the soil
Burial	2	mulch works up to a point		
Fertility	3	can add compost or lime easy, but not necessarily organically		
Competition	1	can use cover crops		
Herbivory	1	can control grazing		

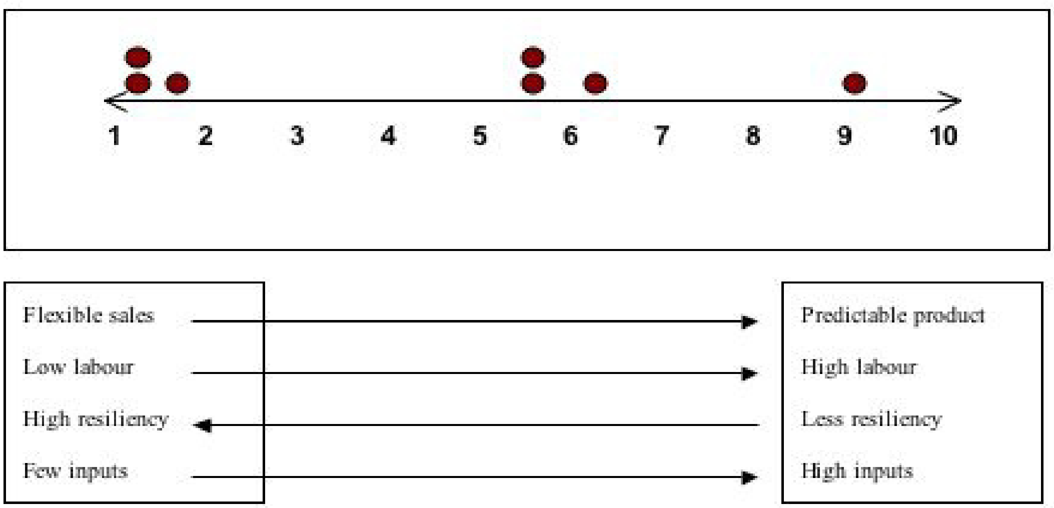

Figure 4.10. Participant position on a scale from designed, predictable product to self-organized, flexible product.

Comments:

Predictable crop:

- having cash flow is important

Flexible crop:

- can't predict what will happen from year to year
- good for a small-scale business

Mid-scale:

- it depends on the crop
- good to keep a balance between guaranteed market and risk crops

The participants' thoughts on methods of water control were also discussed with relation to flexibility. Like the comments on the importance of predictability in a farming scheme, there was no universal opinion regarding the permanence of engineering methods for water control. When asked whether they would be willing to use a pump if necessary, participants were evenly divided in opinion between installing a permanent structure, using a portable pump only when necessary, and using nature as the sole water regulator. The argument behind installing a permanent structure was that it would later save time and effort; the only stipulation was that the structure should be as simple as possible (Kenney, personal communication, 2003). A portable pump was considered to be better by others because it is more versatile, has lower initial costs, and requires less committment to the project (Switzer, personal communication, 2003). Taking advantage of natural water fluctuations and simple gravity controls was strongly advocated by another participant (Singal, personal communication, 2003).

5.0 Simplicity and feasibility: A discussion of wetland restoration in marginal farmland

Wetland restoration in marginal farmland is the first step towards creating a wetland that integrates agriculture and habitat. Simplicity and feasibility are key criteria for a farmer to engage in a restoration project. Thus, the simplest and most feasible methods of restoring wetland ecology to drained land are explored here in terms of the major wetland components, processes, and values. Ecological limitations are outlined and site-specific modifications are suggested for dealing with the problems that arise in different settings.

5.1 Theory and practicality: Setting objectives and criteria

5.1.1 Statement of objectives

A clear statement of function is required for a successful wetland restoration (Hammer 1992, 110). Objectives are therefore defined as commercial production of wetland crops and provision of wildlife habitat; a secondary function is water purification of agricultural runoff. (Use of the term *restoration* may not be entirely accurate since the goal is not necessarily to return the land to a previous state. Wetland *re-establishment* may be a more accurate term. For simplicity's sake, the term *restoration* will continue to be used for the purposes of this paper.) The defined functions for this project are three described by Hammer (1992) as possible goals for a restored or constructed wetland, and are desirable from the perspective of local food producers interviewed in south coastal British Columbia. The restoration plan is derived based on these specified functions.

5.1.2 Criteria

Simplicity and feasibility of restoration are the criteria set out in the research question. The discussions with participants revealed some key aspects regarding the meaning and importance of these criteria for on-farm wetland restoration. To be feasible, a wetland system should:

a) be as self-maintaining as possible, requiring little labour,
b) be simple and involve minimal construction, earthworks, and engineering,
c) have low start-up costs and low equipment needs, and
d) be flexible enough to allow for natural climate variations from year to year.

These suggestions were corroborated by the literature (Hammer 1992; Jarchow 2001; Mitsch and Jorgensen 2004).

Attention to the natural ecology of the area is important when designing for self-maintenance. Other wetlands in the area can be used as a reference in deciding which type of wetland to target as a restoration goal (Hammer 1992, 106). If the area's natural wetlands are wet meadows and marshes, creating a bog or swamp might meet with greater difficulty (Hammer 1992, 117). For enhancing regional biodiversity, historical wetlands may also be of interest. For example, if the basin formerly contained a network of mud flats and marshes but the remnant wetlands are all treed swamps, restoring an early marsh successional stage may have greater benefits for local biodiversity than creating another swamp and may still be simple to restore. Using an area's natural ecology tends to be a less expensive solution (Hammer 1992, 149) and less prone to failure (Mitsch and Jorgensen 2004, 177) than creating new conditions.

While the system ought to be flexible, the crop produced must still be predictable to a certain extent from a farmer's perspective. This need validates the emphasis on a designer approach for this project. A designer approach uses the life histories of desired species to construct the appropriate conditions, in contrast to a self-design approach which focuses on creating a suitable environment for natural plant colonization (Middleton 1999, 67). The need for a degree of predictability in crop production also requires that the system be able to meet its objectives. Including more diverse components into the design increases resiliency but also increases complexity. Diverse and complex systems are able to support more functions, are more able to withstand disturbance, and have a greater degree of self-maintenance (Hammer 1992, 116; Mitsch and Jorgensen 2004, 99). These characteristics are all valuable for farmers. A balance must therefore be struck between designing for diversity and complexity and budgetary and site constraints. An examination of restoration methods for agricultural wetlands is discussed here with an emphasis on the identified functions and criteria.

5.2 Restoring wetland function

Creating an area suitable for wetland crops and wildlife habitat requires restoration of the appropriate ecology. Aspects to be considered include wetland hydrology; soils and nutrient cycling; microorganism, invertebrate, and vegetative communities; and wildlife colonization. Engineers, scientists and landowners have employed different methods over recent years to restore wetland ecology to drained areas. Some are quite simple, while others involve complex engineering. Alternative restoration methods (Tables 5.1 to 5.5) were evaluated according to the criteria identified in section 5.1.2. Those techniques best fitting the feasibility criteria are recommended.

5.2.1 Hydrology

Hydrology is the most critical process involved in wetland restoration. Re-creating an appropriate hydrological regime is the means by which desired vegetation communities can be most successfully established and invading plants discouraged (Middleton 1999; Keddy 2000; Mitsch and Gosselink 2000; Mitsch and Jorgensen 2004, 243). To restore wetland hydrology means:

a) re-wetting the site, and
b) ensuring fluctuations in water levels that will allow the wetland to persist (Hammer 1992, 65; Middleton 1999; Mitsch and Gosselink 2000) (Table 5.1).

Changing water levels create the required disturbance regime, characterized by water depth, flooding duration and timing of flooding (Middleton 1999; Mauchamp et al. 2002).

Recommendations

The simplest way to re-wet an agricultural landscape is to reverse the drainage: break tile drain lines, or interrupt ditch flow with a clay plug (Hammer 1992, 105; Middleton 1999, 183; Mitsch and Jorgensen 2004, 180). The water can then be re-channelled into a depression or excavated area. Using naturally low areas decreases the costs of construction, as excavation can be the most expensive step (Mittag et al. 2001).

Table 5.1. A summary of alternatives for restoring wetland hydrology to drained farmland.

Goal	Alternative techniques	References
Rewetting	interrupt tile lines	Middleton 1999 Mitsch and Jorgensen 2004
	plug ditch flow into a depression	Hammer 1992 John et al. 2001
	hold back seasonal floodwater from a stream using control structures	Miller 2001 Mittag et al. 2001 Perlea et al. 2001 Mitsch and Jorgensen 2004
	excavation to overcome existing topography	Mittag et al. 2001
	keep small internal variations in topography	Abney 2001 Miller 2001 Mauchamp et al. 2002
Creating water fluctuations	water control structures placed in an existing ditch	Hammer 1992 Mitsch and Gosselink 2000 Abney 2001 Jarchow 2001
	stoplogs for water control	Hammer 1992 Abney 2001 Miller 2001
	swivel pipes for water control	Hammer 1992

In riparian areas, flooded backwater can be used as an additional water source by holding it back using berms and/or stoplogs (Mittag et al. 2001; Perlea et al 2001) or check valves (Mitsch and Jorgensen 2004, 149). The idea is that when a neighbouring stream or river is higher than the level of the wetland, water flows in, but backflow out is prevented as water levels drop (Miller 2001). While using outside water sources to re-water a wetland is more involved than constructing simple ditch blocks, additional water is often necessary in order to retain sufficient water year-round.

Adding water control structures that permit water drawdowns is recommended to re-create disturbance dynamics which will allow the wetland to persist and the landowner to manage for the desired successional stage. Water control structures should be simple, inexpensive, easily constructed, easily operated, and require little maintenance (Hammer 1992; Abney 2001; Jarchow 2001). Stoplogs appear to be the best investment (Hammer 1992, 175), and have been used successfully for both internal water management and controlling external water flows (Abney 2001; Miller 2001). Stoplogs are a little more costly than swivel pipes, but they are less vulnerable to beaver damage and debris blockage so they tend to be more effective over the long term. They are also the simplest structure to regulate water elevations; other structures tend to regulate water volumes (Hammer 1992, 170).

To keep the system self-maintaining to the greatest possible extent, natural flooding cycles should complement the management plan and be utilized as sources of water and creators of disturbance. Planning wetland size based on drought year water budgets is often recommended in order to ensure flexibility in terms of exact water requirements since there is great annual variability in water balances (Jarchow 2001). As a guideline, approximately one hectare of contributing watershed is required for each 0.4 ha of basin to retain standing water throughout the year (Galatowitsch and van der Valk 1994, 62).

5.2.2 Soils and nutrient cycles

Hydric soils are unique in their structure, composition, and chemical processes. Structural support is important for the wetland crops, as are the microbial communities supported by the soil (Hammer 1992; Owoputi et al. 2001). Soil structure also influences hydrology by its permeability, which determines the rate of seepage (Hammer 1992; Mitsch and Jorgensen 2004). The composition and chemical nature of the soil determine nutrient availability for the wetland crops (Hammer 1992; Mitsch and Gosselink 2000; Brady and Weil 2002; Kellogg et al. 2003) and also the interception of excess runoff nutrients from the adjacent farmland (Larson et al. 2000). Restoring appropriate soil conditions means:

a) ensuring a strong, impermeable subsurface structure overlain by topsoil,
b) maintaining successional stage of soil composition, and
c) promoting nutrient cycling through periodic wetting and drying (Table 5.2).

Recommendations

Soils with a history of hydric conditions are more likely to retain the desired structure: an impermeable subsurface layer topped with 40 - 60 cm of silt clay or loam (Hammer 1992, 166; Fern 2000, 127). If the hydraulic conductivity of the soil is too great, structural amendments will help the restoration project (Hammer 1992, 165). Compaction of subsurface layers is the simplest and cheapest method of sealing a basin as long as the clay content is sufficient (Hammer 1992, 165; Mitsch and Jorgensen 2004, 253); otherwise imported materials may have to be used, adding to the cost (Hammer 1992, 166; Mittag et al. 2001). However, a degree of seepage is important for filtration of water passing through the system

Table 5.2. A summary of alternatives for restoring wetland soils.

Goal	Alternative techniques	References
Soil structure	soil compaction (if clay content >10%)	Hammer 1992
	low permeability liner	Hammer 1992 Mittag et al. 2001
Soil composition	periodic drawdowns to decompose excess organic matter	Craft 2001
Nutrient cycling	tap into nutrient-rich source water (ie. runoff, tile drainage, stream floods)	Hammer 1992 Galatowitsch and van der Valk 1994 Morgan 1997 Middleton 1999 Mitsch and Gosselink 2000 Grootjans et al. 2002
	retain some plant litter on ground at all times	Mitsch and Gosselink 2000
	periodic drawdowns to increase nutrient availability	Craft 2001
	use dredged sediments as fertilizer	Denevan 2001 Miller 2001 Pokorny and Hauser 2002 Weinstein and Weishar 2002
	use lateral seepage to improve exiting water quality	Larson et al. 2000

(Larson et al. 2000) since water quality is a secondary objective of this design. Sealing or lining should be limited, therefore, and used only if absolutely necessary to retain adequate water storage. When digging, subsurface material can be used for embankments and topsoil saved for later planting.

While previously hydric soils are also quicker than upland soils to revert to wetland chemical processes and nutrient cycling after re-wetting (Mitsch and Jorgensen 2004, 182), the existence of proper water level controls aids greatly in the restoration of soil composition and nutrient cycling. Intermediate levels of organic matter are optimal for vegetation (Kellogg et al. 2003), and can be maintained by periodic drawdowns to increase decomposition rates and nutrient availability (Craft 2001, 119). A dynamic balance between organic matter accumulation and disturbance must be created for wetland vegetation communities to exist. Disturbance resets the successional stage and decomposes organic matter.

Surface runoff and flood pulses are considerable sources of nutrients for wetlands (Hammer 1992, 24; Middleton 1999; Mitsch and Gosselink 2000, 147; Grootjans et al. 2002; Mitsch and Jorgensen 2004, 178). Agricultural nutrients transported by runoff or floodwater can be recycled: the occasional drying event that allows oxygen briefly into the system can produce a surge of nutrients for quick plant uptake. Reflooding tends to draw the pH of soils towards neutral, which also helps increase nutrient availability (Mitsch and Gosselink 2000, 170; Craft 2001, 119). Some plant litter should remain on the ground during harvest in order to maintain nutrient cycling within the system (Mitsch and Gosselink 2000, 411). Dredged sediments from construction or ditch clearing can provide additional cost-effective fertilizer (Miller 2001; Pokorny and Hauser 2002; Weinstein and Weishar 2002).

5.2.3 Microorganism and invertebrate communities

The importance of restoring a strong community of microorganisms and invertebrates lies in their contribution to nutrient cycling and the wetland food chain. Microbes catalyze most chemical changes, thus controlling nutrient availability and energy for vegetative growth (Merritt et al. 1984; Hammer 1992, 71; Mitsch and Gosselink 2000, 110). As decomposers, microorganisms are important determinants of organic matter accumulation (Keddy 2000, 184; Craft 2001, 107). Microorganisms also provide a necessary base for the wetland food chain (Posey et al. 1997; Keddy 2000, 184; Gleason et al. 2003). While invertebrates also contribute to energy and nutrient cycles, their main functional value is to provide a strong food chain base (Hammer 1992, 71). Restoring a healthy soil community requires both successful initial colonization, and providing security from disturbance.

Table 5.3. A summary of alternatives for restoring wetland soil communities and invertebrate populations.

Goal	Alternative techniques	References
Microbial/invertebrate colonization	transfer soil/water plugs from nearby wetland	Brown et al. 1997 Brady et al. 2002
	rely on natural colonization after flooding	Hammer 1992 Posey et al. 1992 Kiritani 2000 Gleason et al. 2003
	maintain low initial reflooding levels	Keddy 2000
Security from disturbance	retain some vegetation and a mix of dry/wet sites at all times	Hammer 1992 Kiritani 2000

Recommendations

Wetland microorganism and invertebrate communities can be most simply restored by rewetting drained land. Flooding causes microbial communities to shift towards anaerobic species. Initially, invertebrates colonize from soil egg banks and then are transported aerially or by wildlife vectors. Transplanting plugs of soils and water from a nearby wetland is simple, and can greatly increase the rate and quality of colonization and promote a greater variety of taxa (Brown et al. 1997; Brady et al. 2002). Planting vegetation soon after hydrological restoration also helps establish microorganism population numbers (Hammer 1992, 92).

Water level controls can help maintain healthy soil communities (Hammer 1992, 31). Flooding should remain shallow initially in order to give benthic invertebrate communities time to develop (Keddy 2000, 187). When drawdowns are initiated, these should be managed in an alternating pattern in order to give aquatic organisms refuges to which to escape.

5.2.4 Vegetation

A designer wetland requires active vegetative restoration, and cannot rely on natural colonization. Active restoration involves deliberate seeding or planting of seedlings or rootstock of desired species. While there is greater cost investment in plants, planted wetlands typically reach productivity goals in a shorter time (Mitsch and Jorgensen 2004). Restoring wetland vegetation in a manner that will create a self-maintaining community of crop plants over the long term may be the most labour-intensive step. Vegetation restoration therefore only involves active planting; maintaining the community depends on the success of the biophysical restoration to create the appropriate conditions that select for the desired plant community.

Recommendations

Ten to fifteen species should be chosen for planting (Hammer 1992, 214). Manual planting of nursery-propagated rootstock may be the simplest and most feasible method, requires little equipment, and creates the least disturbance for soil and microorganism communities (Hammer 1992, 193; Romanowski 1998, 49; Mitsch and Gosselink 2000).

Table 5.4. A summary of alternatives for restoring wetland vegetation communities.

Goal	Alternative techniques	References
Active planting	broadcasting seed	Mitsch and Gosselink 2000
	transplanting emergents	Hammer 1992 Romanowski 1998 Mitsch and Gosselink 2000
	creating a founding community of 10-15 species to exclude unwanted colonizers	Hammer 1992 Keddy et al. 1998 Keddy 1999
	manual planting	Robb 2002
	mowing to reset succession	Keddy 2000

Once planted, the community can be maintained though simple manipulation of natural environmental filters rather than relying on constant labour throughout. Water level fluctuations can be used to initiate short drawdowns, decreasing the proportion of dominant emergents (Keddy 2000, 125). Water levels can also be kept periodically high to stop succession by woody species (Keddy 2000, 192). Mowing and harvesting create disturbances that also decrease the proportion of dominants, and open up the stand to community re-establishment (Keddy 2000, 91). Since wildlife habitat is one of the project goals, herbivory will be a part of this system. Therefore, enough plant material should be produced to allow for an average of 30% herbivore consumption within the crop harvest (Keddy 2000, 371).

Fluctuating water levels, disturbance, burial, and competition are all disturbance processes inherent in flooded farmland in coastal British Columbia: the same conditions that cause marsh or wet meadow plants to thrive (Keddy 2000, 54). Thus, the most feasible vegetation community for restoration would likely be a set of emergents combined with wet meadow species; these plants conform to natural disturbance regimes and provide wildlife habitat. This group of plants will be the founder community for the wetland. Planting a founder community sets the stage for re-establishment of the same plants, as long as competitive dominants are excluded though use of environmental filters. The flexibility in this system is created by allowing natural variations in the relative proportions of planted species from year to year. In a dry year, the species best adjusted to lower water levels may produce proportionally more biomass. In the next year, a herbivore might affect one of these species and its relative contribution to primary productivity will decrease. The wetland will be self-maintaining and flexible within the set of constraints defined by the chosen founder community.

5.2.5 Wildlife habitat

The provision of wildlife habitat is an important functional value of wetlands (Hammer 1992, 70), and often the least understood (Abney 2001). Creating wetlands for wildlife habitat appears to follow the motto, “If you build it, they will come.” If adequate habitat is provided, then the wildlife will stay (Hammer 1992, 227; Kiritani 2000). The most likely taxa to colonize a small wetland restored in an agricultural landscape include birds (particularly waterfowl), reptiles, amphibians, and small mammals (Kiritani 2000). Initial attractors for these species groups include the presence of food, the presence of standing water and shade cover, and adequate shelter. Restoring habitat involves creating shelter and food supplies that are available both spatially and temporally.

Table 5.5. A summary of alternatives for restoring wildlife habitat.

Goal	Alternative techniques	References
Spatial habitat provision	wetland area > 0.4 ha	Hudson 1983 Olson 1999
	hemi-marsh (50/50 ratio of open water to emergent vegetation)	Galatowitsch and van der Valk 1994 Abney 2001 Mitsch and Jorgensen 2004
	structural variety of vegetation types	Keddy 2000
Temporal habitat provision	synchronize food availability with migratory life cycles	Abney 2001

Recommendations

Adequate habitat includes a mix of vegetation types that provide food and shelter. A mix of half emergent vegetation and half open water seems to attract the greatest avian diversity (Galatowitsch and van der Valk 1994, 19; Abney 2001; Mitsch and Jorgensen 2004, 258). Emergent stands provide shelter and nesting grounds for many waterbirds, and food in the form of seeds and large tubers for ducks and small mammals (Hammer 1992, 83; Abney 2001). Emergents such as sedges with clumpy growth provide optimal shelter and wildlife benefits (Galatowitsch and van der Valk 1994, 20). Fluctuating water levels assure the persistence of an emergent community, and increase plant productivity and diversity; this is the greatest lure for birds (Abney 2001). Water levels should range from 5 to 15 cm (Abney 2001). Having individual wetland cells that can be drawn down alternately is good for amphibians as it maintains some patches of standing water year round (Keddy 2000, 137).

Gentle slopes and natural contours decrease predation (Galatowitsch and van der Valk 1994, 83).

Some deeper areas for submergents should also be provided, ideally from 60 to 75 cm in depth (Abney 2001), with less water fluctuation and some shaded areas. This should help in providing amphibian habitat and food for diving ducks as well. Finally, a woody component of shrubs or small trees provides some structural habitat that creates shelter and nesting or denning sites for birds and small mammals (Hammer 1992, 83; Abney 2001).

Maintaining adequate habitat diversity may be difficult in a small system. However, small habitat patches can still provide a measure of food or shelter for species, even if only on a seasonal basis. The labour is only in the design, as the patches would ideally be self-maintaining with proper management after construction.

5.3 Creating a form out of function

A general form to meet the identified functions can be derived from the discussion of restoration of the different wetland components: hydrology, soils, soil and vegetation communities, and wildlife habitat. A common feature that aids the restoration of all these components is the existence of precise and easily manipulatable water level controls that complement the natural flooding regime. A general form for a restored agricultural wetland is outlined in Table 5.6.

Table 5.6. General wetland form for a simple restoration project for crop production and wildlife habitat.

Component	Form
Hydrology	drainage ditches or tiles plugged/re-routed into a depression (natural, if possible, or excavated) with gentle slopes and contours
	water control structures for management of flooding and drawdowns: stoplogs controlling water levels between internal cells or pools, and/or to hold in water from flooding of adjacent stream channels
Soils	subsurface clay layer topped with 40-60 cm of silty clay or loam topsoil with intermediate levels of organic matter content
Soil communities	sections of transplanted topsoil and some plant litter left on wetland ground
Vegetation	marsh/wet meadow vegetation structure including 10-15 species of planted vegetation net guards for young plants
Wildlife	approximately half emergent stands and half open water plus a woody or structural component
	flooding levels ranging from 5-15 cm in shallow zones and up to 75 cm in at least one deep water area, partially shaded

Management of the restored wetland should be low-intensity; the use of environmental filters such as water levels and disturbance by harvesting and herbivory should create an appropriately functioning system for crops and wildlife habitat. Specific management techniques are discussed in Chapter 7.

5.4 Exploring ecological parameters: Effects on project feasibility

The biophysical setting of the area to be restored can affect the feasibility of a project at that site, either simplifying or complicating the restoration process. Ecological parameters with potential impacts on project feasibility are given in Table 5.7, along with site-specific modifications that may be initiated in order to overcome the limitations. Recognition of threats can lead to timely use of mitigation measures and a greater probability of restoration success.

In addition to the biophysical constraints, some regulatory constraints may apply to a site. Different regions enforce different regulations applicable to water channel modifications. In British Columbia, most water regulations deal with fish habitat or potential fish habitat. Here, the distinction is made between constructed ditches and streams. These two categories are controlled by different Acts. Constructed ditches are not identified under the *Water Act* but are regulated by the federal *Fisheries Act* if the ditch directly or indirectly supports fish production (BC Ministry of Agriculture, Food and Fisheries 2001). Constructed ditches often flow into streams. Streams fall under both the *Water Act* and the *Fisheries Act*, and modifications are thus limited by a greater number of restrictions (BC Ministry of Agriculture, Food and Fisheries 2001). If the stream in question is designated salmon habitat, obtaining permits for any water control structures in the area may be a challenge. Depending on the strictness of regulations in the district, permits required may be a strong force in dictating the modifications that are feasible.

Wetland restoration in marginal farmland is the first step towards creating an integrated agricultural wetland. Deciding which crops to plant, according to wetland ecological objectives but also to meet economic needs, is the second stage.

Table 5.7. Ecological parameters affecting simplicity and feasibility of wetland restoration and suggested mitigation measures.

Parameter	Limitation	Suggested solutions	References
Physical site constraints	raised topography	• use any existing basins to reduce excavation costs (expensive)	Mittag et al. 2001 Perlea et al. 2001
	soil contamination	• C4 plants are less susceptible to soil toxins • avoid sites with heavy metal deposits	Mitsch and Gosselink 2000 Mitsch and Jorgensen 2004
Hydrological constraints	groundwater discharge site	• fill deep ditches instead of blocking to decrease evaporation and raise water table	Galatowitsch and van der Valk 1994 Grootjans et al. 2002
	susceptibility to sudden storms/flash floods	• sediment retention pond • emergency spillway	Hammer 1992
	long dry season	• minimize evaporation by planting emergents upwind of any open water	Hammer 1992
		• plan for additional water sources (return irrigation water, diversion berms)	Hammer 1992 Mittag et al. 2001
	pesticides in runoff water	• alternate flooding and drawdowns to increase efficiency of microbial breakdown • minimize pesticide use in catchment	Kiritani 2000
	heavy sedimentation (>0.5 cm accumulation per year)	• forebay or sediment retention pond • bank stabilization • erosion control practices on surrounding farmland • plant less susceptible species (those with larger seeds or tubers)	Martin and Hartman 1987 Hammer 1992 Mittag et al. 2001 Gleason et al. 2003
Biological constraints	high herbivory (>30% mortality)	• protective netting over new plants • alternating enclosures	Middleton 1999 Keddy 2000 Mitsch and Gosselink 2000 Robb 2002
	beaver/muskrat presence	• minimize burrowing possibilities	Hammer 1992

6.0 Economics and ecology: A discussion on wetland crops for temperate climates

6.1 Crop choices: Criteria for success

The wetland crops should be able to provide sufficient economic returns to make the restoration design desirable from a farmer's perspective, while still being ecologically sustainable.

6.1.1 Characterization of design criteria

Based on the results of the interviews, a set of criteria was created in order to provide a basis for decision-making when creating the design. Each crop under consideration could then be evaluated according to the same criteria.

To meet project goals of creating wildlife habitat, providing a source of revenue for the farmer, and being feasible at the same time, a triad of criteria was developed: ecological, economical, and managerial (Table 6.1).

Table 6.1. Characterization of criteria for crop decisions for design.

Ecological criteria	Economic criteria	Management criteria
Appropriateness to water/soil conditions	Investment cost of seed/plant	Access to seed/plants
Invasiveness	Operational cost – labour hours for planting, maintenance, harvest	Physical resources required
Wildlife value	Operational costs – equipment cost for investment, use, maintenance	Expertise required
Contribution to global biodiversity	Money made per unit area [sale price ($/kilo) x productivity (kilos/ha)]	Ability for mechanical planting/harvest
Timing, duration, and degree of disturbance – Planting and maintenance	Established market	Regulatory restrictions
Timing, duration, and degree of disturbance – harvest	Potential market	Susceptibility to pests
Hardiness	Potential for ancillary farm savings	Flexibility in rotations
Water quality impacts	Amortization	Storage requirements
Risk of attracting pests or disease		

Both financial viability and ecological sustainability were mentioned regularly by participants as part of successful farming (Figure 4.1). While financial success is not necessarily defined as profit, the farmer must at least recoup any investment in the project. The local food producers interviewed for this study took financial and practical considerations into account much more than ecological considerations when making production choices (Figure 4.2); this is logical, considering the crops represent the financial assets of the farm. However, the prominence of ecological sustainability within the definition of success described by participants (Figure 4.1) validates bringing ecological considerations to the next level of farm planning, crop choice. Equal weight is therefore assigned to both ecological and economical criteria.

Ecological sustainability involves planting crops that are suitable to the natural conditions of seasonal flooding experienced in the area. It also includes crop diversity, an important component in planning a cropping pattern. Maintaining crop diversity means that invasive or aggressive species must be excluded, at the risk of their creating a monotypic stand. The goal, ideally, is to create a system with ecological integrity (see section 2.2). This concept means that the health of the ecosystem, its resiliency, and its self-organizational capacity should not be compromised by using the environment for crops. Minimal disturbance and reliance on ecological functions and restraints should help protect ecosystem health, while increasing the diversity of both crops and associated animal biodiversity should improve resiliency. The ability of a system to self-organize also relies on the diversity of components (Kay and Schneider 1994; Lister and Kay 2000, 5). Thus, while the wetland is designed with chosen species in mind, the proportions or the success of each species may vary from year to year depending on the environmental conditions. In order to meet the restoration goals, the new agricultural system must provide habitat for wetland species, especially those identified as locally or globally significant.

The primary considerations when choosing crops, according to the food producers interviewed, were the marketability of the crop and the labour requirements (Figure 4.2). Successful marketing strategies identified by participants were niche marketing of specialty crops with sales conducted directly with customers, at farmers' markets, or to restaurants (Figure 4.8). Potential crops for these kinds of sales are targeted in the analysis.

Labour requirements and other practical considerations that would make the project feasible are recognized under the third criterion, management. Under this heading, physical limitations are practical constraints that influence choice of crops. The limitations discussed in local farmers' interviews (Figure 4.2) include physical constraints imposed by the land, constrictive regulations, and equipment required for production. The main problems experienced by participants (Figure 4.7) are also taken into account under the management criteria: weeds, insects and disease.

6.1.2 *Industry analysis: Current situation and outlook for crops in British Columbia*

A brief overview of the agriculture industry in British Columbia outlined in provincial publications gives context to a crop plan, and aids in indicating the types of crops best to target from an economic standpoint. The British Columbia Ministry of Agriculture, Food and Fisheries (BCMAFF) keeps detailed profiles of its industry sectors, including the number of growers in the province, their locations, and farm sizes. Industry sectors are outlined from the perspective of the province as well as the perspectives of local food producers (Table 6.2).

For the most part, the views of local food producers interviewed were in line with the government publications. A greater number of vegetables were typically described as more economically successful than fruits, while some wild plants were also identified as successful crops (Figure 4.3). Vegetables are a competitive market, however, and either labour-intensive or technology-intensive depending on the target market niche (organic versus greenhouse-grown crops). The berry and fruit industry is large and successful in British Columbia, but individual farmers often suffer from problems with market saturation, pests, and high labour demands. The ornamentals sector is growing, requiring little initial investment but also limited by high maintenance costs and consumer demand. Grain and forage crops are not lucrative investments for the coastal area, as land prices are high and the climate less favourable than inland. The specialty crops sector experiences the least regulation and little competition; most sales are direct, and producers tend to be small. Little knowledge exists for many crops under this heading, and marketing and farm reputation are critical aspects of success.

This brief look at the agriculture sector in British Columbia reinforces the comments of many of the local food producers interviewed: the way for a small producer to gain an income is by targeting a specialty market niche. Competition with high-technology, large-scale, or high-intensity production is too ingrained for a grower relying on naturalized land to overcome on the same playing field. The advantages of naturalized growing must be brought to bear on the market niche of the chosen crops. Adding value to products, by reputation (organic, agrotourism), by convenience packaging (salad mixes), or by specialization (new variety, ethnic or health product) maximizes economic benefits for the farmer in all agricultural sectors.

Table 6.2. Current market situation and outlook for agricultural industry sectors in British Columbia.

Industry sector	Participant commentary	Industry commentary	References
Vegetables	salad greens, carrots, beans, potatoes, and squash most successful	• potatoes, carrots, corn, lettuce, squash, cabbage, broccoli, and beans most successful • greenhouse-dominated • niche markets most successful for field growers • labour and competition main challenges	BCMAFF 2003a BCMAFF 2003c
Berries and fruit	strawberries, apples, raspberries, blackberries, blueberries and cranberries most successful	• primary berry crops are blueberries, cranberries, raspberries and strawberries • primary fruit crops are apples, pears, cherries and peaches • currently thriving, but economy tends to follow boom-bust pattern • main niche markets are for new varieties or agrotourism • main challenges are threat of market saturation, competition, labour, disease and marketing	Sweeney and Villanueva 2001a Sweeney and Villanueva 2001b BCMAFF 2003d BCMAFF a BCMAFF f
Ornamentals	flowers (blue iris), water garden plants, trees (willow, poplar) a success	• floriculture the most currently successful enterprise • a growing industry • low production costs and low capital investment • difficulties include unpredictable supply/demand, pest control, and marketing	Koch 1996 BCMAFF 2003b BCMAFF 2003e
Grains and forage	some specialty grains (health foods) successful	• dominated by industry in the interior rangelands • low prices, can be land-intensive	BCMAFF b BCMAFF c
Specialty crops	markets good for many fresh and dried herbs	• herbs are the most valuable product • increasing demand and growing industry • most grown on small farms and involve value added • quality and grower reputation important price determinants • few restrictions, low competition • difficulties include experimentation (crops are little known), marketing	Curtis et al. 2001 Oliver 2001 BCMAFF 2003c BCMAFF d BCMAFF e

6.1.3 Criteria analysis of crops along a wetland ecological gradient

The choice of crops for a wetland restoration design requires an evaluation of the ideas suggested during the interviews and discussed in follow-up sessions. While many of the crops debated with participants must be discarded because of incompatibility with one or more design goals, crops with greater potential are examined here with respect to the design criteria developed previously. A final planting design can be narrowed down from this point.

The interviews and follow-up discussions with participants helped identify the crop ideas that would be considered practical for farmers in coastal British Columbia. Based on the results of the follow-up discussion sessions that considered design possibilities, the most popular wetland crop plants are:

1) blueberries,
2) salad blends, wild iris,
3) mint, watercress, sedge, crayfish, and mulberry.

This selection represents a wide spectrum of crop types: vegetables (salad blends, watercress), fruit (blueberries, mulberry), ornamentals (irises), grains and forage (irises, sedges), herbs and specialty crops (mint) and aquaculture (crayfish). Unfortunately, a combination of all these crops is not possible, as the crops have quite different ecological needs which are irreconcilable in the same environment. Here, a dichotomy arises for a potential crop design: an open, wet meadow/marsh structure or a shrub- and tree-based swamp setting. A shrub swamp could incorporate berries, fruit crops and nursery trees, while a wet meadow/marsh complex might be used for salad blends, sedges, and watercress. Growing an enterprise of berries and fruit crops would require more time investment, but the returns on both crop sales and habitat value could be worth the time. Ecologically, a seasonally flooded wetland could provide the appropriate conditions, provided flooding didn't extend too long into the growing season. Otherwise, farmland areas with a greater degree of disturbance and unpredictable, extended floods might more feasibly produce marsh and wet meadow specialty salads and herbs. A further examination of the ecology and economics of plants for these environments gives an indication of which approach may be simpler and more feasible to realize given the current situation in coastal British Columbia.

A typical agricultural approach is to discuss the crops by their industry sector, as in the previous section. However, this discussion of potential crops will loosely follow ecological boundaries rather than sector boundaries. The intent is to place the emphasis on ecological compatibility and appropriate habitat restoration. The generic wetland gradient (Figure 4.9) set up for the follow-up interview sessions forms the template for this discussion.

The simplest and most feasible wetland restoration for most farm sites is to create a marsh environment (see Chapter 5). Many crops with potential for wetland cultivation are short plant species that prefer the damp environment of stream or wetland banks (Table 4.2). Crops suggested by participants include mints, arrowroot, and wild herbs (violets, nodding wild onion, anise hyssop), while suggestions from the literature include alfalfa and clover. Neither alfalfa nor clover was popular, and the literature did not indicate that either brings in significant revenues or provides critical habitat. Beyond the initial suggestion, arrowroot turned out to be an unknown crop among participants. Only two participants had heard of it being sold in local Japanese and Asian markets (Switzer, Wheeler, personal communication, 2003). The plant may prefer a warmer climatic setting. Mints and wild herbs show greater potential. An advantage of growing herbs is that they are lightweight, easy to store, and easy to transport when dried (Miller 1988, 19). This makes the location of the farm relative to the market less critical.

Grading from streambanks into the ecological niche of saturated soils, mud flats and areas of low seasonal flooding, a different set of plants with widespread uses is considered (Table 4.3). The yellow iris, *Iris pseudacorus*, is a plant that was popular among participants for its seed. It spreads aggressively in areas of saturated soil. Blue iris is often planted as well; it is sold mostly as a cut flower or for the nursery trade rather than for seed. Irises tend to be strong sellers for targeting farmers' markets (Switzer, personal communication, 2003). Millet was mentioned in the literature as a grain species for wet meadows (Missouri Department of Conservation 2004a), but it was not popular and was considered invasive in some areas (Tattam, personal communication, 2003). On the other hand, reed canary grass was quite popular, being a common forage crop for the Cowichan Valley (Haddow, Wiebe, personal communication, 2003). Other native wet meadow species such as sweetflag, *Acorus calamus*, may thrive in this ecological niche. Some of these may be valuable and novel additions to a salad or spice blend, especially if catering to a specialty market. Galingale, *Cyperus longus*, was discovered while researching wild herbs promoted by participants and considered as a potential herb and salad crop for saturated soils.

Moving still deeper from mud flats into shallow standing water, there are still plants that can be sold as a salad and spice blend: watercress, water chestnut, wasabi, duckweed, and smartweed were discussed with participants (Table 4.4). The water chestnut, *Trapa natans*, and Chinese water chestnut, *Eleocharis dulcis*, were previously suggested by participants but later considered to have too low a market value and to be too tender even for the British Columbian climate (Fern 2000, 128; Haddow, Wheeler, personal communication, 2003). Both duckweed and smartweed were included for discussion from the literature, each getting a moderate response from participants. These plants may arrive in a wetland as volunteers without intentional planting; therefore their use as potential crops was discussed as a way of making use of "weeds" that might come up. Duckweed, *Wolffia arrhiza*, is cultivated as a nutritious vegetable in Laos, Thailand, and Burma and tastes like sweet cabbage when cooked (Fern 2000, 128). Smartweed may additionally be sold as a spice or packaged condiment. Native peoples such as the Cherokee made use of this plant in the past, and ate it boiled or in spicy salads (Foucher, personal communication, 2003). Other emergents growing in a seasonally flooded to shallow marsh setting were considered for their grains or tubers: sedge, cattail, wild rice, domestic rice, arrowhead, bulrush, and common reed (Table 4.4). The most enthusiastic response from participants was for the slough sedge, *Carex obnupta*, and cattail, *Typha angustifolia*. *C. obnupta* was described as a successful grain crop by one experimental farmer because its seed is so easy to harvest (Foucher, personal communication, 2003). Cultivated rice, *Oryza sativa*, was mentioned during the initial interviews as people have grown rice in British Columbia (Kiewitz, personal communication, 2003). It was not discussed further, however, as the market is already saturated with large operations and it is questionable whether it could provide income to a small, naturalized wetland grower without creating involved dikes and water control structures (Keenan, Kiewitz, personal communication, 2003). Large commercial rice production may not even be economically feasible without government subsidy, because of increasing production costs and disease outbreaks (Musacchio and Coulson 2001). Bulrush and common reed each received a moderate but not enthusiastic response from participants, having most of the same edible properties as cattail without its versatility and palatability. Like cattail, the shoots, pollen, seeds and rootstalk of the bulrushes *Scirpus validus* and *S. acutus* are edible (Peterson 1977, 230). The common reed, *Phragmites australis*, has edible roots and shoots and provides good wildlife habitat, but it can also be invasive in many areas (Fern 2000, 134). Both *Scirpus* and *Phragmites* are extremely aggressive colonizers (Hammer 1992, 213). These two crops were therefore left out of further design work.

Growing more conventional crops on raised beds within the wetland was discussed (Table 4.5), but would be less ecologically sustainable (because of tilling and cultivation practices) and provide smaller economic returns due to high competition in conventional vegetable, fruit, and even ornamentals industries.

Aquaculture crops were discussed (Table 4.6), but the enterprise was generally considered to have greater challenges than benefits for growing in a naturalized system. High maintenance, regulations, expertise, and consistency of water supply restrict the venture (Table 4.10). Similarly, submergent and floating plants (Table 4.7) may colonize deeper pond areas or may be planted for wildlife purposes, but would not likely produce an economically viable crop because of insufficient summer water on many British Columbian farmlands.

Hydrophilic bank plants such as some berry bushes and fruit-bearing trees were discussed with participants for drier sites, banks, or swamp wetlands (Table 4.9). While blueberry, raspberry, and cranberry were popular, other suggestions were dropped from the design process. Blackberry was suggested as an easy crop as it easily introduces itself into many areas and there is potential to make use of the fruit (Keenan, personal communication, 2003). However, blackberry can become quite rampant and would have to be controlled by some means (Hammer 1992, 210; Kelhammer, personal communication, 2003) so deliberate planting is not recommended. Salmonberry was dismissed because of its popularity with wild pickers, and Juneberry and rowanberry were dismissed as unfamiliar despite its popularity in the wild plant literature. Like salmonberry, Juneberry was considered easier to harvest from the wild than to cultivate (Haddow, Wiebe, personal communication, 2003).

Finally, a system of swamp trees with an understory of herbs and mushrooms was discussed. This is a more agroforestry-style of wetland crops that may or may not be appropriate, depending highly on the natural conditions of the site being restored. This is a higher-investment, longer-term project for which the risk may not be economically feasible for many farmers.

A final selection of twenty crops showing the greatest potential for wetland agriculture were examined in greater detail. Table 6.3 gives a summary of the main benefits and challenges coming from the discussion of these crops. Most of these crops have detailed literature available regarding their ecologies and often on their ethnobotanical uses. Only the details most relevant to design goals are presented in this discussion; interested readers can refer to the cited literature for further information. The literature and information from participants is often sparse with respect to the economics and cultivation of these wetland plants from an agricultural perspective, as little experimental work has been done to date for some of these species.

Table 6.3. Main reasons for including or excluding crop species from an integrated wetland agriculture design, according to ecological, economic, and managerial criteria.

	Crop	Major reasons for: Including	Major reasons for: Excluding	Market niche	References
Wetland banks (*M. aquatica* at ditch channel)	Mint (*Mentha aquatica*, *M. spicata*)	• high popularity • grow readily • stabilize banks • deter rodents	• species that are used for their oil (eg. M. piperita), as oil quality can't be guaranteed	• herb/specialty market • salad mix	Peterson 1977 Greenwood 1995 Middleton 1999 Water Mint 2000 Cronk and Fennessy 2001 Mints 2002
	Violet (*Viola glabella*)	• good attractors of beneficial insects	• require shady conditions	• salad mix	Albert 2002 Fern 2002 Hebda
	Nodding wild onion (*Allium cernuum*)	• many edible parts • low maintenance • repels rodents and insects	• may need drier conditions • intolerant of competition	• salad mix • spice • vegetable (onion bulb)	Fern 2002 Hebda Native Plants
	Anise hyssop (*Agastache foeniculum*)	• appropriate to bankside conditions • attracts wildlife • scored high in new salad taste tests (identified as new potential crop) • established dried flower market • takes up nitrogen before entering water	• tall for a bank plant • can be outcompeted when young • can be predated by slugs, beetles	• salad mix • floriculture	Anise Hyssop 2001 Fern 2002 Thomas 2004

	Crop	Major reasons for:		Market niche	References
		Including	Excluding		
Mudflats, shallow flooding	Yellow iris (*Iris pseudacorus*)	• can withstand fluctuating flooding • clumpy growth provides good habitat • low maintenance • high popularity • coffee a popular market niche	• invasive alien in some areas of British Columbia	• coffee substitute (specialty market)	Hammer 1992 Thunhorst 1993 White et al. 1993 Middleton 1999 Mitsch and Gosselink 2000 Ramey 2001 Cronk and Fennessy 2001
	Blue iris (*Iris versicolor*)	• high popularity	• no known edible uses	• floriculture	Hammer 1992 Thunhorst 1993 Middleton 1999 Cronk and Fennessy 2001
	Reed canary grass (*Phalaris arundinacea*)	• good under fluctuating water conditions • medium established market value	• major invasive plant • not recommended for restoration projects (takes over)	• forage	Cariboo 1992 Hammer 1992 Thunhorst 1993 White et al. 1993
	Sweetflag (*Acorus calamus* var. *americanus*)	• native plant • long list of edible uses • identified as new potential crop (some cultivation already in Europe, Asia) • soil stabilizer • anti-fungal properties	• no domestic market yet (regulations) • high rodent predation on root • little known	• salad mix • spice (specialty market)	Peterson 1977 Erichsen-Brown 1979 Hammer 1992 Thunhorst 1993 Motley 1994 Trenary 1997 Small and Catling 1999 Fern 2000 Keddy 2000 Mitsch and Gosselink 2000 Cronk and Fennessy 2001
	Galingale (*Cyperus longus*)	• adapted to unpredictable conditions • potential for creative marketing	• little known	• spice (specialty market)	Hammer 1992 Fern 2000 Cronk and Fennessy 2001 Cyperus 2004
	Cranberry (*Vaccinium macrocarpon*)	• high demand	• high competition from large growers • high investment costs • long time to develop a crop • high water regulation demands • easily outcompeted	• berry	Thunhorst 1993 Small and Catling 1999 Fittante

	Crop	Major reasons for: Including	Excluding	Market niche	References
Ditch channels	Watercress (*Nasturtium officinale*)	• high popularity • strong market • easy to grow and propagate	• requires containing	• salad mix	Peterson 1977 Babadoost 1989 Forey and Fitzsimons 1989 Hammer 1992 Thunhorst 1993 Fern 2000
	Wasabi (*Wasabia japonica*)	• high market value	• temperamental, needs specific conditions for growth • requires shady conditions	• spice (specialty market)	Fern 2000
Shallow water	Sedge (eg. Slough sedge, *Carex obnupta*)	• high popularity • good wildlife value • important marsh component • easy to harvest	• sensitive to siltation • tiny market	• specialty grain (health food)	Furlong and Pill 1980 Hammer 1992 Thunhorst 1993 Cronk and Fennessy 2001 Streamside Native Plants 2001 Hansen 2003a Hansen 2003b
	Cattail (*Typha* spp.)	• very adaptable • long list of edible uses	• aggressive competitor	• specialty vegetable • craft industry	Peterson 1977 Hammer 1992 Thunhorst 1993 Fern 2000 Mitsch and Jorgensen 2004
	Wild rice (*Zizania aquatica*)	• high premium prices	• requires specific conditions • high labour and harvesting costs • high competition from large growers	• grain	Fern 2000 Mitsch and Gosselink 2000
	Arrowhead (*Sagittaria latifolia*)	• adapted to fluctuating water conditions • resilient • high wildlife value • long list of edible uses	• ducks and muskrat also enjoy eating the tubers	• tuber (specialty vegetable)	Petersen 1977 Erichsen-Brown 1979 Furlong and Pill 1980 Forey and Fitzsimons 1989 Hammer 1992 Thunhorst 1993 Fern 2000 Mitsch and Gosselink 2000 Cronk and Fennessy 2001 Streamside Native Plants 2001
	Crayfish (*Procambarus clarkii*)	• a part of natural environment	• little profits	• aquaculture	Mitsch and Gossselink 2000

	Crop	Major reasons for:		Market niche	References
		Including	Excluding		
Banks	Blueberry (*Vaccinium* spp.)	• most popular crop choice • strong market	• requires bog conditions • high labour and harvesting costs • long time to develop a crop • heavy bird predation	• berry	Thunhorst 1993 Lalonde and Hughes-Games 1997 Bilodeau 1998 BCMAFF 2001 Blueberries
	Raspberry (*Rubus* spp.)	• strong market	• susceptible to disease • high labour and harvesting costs	• berry	
	Elderberry (eg. Red elderberry, *Sambucus racemosa*)	• very hardy • high wildlife value • potential lure crop	• small market	• berry • flower (specialty crop)	Miller 1988 Thunhorst 1993 Schooley 1995 Fern 2000 Hebda

6.2. Choosing a planting assembly

From these crops a small selection of plants should be chosen to best fit the ecological characteristics of the site. The plants chosen should prefer the same soil characteristics and water regime, but complement rather than compete with each other. Thus, choosing plants of similar growth rates but different height and structure would be beneficial. Plants grouped together should ideally have the same harvestable parts, or at least timing of harvest. This will minimize damage and maximize yield per labour effort. A small assemblage of plants for each major habitat type can also maximize wildlife value of the restored land. The choice of plant assembly is informed by the previous discussions: the general wetland form for simple farmland restoration (Table 5.6), design priorities identified by participants (Table 4.10, Figure 4.10), the industry analysis (section 6.1.2), and the criteria analysis of the specific plants (section 6.1.3).

Conforming to a simple and feasible restoration plan

Typically, a manageable level of diversity includes about 10 to 15 species of plants for a shallow water site (see Chapter 5). For a restored farm wetland in coastal British Columbia, most plants should be emergents as these conform to natural disturbance regimes and provide wildlife habitat. At least one woody plant should be included to provide structure and partial shade. This group of plants will be the founder community for the wetland.

Conforming to priorities of local food producers

When different angles for approaching wetland farming were suggested to participants, both agrotourism and marketing native plants received positive feedback (Table 4.10). Targeting agrotourism as revenue requires having something worth seeing or doing on the farm, such as bird-watching or pick-your-own operations. Selling native plants successfully requires crops amenable to creative marketing strategies, such as historical or native uses. Creative marketing may include provision of recipes or sample foods.

A compromise between predictability and flexibility of the crop produced is probably the best option for small producers marketing locally (Figure 4.10). This means choosing some crops with a guaranteed market combined with higher-risk crops requiring little to no management.

Targeting market niches identified by industry analysis

New markets with low existing competition may be the best target for small producers with diverse product. Specialty crops are a growing sector of British Columbian agriculture, with few regulations or quotas. Premium prices may be obtained by emphasizing a wildlife-friendly product to increase farm reputation; by providing pre-packaged mixes of fresh salads or herbs; by meeting a unique ethnic or health goal; or providing a novel variety of product.

Defining crop choices based on the criteria analysis

The twenty potential crops discussed are narrowed down to a final choice of nine crops (Table 6.4). The decision to go with a founding community of nine planted crops is based on the assumption that others will colonize on their own accord. Many of the plants discussed are often found growing naturally on flooded sites, and may colonize readily depending on their dispersal characteristics and presence in the area. Plants with crop potential that may colonize include violets, nodding wild onion, yellow iris, duckweed, and smartweed. These were therefore not included for deliberate planting. Submergent plants will also be left to naturally colonize deeper areas. Other natural colonizers, if not invasive, may also have uses as wild edible plants that may be marketed with the planted crops.

The crop selection forms a wet meadow and marsh ecology, with elderberry as a token structural component. It is likely that elderberry will be able to provide for home consumption only, as birds tend to eat most of a crop unless it is protected in some way. Since one of the

Table 6.4. Wetland crop selection on an ecological gradient from banks to water channel.

Crop	Market		Marketing angle	Added value
	Guaranteed	High risk		
Elderberry	-	-	native plant	home use; can also sell fruit jams, wines or elderflowers
Anise hyssop	x (dried flower)		native plant	convenience packaging - salad mix
Spearmint	x		popular product	convenience packaging - salad mix - spice mix
Aquatic mint	x		native plant, popular product	convenience packaging - salad mix - spice mix
Galingale		x	native plant, historical use	specialty product - ancient spice
Slough sedge		x	native plant, health product	specialty product - gluten-free grain alternative
Sweetflag		x	native plant	convenience packaging - salad mix - spice mix
Arrowhead		x	native plant, agrotourism	specialty product - potato alternative
Watercress	x		popular product, popular product	convenience packaging - salad mix - spice mix

objectives for the wetland design is provision of wildlife habitat, netting the berries would be counterproductive. If the birds preferentially feed on the elderberry, other more lucrative crops may be left alone. Elderberry is hardy, easy to maintain, and provides an important wildlife value.

While other combinations of crops may be more appealing to an individual producer, this selection of crops gives a good diversity of product and of wildlife habitat. A balance is struck between crops that are both high-risk and low maintenance on the one hand, and crops such as herbs with a guaranteed market on the other.

The main marketing angle for this design is native plants, thought to be the most realistic approach by producers interviewed (Table 4.10). Bird- and wildlife-watching may still provide an outlet for agrotourism, or ecology education visits. Digging for arrowhead tubers with one's toes is described in the literature as the traditional harvesting method; this might provide an interesting twist on a "pick-your-own" operation for children!

This crop design puts an emphasis on salad mixes and spices. Salad blends were mentioned next to blueberries as the most popular crop among participants. Fresh salad mixes are successful sellers for local food producers as they do not transport well and are therefore often bought locally (Haddow, Kiewitz, personal communication, 2003). Because of their delicacy in transport, they are also high value (Kiewitz, personal communication, 2003). A salad mix could feasibly be made of wild greens, with additions of herbs and spices. This provides strong added value: a specialization of product, convenience packaging, and advertisement of the use of native plants and wildlife-friendly farm practices.

7.0 Structure and strategy: Proposed design for an integrated agricultural wetland

A restoration design integrating crops and habitat in flooded farmland was generated from the discussion of study results. A potential structure is suggested and a management strategy outlined.

7.1 Structural design: A new spin on old structures

The restoration design builds on existing drainage structures present on many farms in coastal British Columbia (Figure 7.1). Thus, the commitment in terms of installing a complex system is minimized. The design involves a series of modifications to bring water back to the land, and also taps into the nutrient-rich water source from seasonal stream flooding so common in coastal British Columbia. Seasonal water fluctuations are utilized in order to mimic a natural wetland as closely as possible.

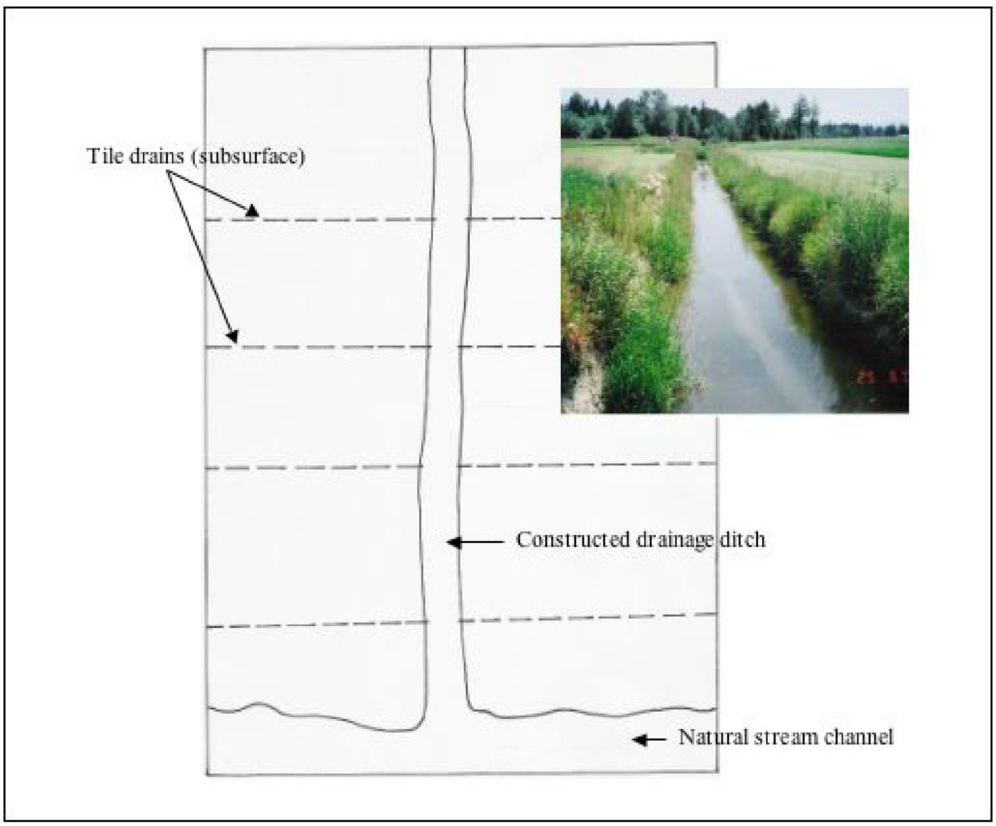

Figure 7.1. A typical drainage plan in which parallel subsurface tile drains discharge into a surface collector ditch.

Landscape requisites include a set of parallel tile drains (subsurface perforated pipes) through which water is released into a channelized drainage ditch. These surface ditches typically terminate in an outlet to a natural stream; it is near this outlet that the restoration design is planned. The structural design for the restoration project is pictured in Figure 7.2a and 7.2b.

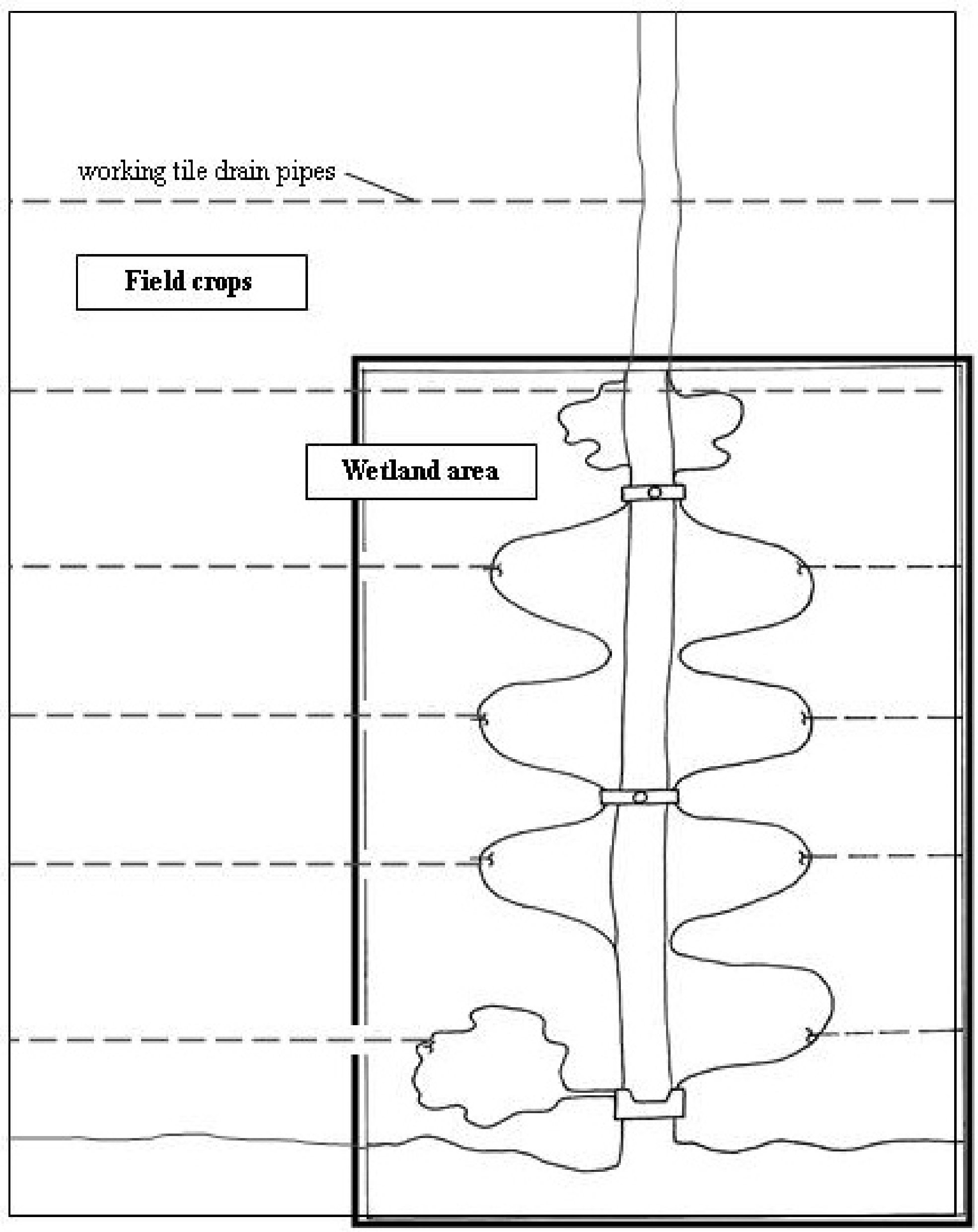

Figure 7.2a. Pictorial representation of the wetland design as part of the farm landscape.

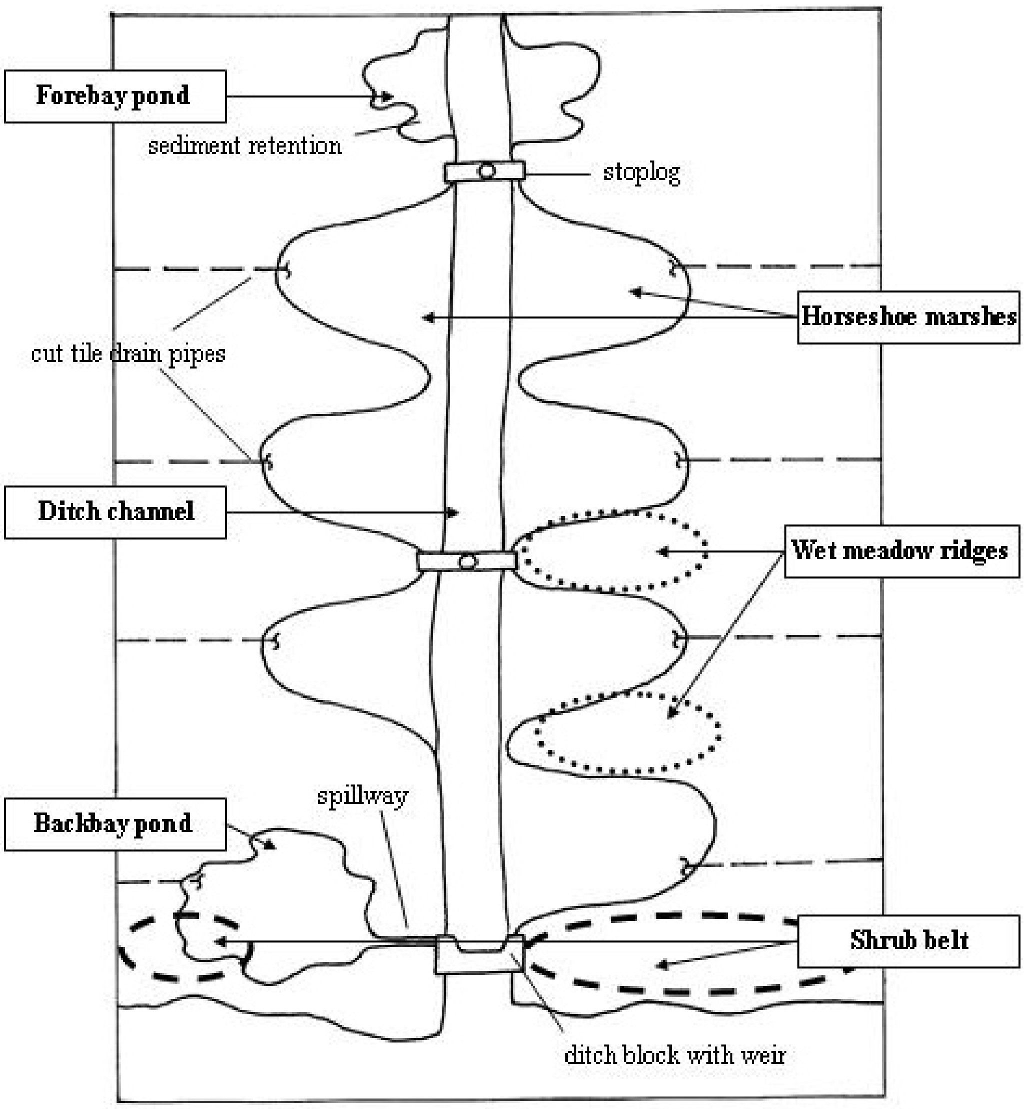

Figure 7.2b. Pictorial diagram of the wetland complex, associated structures, and habitat areas.

A ditch block is placed in the ditch near its outlet to a natural stream. A weir in the block allows the stream to backwater over the weir during winter flooding, adding supplemental water to the wetland area. When water levels in the stream drop in the spring, the wetland is disconnected from the creek by the ditch block and water is retained behind the barrier for the dry season. This type of structure was successful in several riparian wetland restoration projects (Mauchamp et al. 2002; Mitsch and Jorgensen 2004, 149). In addition to the ditch plug, tile drain lines are cut and removed, and shallow, horseshoe-shaped depressions created at the mouth of each. The result is a set of curved marsh cells alternating with raised soil beds along the ditch sides. Stoplogs are placed within the ditch channel in order to gain greater water level control between the marsh cells.

The intention is to create a habitat similar to that created by a beaver blockage: inundated by seasonal flooding and maintained in an early successional marsh stage by disturbance dynamics caused by water level fluctuation and plant harvesting. Excavation, diking, and control structures are kept to a minimum to keep costs down and minimize the potential for muskrat damage.

The design thus creates five integrated habitats:

a) horseshoe marshes,
b) wet meadow ridges,
c) ditch channel,
d) shrub belt, and
e) forebay and backbay ponds.

The first three are planted in commercial crops, the shrub belt may be harvestable on a home-scale basis, and the ponds are only managed moderately as plant nurseries. Each area has a different crop and habitat function.

7.1.1 Horseshoe marshes

The first habitat is the curved series of marshland cells, cut into the banks of the drainage ditch and fed by cut tile drains as well as surface water coming down the collector ditch. Horseshoe wetlands were originally designed to treat point-source pollution coming from drainage tiles and entering a watercourse. They were thus designed as semi-circular excavations at the mouth of each drain tile, dug into a buffer strip adjacent to the stream into which the tiles were emptying (Peterson et al. 1992, 300). The excavations expose the drainage tile and remove the last section of pipe, allowing the draining water to flow across a section of wetland before coming in contact with the stream (Peterson et al. 1992, 300). The original horseshoe wetland is therefore designed to fit within the 10 m stream buffer zone recommended for treating agricultural runoff. Recommended sizing is 8 m back from the stream, leaving a 2 m strip between the farmer's field and the wetland, and 10 m wide (Peterson et al. 1992, 300).

In this design, the primary function of the horseshoe wetlands is to provide a growing substrate for emergent marsh plants and create a marsh habitat. The main concern, therefore, is providing proper hydrological conditions that will allow these plants to thrive; not simply fitting within a 10 m buffer zone.

Water levels are low, and allowed to fluctuate with the seasons between depths of about 15 to 60 cm. The stoplogs allow a minimum level to be maintained or complete drawdowns to be initiated if required. The main habitat value of these marsh cells is to provide feeding grounds for dabbling ducks in the spring and summer (Olson 1999; Abney 2001), winter feeding for Trumpeter swans (Galatowitsch and van der Valk 1994, 28; Keenan, personal communication, 2003), and spring nesting grounds for small birds (Galatowitsch and van der Valk 1994, 20). Sedges in particular provide a valuable food source for dabbling ducks (eg. Mallard, pintail, gadwall, teal, widgeon) (Missouri Department of Conservation 1994a; Olson 1999). The clumpy growth provided by many sedge species is ideal for nesting sites for such birds as the mallard, northern shoveler, wrens, and sparrows (Galatowitsch and van der Valk 1994, 20). The area may also be a feeding ground for wading birds such as herons, egrets, and bitterns: they often feed on invertebrates and small amphibians sheltering in shallow wetland margins (Cole et al. 1996; Olson 1999).

Additional habitat value is created by planting emergents which support large invertebrate populations which provide prey for shrews and other small mammals (Hammer 1992, 206; Galatowitsch and van der Valk 1994, 21). Muskrat and beaver may also be attracted because of the tubers produced by some emergent species (Hammer 1992, 83; Galatowitsch and van der Valk 1994, 22).

7.1.2 Wet meadow ridges

Each horseshoe wetland cell is surrounded by an area of higher ground, saturated in the winter and gradually drying though the summer. These ridges of meadow plants create herbaceous islands for wintering waterbirds. High marsh islands such as these are often used by nesting birds and small mammals during times of high water (Miller 2001; Mauchamp et al. 2002). They also provide a refuge for spiders, a natural enemy of many agricultural pests (Kiritani 2000).

7.1.3 Ditch channel

The ditch channel creates a narrow, deeper habitat that can accommodate low marsh plants requiring slightly greater water flows. Planting floating mat crops such as watercress can provide habitat for aquatic invertebrates, small fish, and amphibians (Keddy 2000).

7.1.4 Shrub belt

The shrubs are planted along a buffer zone on a ridge of higher ground between the stream channel and the wetland area, also extending to the south side of the backbay pond to create an element of shade. The habitat value of this area is to provide a structural component to the wetland, which can provide nesting cover to waterfowl in the late spring (Olson 1999; Abney 2001), shelter wading birds and songbirds, and provide perches for birds looking for prey (Hammer 1992, 83). The berries provided by many shrubs create a lure that is hard for birds to resist. Woody habitats also provide denning sites for mammals, although the area created is only large enough for small mammals to benefit (Hammer 1992, 83).

7.1.5 Ponds

The forebay pond is a depression located at the head of the wetland, collecting surface runoff from the small catchment before it enters the planted marshes. Sediments created by erosion within the watershed will have a greater chance to settle out, and may reduce the damage to the wetland by siltation.

The backbay pond is built at the downstream end of the drainage ditch. It is created by means of a spillway redirecting excess water flow coming down the ditch. The spillway is built as a base canal along the inside face of the ditch plug leading off into the excavated basin (Mollison 1988, 354). In order to deal with siltation and sedimentation in this area, the base canal can be filled with stones. This acts as a filtered seepage to the pond area (Mollison 1988, 354). The backbay can be useful for storing the seasonal excess water for potential use during the dry season instead of having it wash out to the creek, as well as creating additional habitat. Small pond areas such as these are ideal habitat for nesting waterfowl in the spring and early summer (Hammer 1992, 159).

The ponds are left to colonize naturally; there is no planned harvest from these areas at this stage. However, part of the backbay will be used as a sort of tuber "nursery" for plants growing in the wetland cells, as this pond will be most likely to retain water during the dry season. Growing these plants necessitates one shallow side to the pond: this also improves reptile and amphibian habitat, as animals can easily get in and out (Fern 2000, 126). Having the shrub belt nearby helps prevent evaporation and provides protection from high winds.

Submergents and free-floating plants colonizing this habitat provide more food than shelter. These plants tend to have larger seeds and smaller tubers, often making them more palatable to waterfowl than their emergent counterparts (Hammer 1992, 206). Micro- and macroinvertebrates use these plants as substrate, creating an important food source for many small fish and growing amphibians (Hammer 1992, 206). Areas designed for submergent species may also attract diving ducks if sufficient water depth is possible (Abney 2001).

7.2 Planting design: Planning in space and time

A planting design for the chosen crops involves:

a) grouping them in the appropriate habitats with other crops requiring the same growing conditions, management and harvest characteristics, and
b) devising a schedule for planting and harvest rotations.

Thus, the planting design involves both a spatial and a temporal component.

The spatial planting design takes into account the preferred growing conditions, management, and harvest characteristics of each species of plant. Compatible crops are grown together in alternating clumps. Crops grown together should ideally have matching ecological and management characteristics: a crop that requires mowing, for example, would be a difficult companion for a root crop that requires its shoots to put energy into tuber growth.

Since many of these plants are new to commercial cropping, spacing for planting is estimated from the use of these plants in restoration projects. Typically, plants designed for wildlife habitat are placed in clumps about 30 cm apart, while plants for bank stabilization are usually placed a little closer, at 20 cm spacing. These recommendations can be used as a starting point; further experimentation may reveal a more effective spacing plan. For further reference, a summary of planting and harvest characteristics of the nine chosen crops is given in Appendix A. The proposed planting design in sketched out in Figure 7.3.

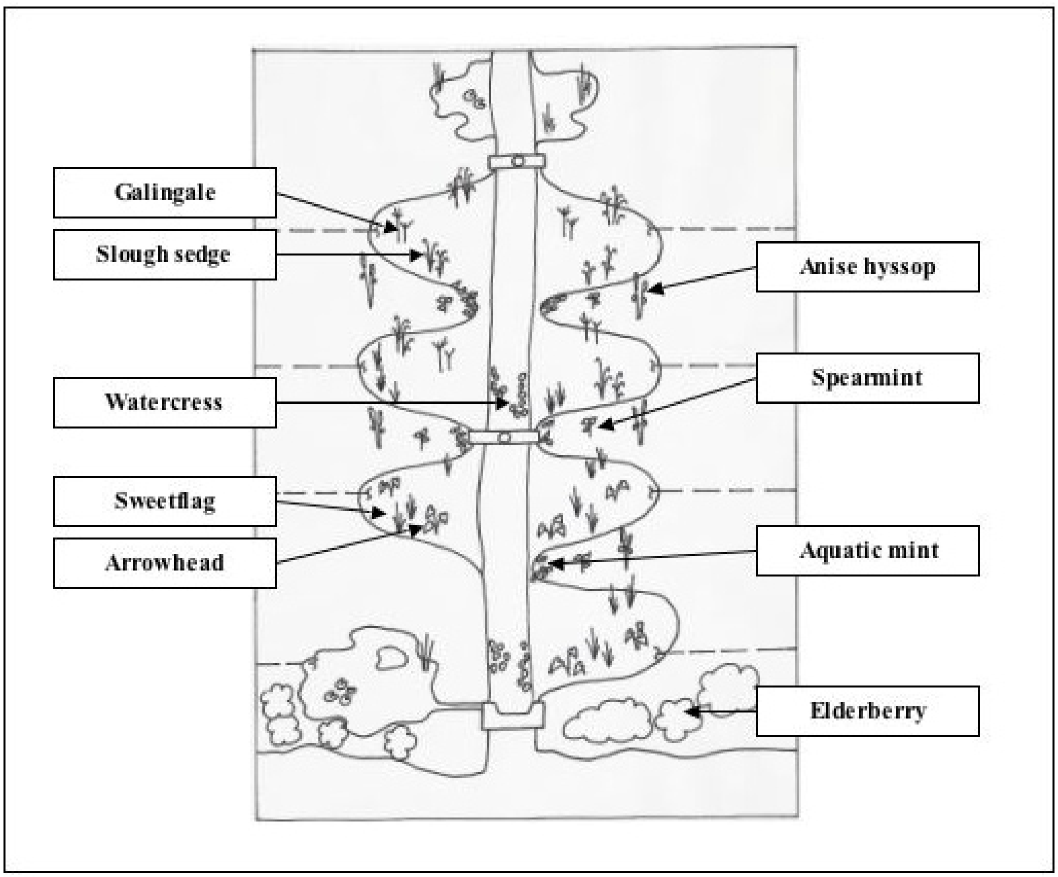

Figure 7.3. Planting design for the proposed agricultural wetland.

The wet meadow ridges between the horseshoe cells are planted with bank plants and ground cover species such as anise hyssop and mints. These areas may be flooded in the winter, but are the first to dry out in the summer. The wet meadow soils, while too wet during the spring to hold machinery for conventional farm operations, are ideal for growing alternative greens and low salad crops in the summer. Anise hyssop would tend to thrive best near the top of the ridges, in slightly drier soil, with spearmint on the banks. Aquatic mint, surviving in both flooded and dry conditions, is planted along the border of the banks where water fluctuations may leave the plants occasionally inundated. For all three of these plants, harvesting involves mowing or cutting the vegetative parts.

Below the banks, the horseshoe marshes form a second crop region and habitat ecology. On a natural gradient from low seasonal flooding to shallow standing water, grasses appear first in saturated soils followed by sedges (*Carex* and *Cyperus* spp.) and irises, grading into sweetflag and arrowhead as the water deepens (Hammer 1992). Marsh cells closest to the creek will likely receive the highest water depths and remain inundated the longest because of their proximity to the main source of seasonal flooding. Thus the crops with the highest water tolerances, sweetflag and arrowhead, are planted in the cells closest to the creek while sedge and galingale are planted in the upstream cells. Watercress is contained by the stoplogs within the ditch channel, where it can enjoy the deeper water and occasional flow.

The harvested parts of sweetflag and arrowhead are both buried in the sediment: the arrowhead tuber and the sweetflag rhizome are harvested by raking from the mud in the fall. This marsh cell would remain undisturbed for the duration of the summer, until fall tuber harvesting. This simultaneous harvest minimizes labour. Because the sweetflag rhizome takes two years to mature, a cell planted with these two crops would need to lie fallow in alternating years. A rotational scheme involving two arrowhead/sweetflag cells would enable one cell to be harvested and one to lie fallow each year.

The young shoots and leaves of sweetflag can also be harvested as a flavourful salad crop. Harvesting the growing parts, however, reduces the ability of the plant to store energy in its rhizome. A third cell must therefore be planted with sweetflag if it is to contribute to a wild salad mix. Sweetflag is adaptable to a wide range of conditions, and would be able to grow in the slightly shallower conditions of the third marsh cells along with galingale and sedge. Both sweetflag and sedge can have their young shoots and leaves harvested without disturbing the growing galingale, which would remain untouched until the fall. Then, the galingale root is dug from the mud.

If the young shoots and leaves of the sedge are harvested in the third cell, a fourth cell would be needed to grow the sedge to seed maturity in the fall. Galingale could be planted as its companion in the fourth cell as well.

Most shrubs tolerate limited flooding during the growing season, although they can take significantly higher flooding levels during the winter (Hammer 1992, 195). Elderberry is therefore placed on the built-up ground beside the stream, where it is subject to winter floods but can maximize habitat benefits. This area is the least disturbed, which is beneficial for nesting birds and mammals most likely to use the habitat. The shade provided by these bushes will also be focused on the areas that need it most, the creek and the pond, rather than over cropped plants. As both the flowers and the fruit of the elderberry are harvestable, but the maturing flower is needed to produce a fruit, these two crops can be harvested in alternating years from different plants.

Planting over several years instead of all at once creates the needed diversity while minimizing risk due to a bad weather season or accidental failure of the restored system. Staggered planting also minimizes investment costs for planting, as cuttings can usually be taken for most of the plants discussed. Once a small number of stands are established in the first year, these can be thinned out and a new set of stands propagated in the following season. A summary of the crop placement is given in Table 7.1. Year One begins in the spring following construction.

Table 7.1. Staggered crop planting for the wetland habitats.

		YEAR ONE	YEAR TWO
Wet meadow/ Banks		Anise hyssop Aquatic mint	Anise hyssop Spearmint Aquatic mint
Horseshoe marsh cells	**1**	Arrowhead	Arrowhead Sweetflag (for rhizomes)
	2	Sweetflag (for rhizomes)	Sweetflag (for rhizomes) Arrowhead
	3	Galingale	Galingale Sweetflag (for shoots and leaves) Sedge
	4	Sedge	Sedge Galingale
Channel			Watercress
Spillway pond		open colonization	Sweetflag nursery Galingale nursery Arrowhead nursery
Shrub belt/ Buffer		Elderberry	

Anise hyssop is planted in the first year because it could be outcompeted by spearmint while young. It is also easy to transplant later on, if more space is needed for spearmint. Aquatic mint would be planted as close to the waterline as possible to prevent outcompeting the anise hyssop as well. Ideal conditions would then be provided for spearmint in the following year, as it grows best when the young plants are partially shaded.

Rotating the harvest is also important in ensuring that wildlife habitat is provided in at least one or two cells at all times, as well as minimizing labour spent in harvest and planting. A rotation scheme is devised for the agricultural wetland to meet these needs (Table 7.2). The first three years involve mainly establishment of the plants; the fourth and fifth year begin the bi-yearly rotation sequence.

A diverse mix of crop products is provided throughout the year under this rotational scheme.

7.3 Practical considerations

7.3.1 Preliminary monitoring

Before constructing at a site, certain water balance parameters and soil characteristics should be measured (Table 5.7). Many of these parameters may already be known at a landowners' site. However, assuming no prior knowledge, a monitoring program is developed for a site four years prior to design construction. This length of time is thought more than adequate for baseline water balance and soil assessment for wetland construction (Mauchamp et al. 2002; Wetland Studies and Solutions Inc. 2002).

Water balance

First, a topographic survey of the drained area intended for restoration is taken, in order to determine natural depressions and the catchment area for the restored wetland. Simple survey methods are outlined in Galatowitsch and van der Valk (1994, 54).

Monitoring wells are then drilled with an auger to the approximate level of the local water table. Groundwater levels are measured weekly in the spring (March to June) and monthly during the summer and winter (Wetland Studies and Solutions Inc. 2002). Monitoring wells are placed in the middle and on each edge of the design in order to develop a groundwater profile for the site. A rain gauge can measure direct precipitation at the site, and pan evaporation can be measured as well. Monthly averages can give an approximation of the seasonal climatic water balance.

Table 7.2. Planting and harvest schedule for the integrated agriculture wetland.

YEAR ONE				
		Spring	**Summer**	**Fall**
Wet meadow/ Banks		anise hyssop aquatic mint	HARVEST - anise hyssop	
Horseshoe marsh cells	**1**		arrowhead	
	2		sweetflag	divide some rhizomes and store for spring
	3		galingale	
	4		slough sedge	
Channel				
Spillway pond		open colonization		
Shrub belt/ Buffer				elderberry from rootstock
CROP HARVEST			ANISE HYSSOP (flowers or salad)	

YEAR TWO				
		Spring	**Summer**	**Fall**
Wet meadow/ Banks		spearmint	HARVEST - anise hyssop (x2)	
Horseshoe marsh cells	**1**	plant 1/3 stored sweetflag rhizomes divide some arrowhead tubers		
	2		plant 1/2 divided arrowhead tubers	
	3	plant 1/3 stored sweetflag rhizomes divide some galingale roots		propagate sedge
	4	plant 1/2 divided galingale roots		HARVEST - sedge seeds
Channel		watercress		
Spillway pond		plant 1/3 stored sweetflag rhizomes (nursery) plant 1/2 divided galingale roots (nursery)	plant 1/2 arrowhead tubers (nursery)	
Shrub belt/ Buffer				
CROP HARVEST			ANISE HYSSOP (flowers or salad)	SEDGE (seeds)

YEAR THREE				
		Spring	**Summer**	**Fall**
Wet meadow/ Banks		HARVEST - anise hyssop	HARVEST - anise hyssop (x2) HARVEST - spearmint	
Horseshoe marsh cells	**1**			
	2			HARVEST - arrowhead tubers HARVEST - sweetflag rhizomes
	3	HARVEST - young sweetflag shoots/leaves		HARVEST - sedge seeds
	4	HARVEST - young sedge shoots/leaves		HARVEST - galingale root
Channel		HARVEST - watercress		HARVEST - watercress
Spillway pond				divide sweetflag rhizomes
Shrub belt/ Buffer		HARVEST - elderberry flower		
CROP HARVEST		SALAD MIX - sweetflag, sedge, watercress, anise hyssop	SPICES - anise hyssop, spearmint	SALAD MIX – sweetflag root, watercress SPICES – galingale, sweetflag GRAINS/TUBERS – arrowhead tuber, sedge seeds

YEAR FOUR, AND ALTERNATING EVEN YEARS				
		Spring	**Summer**	**Fall**
Wet meadow/ Banks		HARVEST - anise hyssop	HARVEST - anise hyssop (x2) HARVEST - spearmint	
Horseshoe marsh cells	**1**			HARVEST - arrowhead tubers HARVEST - sweetflag rhizomes
	2	plant sweetflag (if needed)	plant arrowhead tubers from nursery	
	3	HARVEST - young sweetflag shoots/leaves HARVEST - young sedge shoots/leaves		HARVEST - galingale root
	4	plant galingale roots		HARVEST - sedge seeds
Channel		HARVEST - watercress		HARVEST - watercress
Spillway pond		divide arrowhead tubers divide galingale roots		divide sweetflag rhizomes
Shrub belt/ Buffer				HARVEST - elderberry fruit
CROP HARVEST		SALAD MIX - sweetflag, sedge, watercress, anise hyssop	SPICES - anise hyssop, spearmint	SALAD MIX – sweetflag root, watercress SPICES – galingale, sweetflag GRAINS/TUBERS – arrowhead tuber, sedge seeds

YEAR FIVE, AND ALTERNATING ODD YEARS				
		Spring	**Summer**	**Fall**
Wet meadow/ Banks		HARVEST - anise hyssop	HARVEST - anise hyssop (x2) HARVEST - spearmint	
Horseshoe marsh cells	**1**	plant sweetflag (if needed)	plant arrowhead tubers from nursery	
	2			HARVEST - arrowhead tubers HARVEST - sweetflag rhizomes
	3	HARVEST - young sweetflag shoots/leaves plant galingale roots		HARVEST - sedge seeds
	4	HARVEST - young sedge shoots/leaves		HARVEST - galingale root
Channel		HARVEST - watercress		HARVEST - watercress
Spillway pond		divide arrowhead tubers divide galingale roots		divide sweetflag rhizomes
Shrub belt/ Buffer		HARVEST - elderberry flowers		
CROP HARVEST		SALAD MIX - sweetflag, sedge, watercress, anise hyssop	SPICES - anise hyssop, spearmint	SALAD MIX – sweetflag root, watercress SPICES – galingale, sweetflag GRAINS/TUBERS – arrowhead tuber, sedge seeds

Water flow should be measured in the existing drainage ditch. Monthly averages can again be taken. This flow measurement gives the approximate water volume directly available for the wetland design. When the stream into which the ditch drains floods, the flooding stage and frequency can be measured to determine the water potentially available for the wetland design.

These measurements should give enough baseline information to adapt the design to the specific site, without the need for previously existing site data.

Soils

Organic matter content can be assessed from soil samples, as well as the presence of any toxins or heavy metals. Hydraulic conductivity is measured with an auger hole to determine whether sealing is necessary at the site. A description of the auger hole method is given in Lalonde and Hughes-Games (1997). A measure of the rate of sedimentation in the drainage ditch is taken; if greater than 0.5 cm per year, building a sediment retention pond (ie. the forebay) is necessary. Sediment accumulation rates are taken by inserting a nail through a washer to ground surface level; the sediment accumulated around the washer is measured for a given time period (Clarke 1986, 58).

7.3.2 Planning for best construction practices

Construction should take place in the fall, at the end of the dry season. Equipment does not get stuck in the mud, and there is the least disturbance to the land (Hammer 1992, 189).

Ponds can be constructed either by building levees or embankments around a landscape depression, or by excavation alone. Excavated ponds are recommended over embankment ponds in areas of flat topography where evaporation losses can be high, as they can be built with minimal surface area relative to volume (Soil Conservation Service 1982). Levees can be susceptible to leakage or to damage by burrowing animals such as muskrat (Mitsch and Jorgensen 2004). The minimum recommended pond depth for normal evaporation and seepage is 1.5 m, greater if seepage and evaporation exceed 8 cm per month (Soil Conservation Service 1982). Excavation is usually the most costly step in construction, so ponds should be placed in natural depressions if possible.

While excavating, soils with low permeability should be left in place to avoid creating greater seepage (Hammer 1992, 190; Abney 2001). Excavated material can be put to different uses, depending on the soil removed. Clay material can be used to build the ditch plug. Peaty material can be used to supplement the wet meadow ridges, adding fertility to the soil (Pokorny and Hauser 2002). Excavated material can also be added to the shrub belt separating the wetland cells from the creek. This earth can help to filter water seeping into the creek, improving water quality downstream (Larson et al. 2000). Topsoil should be saved and replaced on top of any exposed clay after excavation, in order to aid plant establishment. Storing topsoil underwater can help conserve bound nutrients (Hammer 1992, 190). Accumulating sediment during construction can be prevented by proper application of erosion controls, such as temporary silt fences (Wetland Studies and Solutions Inc. 2002).

Fish screens must be placed on all inlets and outlets to the wetland. Fish such as carp can be extremely destructive in a newly planted wetland (Galatowitsch and van der Valk 1994, 153); also, having fish stranded during a drawdown would not be desirable from a conservation standpoint.

The site is then ready for planting the following spring, leaving the winter free to monitor and correct problems of leakage or water control (Hammer 1992, 189). If the site was previously covered by a dense thatch of grasses, a burn can make the soil more amenable to planting of a new wetland community (Galatowitsch and van der Valk 1994, 152). Planting seedlings in rows perpendicular to the main water flow minimizes channelling and increases the coverage of vegetation (Hammer 1992, 193). Details of planting techniques can be found in Hammer (1992), Daigle and Havinga (1996), Romanowski (1998) and other similar restoration manuals. Finally, adding a bucket of water and mud from a nearby pond or wetland area can help start natural colonization within the pond area (Fern 2000, 126).

7.4 Management plan: Using environmental filters to minimize labour

Site management requirements should be minimal. To optimize crop productivity and wildlife habitat on the site, a low intensity management plan that mimics a natural disturbance pattern should be followed. Integrating environmental filters into a plan can minimize the labour investment of the farmer while managing succession to promote the growth of desired plant species. Controlling water levels is the most powerful method of regulating species colonization and subsequent productivity (Luken 1990, 117; Hammer 1992, 241). Hydrology and physical disturbance are the two critical environmental filters thought to be the most easily manipulated by the farmers interviewed in this study (Table 4.11).

The management plan for the site has two parts: the first is a regular management plan to maintain the marsh and wet meadow complex in the desired successional stages, while the second is a contingency management plan for dealing with problems or irregular events. Of the five habitats created in this design, only the horseshoe marshes and wet meadow ridges require management on a regular basis. The ditch channel, ponds, and shrub belt may only require remedial management every few years as required, to deal with potential problems such as sediment buildup or invasive species.

7.4.1 Regular management: Maintaining pulse events

Maintaining the marsh and wet meadow habitats over time requires appropriate disturbance management. Flooding and drawdowns are the main means of managing conditions in the marsh cells; management of the wet meadow ridges requires an additional degree of physical disturbance, as this area may be more susceptible to succession by terrestrial species. Active manipulation of water levels is especially important during plant establishment in the first growing season, as this sets the stage for a strong founder community requiring little future maintenance.

Horseshoe marshes

Periodic drying and flooding cycles are required for the persistence of a marsh and wet meadow complex. While seasonal flooding creates a natural disturbance pattern, the timing and rate of flooding and drying is managed through the stoplog structures. Water depth, flooding duration, and timing of flooding are the critical hydrological disturbance parameters to be manipulated. These parameters can be managed to maximize productivity of commercial species, and to promote wildlife habitat for different marsh inhabitants.

Emergent vegetation is planted in moist soil in the spring. Water is then let out of the forebay pond to flood the wetland cells with 2 to 3 cm of water for 5 to 7 days. As long as this water level does not overtop the young plants, low flooding should stop germination and early competition from terrestrial plants (Hammer 1992, 241). After this, water levels should be lowered again to keep the soil saturated but not flooded for the next 15 to 20 days (Hammer 1992, 241). The nutrient renewal produced by the drawdown should give the planted species a burst of growth. A second release of water should then be applied to cover the marshes with a slightly higher flooding of 3 to 5 cm for 5 to 7 days, followed by a second drawdown (Hammer 1992, 241). If plant mortality is high, new plants can be added during this time. By midsummer, competition can again threaten a newly planted wetland (Hammer 1992, 241). Emergents may be interspersed with opportunistic wet meadow species, while the planted species on the wet meadow ridges may be competing with terrestrial species. A gradual flooding tracking increasing stem height of the planted species is a useful treatment at this time, although the plants should be watched for signs of stress (Hammer 1992, 242). High water levels of up to 30 to 50 cm, enough to just cover the transitional zones without overtopping the emergent plants, should take out the competition within 20 days. Water levels may be allowed to evaporate to a 5 cm cover over the end of the summer and then increase naturally with the fall rains.

For regular management of the horseshoe marsh habitats in the following years, water should be allowed to cover the substrate throughout the winter right up until early summer. Keeping high water levels until mid-May to June prevents the germination of dryland species in the seedbank (Missouri Department of Conservation 2004a) and retards the development of annual plant dominance in the system (Luken 1990, 118). Winter rains and spring runoff keep water levels naturally high in the horseshoes during this time. Water levels should be allowed to drop slowly, about 2 cm/day until the marsh bottom is exposed, to encourage establishment of the marsh species (Olson 1999, 39; Missouri Department of Conservation 2004a). The drained water collects in the backbay pond during this time. Again, natural drought during this time simplifies management. A release of water from the forebay can then reflood the area. Water levels can be reduced to saturated soil around the perimeter from July through the summer (Olson 1999) while keeping about 15 cm of water in the deeper portions of the horseshoes. These water levels are important for waterfowl: migratory wildlife prefer moist soil conditions, while shallow water conditions over the growing season favour resident wildlife (Mitsch and Gosselink 2000). Around the beginning of September or October the marsh should be slowly reflooded for wintering waterfowl (Olson 1999, 41; Missouri Department of Conservation 2004a). Winter flooding decreases the risk of disease and pest accumulation, both by the reinstatement of anaerobic conditions as well as by the foraging of waterbirds on the site (van Diepen et al. 2004).

A small amount of plant litter should be kept on the ground after harvesting, as decomposing plant litter creates a substrate for invertebrates in the fall (Galatowitsch and van der Valk 1994, 19; Missouri Department of Conservation 2004a).

Periodic checks of the water control structures can save structural damage later on (Galatowitsch and van der Valk 1994, 112). Routine maintenance can be as simple as removing any debris from the structures or screens after large storms.

Wet meadow ridges

The land on the wet meadow ridges is managed to promote the persistence of moist soil conditions during the growing season. Seeds produced by moist soil plants during this time attract and concentrate wetland wildlife such as waterbirds (Missouri Department of Conservation 2004a).

Mowing, disking, and tilling are often used by wetland managers to control succession (Gray et al. 1999). This controls invasion by woody plants. Mowing is also beneficial in that it decreases excess density of moist soil plants as well. When plants become too dense or too high, they become inaccessible to wildlife. A single mowing to a height of 35 cm at midsummer can control excess productivity (Missouri Department of Conservation 2004a), creating both a harvested product and a more attractive wildlife habitat at the same time.

A fall mowing is also recommended to increase seed yield for wintering birds (Gray et al. 1999). Different mowing times can select for different plant species composition. For example, a mid-summer mowing has the greatest impact on rhizomatous species that put their energy into carbohydrate stores during this time (Keddy 2000, 383). Thus, mowing may also help control some invasive plants.

Any additional weeds in the system should be mowed, and could be used and sold as mulch and compost to organic farmers. A common problem among organic growers is the lack of sufficient organic material (Fern 2000, 9; Kiewitz, personal communication, 2003); the natural productivity of a wet meadow area could be used for this purpose.

Managing the surrounding farmscape

Since the integrated agriculture wetland is an open system, management must also include the greater farm system in order to gain maximum production and wildlife benefits. This requires that other disturbances created by some farm practices be minimized.

Pesticide use should ideally be reduced within the surrounding fields and catchment. Pesticide residues can significantly reduce wetland invertebrate populations, reducing the food supply for wildlife, as well as harming amphibian populations and stressing emergent vegetation (Hammer 1992, 250; Galatowitsch and van der Valk 1994, 116). Practicing IPM in the surrounding fields could be a compatible alternative.

Application of fertilizers to fields in the catchment should be timed for maximal crop uptake, reducing runoff of excess nutrients into the restored wetland. Excess nutrient runoff promotes the growth of algae, which outcompete other pond plants with higher wildlife value (Galatowitsch and van der Valk 1994, 46).

Farming practices in the adjacent land should promote erosion control. These practices could include contour farming, terracing, or conservation tillage (Galatowitsch and van der Valk 1994, 89). If the adjacent farmland is intensively farmed in row crops, a buffer zone of perennial grasses may improve the quality of the created wetland. A grass buffer can help filter pesticides, nutrients, and sediments before they enter the wetland (Galatowitsch and van der Valk 1994, 87).

7.4.2 Contingency management: Remedial actions

Possible problems that may arise within the wetland area include limited summer water, sedimentation, nutrient accumulation or depletion, invasions by terrestrial plants or aggressive wetland colonizers, or excessive herbivory by wildlife. There are some actions managers can take to mitigate the impacts on the wetland complex.

If water levels are a concern during a dry year, thinning out the vegetation in the horseshoe marshes by selective early harvesting can help maintain moist soil conditions on the neighbouring wet meadows. Midsummer thinning or harvesting reduces the evapotranspiration of the marsh, making more water available to the adjacent plant communities (Olson 1999).

Sedimentation in the ponds or ditch channel may build up to the point where dredging or mucking of the bottom sediments is required. These sediments can be put to use, however: fertilization by mucking, transferring nutrient-rich aquatic deposits onto field surfaces can be effective in promoting healthy plant growth (Denevan 2001, 37).

An occasional flushing or short flooding of a wetland cell can be used as a management tool as required, to discourage invading species or renew soil nutrients. The stoplogs can be used for this purpose. Reflooding stops the process of colonization and selectively eliminates terrestrial species depending on their tolerances (Luken 1990, 120; Mauchamp et al. 2002). Reflooding should only be used once the desired or planted vegetation has established itself, however (Middleton 1999, 5; Mitsch and Jorgensen 2004, 244). A pulse of water can be released from the forebay pond, or taken from the backbay. This treatment may be necessary for the cells containing sedges, in particular. Since drying the soil tends to increase availability of nitrogen but decreases that of phosphorus, prolonged drawdowns tend to increase the proportion of grasses over sedges (Lamers et al. 2002). A reflooding should be kept to a maximum of 50 cm for a two week period, a general tolerance limit for many emergent marsh species (Hammer 1992, 162). Higher water levels during the growing season should be avoided, however, as this may eliminate some desired emergents (Mauchamp et al. 2002).

The occasional heavy runoff event may flush the system. These events should be permitted, and can be beneficial for both nutrient renewal and enhanced water quality (Mitsch and Gosselink 2000, 147; Jarchow 2001).

Potential invasive plants that may compete with desired crop plants include purple loosestrife, *Lythrum salicaria*, reed canary grass, *Phalaris arundinacea* and marsh dominants such as cattails (*Typha* spp.) or reeds (*Phragmites* spp.). Creating a strong founder community and maintaining fluctuations in water levels should be sufficient to discourage competitive marsh dominants such as *Phragmites* or *Typha* (Galatowitsch and van der Valk 1994, 118; Middleton 1999, 4; Mitsch and Gosselink 2000, 145; Jarchow 2001). However, to manage aggressive emergent colonizers, the Missouri Department of Conservation (2004b) suggests burning twice during the summer and then flooding to a 1 m depth from that fall over the following growing season. While this procedure would destroy the cropped plants in that area, having the repeated wetland cells could mitigate the damage by only treating the one affected wetland cell during a season. Fire does have additional benefits: it releases nutrients, opens the detrital layers, removes other undesirable vegetation including floating mats, and generally improves waterfowl habitat (Hammer 1992, 47). Galatowitsch and van der Valk (1994) caution against using fire until August or September, however, after nesting season is over. If fire is not desired, manually removing invading cattail stands or cutting them down and then flooding the site may also help reduce the spread of aggressive dominants (Galatowitsch and van der Valk 1994; Keddy 2000, 299).

Purple loosestrife may be difficult to eradicate. If water levels are kept high until late spring or early summer, the plant should have difficulty becoming established (Hammer 1992, 245). If some plants do colonize, Galatowitsch and van der Valk (1994, 117) recommend removing the plants manually as quickly as possible, by hand or with spot herbicide application. Flooding to a depth of 5 cm in early summer can restrict the plants' development (Weiher et al. 1996). Reed canary grass can be removed by hand-digging combined with burning, or herbicide application on young plants (Galatowitsch and van der Valk 1994, 118). However, herbicides are not recommended for management in this design. Herbicides often have non-target effects on neighbouring species (Galatowitsch and van der Valk 1994, 118).

Herbivory by muskrat and geese may need to be managed as well (Keddy 2000, 288) and the impacts that these animals have on such a system will need monitoring. Determining the acceptable levels of herbivore damage will be part of a system monitoring plan.

Mosquitoes are often perceived as a problem in wetlands. As long as a pulsing water regime is maintained and debris such as floating dead vegetation is removed, they should not be a problem in this system as there is no standing backwater in the design. If mosquitoes are a concern, control measures described by Hammer (1992, 249) include shading water surfaces, flushing, or introducing bacterial colonies or mosquitofish (*Gambusia*).

8.0 Design application: Turning a problem to profit for a Vancouver Island farm.

This chapter outlines the case study site: a farm on Richards Creek, a part of the Somenos Watershed near the city of Duncan, on Vancouver Island. The case study demonstrates how the structural and planting design proposed in chapter 7 can be applied to provide an alternative species-friendly solution to problems of flooded farmland.

8.1 Introduction to the study site

The land surrounding Richards Creek has a rich agricultural heritage combined with high biodiversity values. Primary local economic activities are agriculture, wildlife viewing, and recreation (Madrone Consultants 2001). Here, applying the design for integrated wetland agriculture may be able to help a farmer restore some of his land to valuable wildlife habitat while still making ends meet. Many farmers in the area are quite innovative (Tattam, personal communication, 2003) and most are fighting a losing battle with seasonal flooding. Working with nature and creating an ecological design may provide a more sustainable opportunity for a small farmer in the region.

Box 8.1. *The Somenos story*.

The grey of late winter still covers the landscape. A group of trumpeter swans is feeding on the flooded stubble of a farmfield. The sound of splashing erupts, and a flock of widgeons streams upward to sit on the tractor, a useless structure mocked by the lapping water until the June sun chases it back into its proper creekbanks. Not all the farmer's efforts have succeeded in draining this portion of the land. The waters stubbornly fill the drainage tiles and turn the soil into a muddy soup year after year, persisting in spilling over the well-kept ditch channel and gripping the farmer's field equipment until the struggling crop is pre-empted by imported produce in the local stores. Each winter brings a slew of wildlife to the area: migrating waterfowl rely on the flooded fields as feeding and resting grounds on their long journey down the Pacific Flyway. But the farmer can't make a living where half his field is inaccessible until well into the growing season. The land is drained, and the wildlife must move on. But space is running out. Urbanization and reversion of wet meadows and seasonally flooded pasture to scrub forests are taking their toll on animals dependent on these habitats. The farmer is looking for solutions, himself an integral part of the rich heritage of local agriculture in the small, coastal British Columbian valley. This is the farmland of Richards Creek.

One farmer agreed to the use of his land as a theoretical site for a case study. The parcel of land is an 8 acre (3.7 ha) farm located in the upper reaches of Richards Creek; this land will be referred to as the "Richards Trail farm" as the participant wished to remain anonymous. A regional and local site description is provided as background.

In British Columbia, most wetland conservation efforts focus on land acquisition. These efforts are often led by partnerships between diverse governmental and non-government groups. A successful example of such a conservation initiative is the Pacific Estuary Conservation Program (PCEP), a program whose mandate is the protection of estuarine habitat and associated wetlands along British Columbia's coast. Land acquisition, Crown land preservation, and developing and promoting land stewardship are the main tools used in this program (NRTEE 2004). Current partners include Environment Canada (Canadian Wildlife Service), the Department of Fisheries and Oceans (DFO), the B.C. Ministry of Water, Land and Air Protection (formerly B.C. Ministry of Environment, Lands and Parks), the B.C. Habitat Conservation Trust Fund, The Nature Trust of British Columbia, the Nature Conservancy of Canada and Ducks Unlimited Canada (NRTEE 2004). Provincial government cutbacks have caused partnerships such as the PECP to be the most prominent conservation groups in the province (NRTEE 2004). Funding shortages are still a current problem.

8.2 Site description

Richards Creek belongs to the Somenos watershed, a basin located on the eastern side of Vancouver Island between Victoria and Nanaimo. This 7,000 ha area consists of low geomorphological relief, including extensive riparian lowlands and two lowland lakes, Crofton Lake and Somenos Lake (Figure 8.1) (Lanarc Consultants 1999; Madrone Consultants 2001).

Figure 8.1. Somenos Lake in mid-August.

The entire lowland area is designated Agricultural Land Reserve (Willis, Cunliffe, Tait/DeLCan 1981), but it also includes 170 ha of conservation lands owned by Ducks Unlimited Canada and The Nature Trust of BC (Lanarc Consultants 1999).

The watershed is composed of two lakes and five creeks (Figure 8.2). Crofton Lake is a reservoir located in the north of the watershed. It has a controlled outlet that drains into Richards Creek, one of the three main streams flowing into Somenos Lake (Lanarc Consultants 1999). Somenos Lake then releases its water through a single outlet, Somenos Creek, which drains into the Cowichan River (Lanarc Consultants 1999).

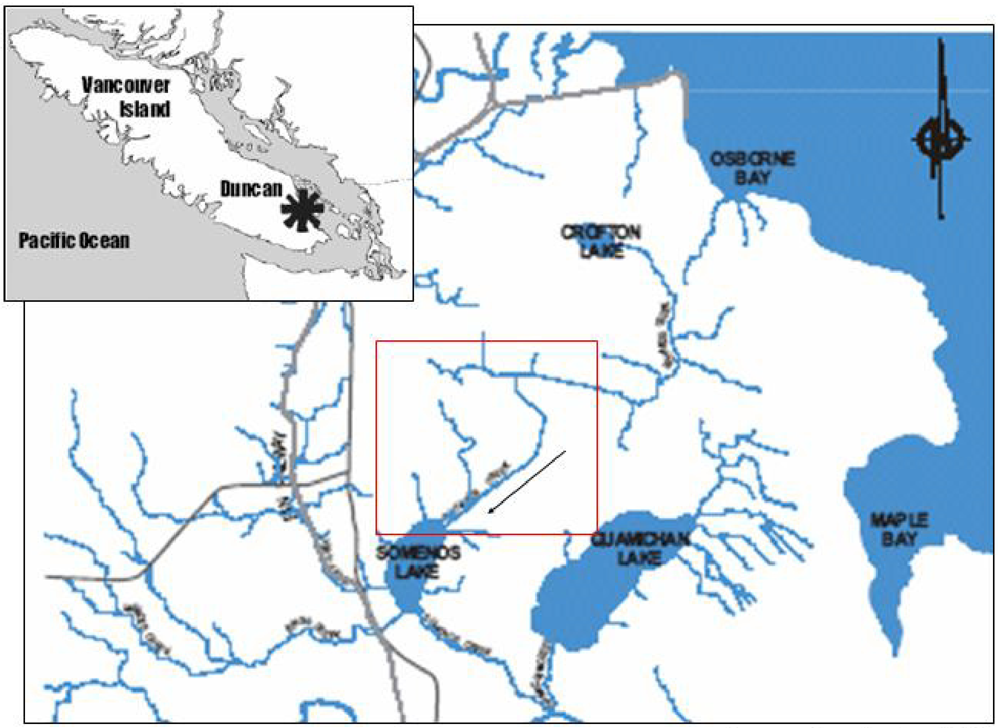

Photo source: Lanarc Consultants (1999)

Figure 8.2. Map of the Somenos Watershed, showing the location and direction of Richards Creek.

Richards Creek drains approximately 2300 ha in the northeast portion of the Somenos watershed. The property in question is located on Richards Trail, a road lying midway through the Richards Creek watershed. The road traces a boundary between the lower, agricultural portion of this sub-basin and the upper forested reaches of the watershed. From Richards Trail southwards to the creek outlet, the creek drains 192 ha of farmland. This lowland area contains 80% of the farmlands affected by flooding (Willis, Cunliffe, Tait/DeLCan 1981). The creek runs 5 km from Richards Trail to Somenos Lake with a gradient of 1.5 m (Willis, Cunliffe, Tait/DeLCan 1981), giving an average slope of less than 1%. The Richards Trail farm drains approximately 4 hectares through a ditch into Richards Creek.

The Somenos watershed has a history of human disturbance. Until the early 20th century, wetlands surrounded Somenos Lake. Then these lands were drained and put into agricultural production (Madrone Consultants 2001). Flooding of both agricultural and residential land has been documented for a hundred years, with early settlers on Somenos Lake blaming beaver activity for the annual flooding (Lanarc Consultants 1999).

Somenos is a basin, which means that naturally occurring wetlands in such an area undergo terrestrialization over time (Madrone Consultants 2001). In an undisturbed basin, new wetlands are created in other areas due to geomorphic and biological process, compensating for wetland losses (Madrone Consultants 2001). In such a human-dominated landscape as the Somenos basin, however, new wetland creation is constrained and shifting vegetative patterns in the landscape are arrested (Madrone Consultants 2001). If left alone, the agricultural lands now surrounding Somenos Lake might gradually revert to some stage of marsh, swamp or other wetland. However, without active management, the area could terrestrialize and eventually the lake and wetland complex would be lost (Madrone Consultants 2001). Since additional wetland complexes would be unlikely to develop due to the constraints imposed by human land uses, the basin would lose many of its natural values (Madrone Consultants 2001).

Key water management issues in the watershed are the increase in spring and early summer flooding, low late summer water flows, and high nutrient levels in the lake and creeks (Figure 8.3) causing algae blooms and low dissolved oxygen levels during the summer (Lanarc Consultants 1999; Madrone Consultants 2001). Increased stream sedimentation is also a problem (Lanarc Consultants 1999). These issues affect management in other areas, including vegetation management, agricultural production, and fish and wildlife values.

Annual flooding occurs through the backwatering of the Cowichan River during periods of high discharge (Lanarc Consultants 1999). As the water level in the river rises during seasonal high water periods, the water flows backwards into Somenos Creek causing Somenos Lake and Richards Creek to overflow their banks and fill the surrounding lowland, mostly agricultural fields, with water (Lanarc Consultants 1999). The extent of the floods reaches as far as the agricultural lands upstream of Somenos Lake along Richards Creek (Lanarc Consultants 1999), flooding 228 ha of farmland (Willis, Cunliffe, Tait/DeLCan 1981). As water levels drop in the river, the floods slowly recede from the land.

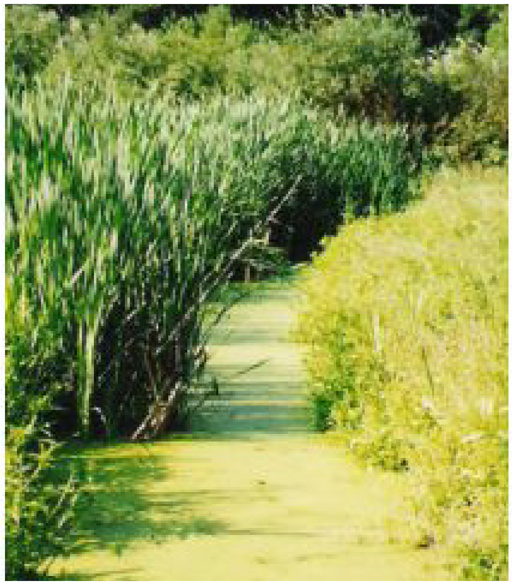

Figure 8.3. Somenos wetland showing heavy algal growth because of high summer nutrient levels.

High water levels continuing into the growing season are of critical concern to farmers because the floods decrease the area of arable land, shorten the growing season, and result in poor crop yields (Lanarc Consultants 1999; Madrone Consultants 2001). Getting equipment onto the fields earlier than mid-July is often impossible because soils are fully saturated (Willis, Cunliffe, Tait/DeLCan 1981; Madrone Consultants 2001). Fall flooding, also on the increase, can decimate a harvest (Lanarc Consultants 1999). Annual flooding is predicted to continue or be exacerbated by the rising level of the Cowichan River caused by increased bedload deposition from channels diked in the 1970s (Lanarc Consultants 1999).

Low late summer water flows are an apparent contradiction to the flooding problem. All streams in the area become increasingly low and sometimes intermittently dry between July and September (Lanarc Consultants 1999). Water withdrawal from the Somenos Basin is fully committed (Willis, Cunliffe, Tait/DeLCan 1981).

Water quality in the watershed is fairly poor. Analysis of water chemistry in Somenos Lake shows high levels of both phosphorus and nitrogen (Madrone Consultants 2001).

It has been recommended that drainage improvements be put in place to lower water levels for the growing season beginning in June. The recommendations include improving ditches, clearing Somenos Creek of vegetation to improve flow, and managing beaver dams in the area (Madrone Consultants 2001). A more habitat-friendly alternative might be acceptable to farmers if a feasible solution was proposed.

There are some data limitations with the study area, in that there is very little baseline data for the area in terms of natural values. Natural fluctuation patterns of water, sediments, nutrients, and biological resources have not yet been clearly identified, but have been prioritized for action over the next decade (Madrone Consultants 2001). The design will therefore be applied within the limits of the existing data.

8.3 Applying the general wetland restoration form to the site: Obtaining parameters

The first step in creating an integrated agricultural wetland on the Richards Trail farm is to apply the general wetland form for the restoration work (Table 5.6) to the natural ecology of the area. Ecological parameters to be examined include the hydrology and local water balance; the soils and physical aspects of the site; major local disturbances that would affect plant growth and propagation; and the global biodiversity value of the site including any rare or threatened species in the area (see Table 5.7).

8.3.1 Water balance

Water balance in a wetland is determined by precipitation, soil water storage, runoff, and groundwater (Kreymborg and Forman 2001). The water budget of the area, the balance between water storage, inflows, and outflows, has a general expression described by equation 8.1 (Box 8.2). Change in either depth or volume per unit time can be measured, and the change in storage calculated on a cumulative monthly basis (Mitsch and Gosselink 2000, 120).

A preliminary water balance is calculated for the site based on existing data, which is limited to average values for the basin and is likely not accurate for the specific farm site. Still, an initial estimation is able to provide a reasonable estimate of the size and design configuration required at the site. Pre-construction monitoring can then determine the details for construction work.

Box 8.2. *Equations used for evaluating water balance and wetland sizing.*

(8.1) $\Delta V/\Delta t = (P - ET) + (S_i - S_o) + (G_i - G_o)$

$\Delta V/\Delta t$ = change in volume of water storage per unit time,
P = precipitation,
ET = evapotranspiration,
S_i = surface inflows,
S_o = surface outflows,
G_i = groundwater inflows, and
G_o = groundwater outflows (Mitsch and Gosselink 2000, 119).

(8.2) $S_i(\text{runoff}) = P*R_c*A_w$

$S_i(\text{runoff})$ = surface runoff into wetland (m^3)
P = average precipitation in watershed (m)
R_c = hydrologic response coefficient, and
A_w = area of contributing watershed (Mitsch and Gosselink 2000, 128).

(8.3) $Q = I*R_c*A_w$

Q = peak streamflow at the outlet of the catchment (m^3/s), and
I = rainfall intensity (m/s) (Marsh 1998, 151).

(8.4) $SA = (\pi*W/2*L)/2$

SA = surface area of a marsh cell (approximately 1/2 an ellipse),
W = width of the marsh cell (2/3 of the spacing between tile drains), and
L = length of the marsh cell.

The following sections go through the steps for assembling figures for the water balance evaluation in greater detail. Once the hydrological parameters are estimated, the size of the design wetland can be calculated and specific requirements or modifications identified.

On a wider scale, the water balance in the area will determine how many of these wetland designs can be created within a given catchment area. Unless the catchment is exceedingly wet, it is likely that only one wetland complex would be feasible in a small watershed.

Qualitative assessment of water balance at the site.

An idea of the relative importance of different components of the water balance can be assessed by basic observation of a site: whether precipitation is the major contributor, or whether the area is wet even in dry periods and is receiving major groundwater inputs. The major sources and sinks of water can become obvious before measurements are even taken; this gives an idea of the kind of restoration project that is feasible for a given site and a forecast of the issues that may arise in fitting a design to that site.

The main water sources appear to be winter storm precipitation and runoff, as well as flooding coming from the backwatering of Richards Creek during winter and spring. Groundwater inputs and seepage have not been measured to date.

Climatic water balance

Determining climatic data on a monthly basis can indicate whether the area experiences a surplus or a deficit of water throughout the year, and the timing of water surplus or deficits. Deciding whether excess water or too little water will create more of a problem is a key design question (Hammer 1992, 151).

Mean annual precipitation for the basin ranges from 647 to 1263 mm, with an average of 1042 mm (Madrone Consultants 2001). Eighty percent of this precipitation occurs between October and March; very little falls as snow (Madrone Consultants 2001). Monthly climate data appears in Table 8.1.

Table 8.1. Climate data for estimating water balance at case study site.

	Mean precipitation, P (mm)	Estimated evapo-transpiration, ET (mm)	P - ET (mm)	Cumulative water balance (mm)
January	162.2	0	162.2	162.2
February	122.1	60	62.1	224.3
March	97.5	60	37.5	261.8
April	53.6	123	-69.4	192.4
May	41.6	123	-81.4	111
June	32.8	123	-90.2	20.8
July	21.0	123	-102	-81.2
August	25.0	123	-98	-179.2
September	46.0	123	-77	-256.2
October	90.5	60	30.5	-225.7
November	164.4	0	164.4	-61.3
December	194.3	0	194.3	133
Yearly	1051	918	133	133

Precipitation values are taken from the Duncan Forestry climate station for a 30-year mean. The values for evapotranspiration, for lack of empirical data, are estimated based on the peak evapotranspiration rate of 4.1 mm/day for Duncan given by the Irrigation Industry Association of British Columbia (IIABC 1999). For a conservative estimate of water availability, peak evapotranspiration is projected for six months of the year. For February, March, and October, evapotranspiration is estimated as half of the peak level. When rainfall is extremely high, during November, December, and January, evapotranspiration is given as effectively zero. The annual total of 918 mm is close to the measured annual total evapotranspiration measured at nearby Environment Canada stations at Nanaimo (831.3 mm) and at Victoria (859.9 mm). Estimating evapotranspiration in this way is thought to provide a conservative estimate for water availability.

The precipitation/evapotranspiration patterns show extreme seasonality. For six months of the year, precipitation is greater than evapotranspiration and there is a water surplus. For another six months, there is a water deficit as high evapotranspiration rates dominate. The problem therefore becomes a matter of storing the excess winter water to use during summer water shortages for wetland areas.

Surface water inputs

Surface water inputs include runoff from the immediate catchment, including overland flow plus channelized runoff through agricultural drainage systems, and also overbank flooding from adjacent streams. Restoration designs need to consider these two water sources.

a. Runoff estimation

A portion of the precipitation falling on a small agricultural catchment travels through the network of tile drains and collector ditches making up the farm drainage system. This runoff can be used to feed a restored wetland. Surface flows through drainage pipes and ditches can be measured on-site, by taking the product of the cross-sectional area and the average water velocity (Mitsch and Gosselink 2000, 128). Surface runoff can also be predicted based on climatic and watershed data (Hammer 1992, 26). The amount of precipitation falling on a watershed during a storm event resulting in runoff to the wetland can be determined by using equation 8.2.

Similarly, the rate of runoff flow from a storm event can be described by the rational method (equation 8.3, Box 8.2).

The value of the hydrologic response coefficient represents the proportion of precipitation that becomes direct surface runoff (Mitsch and Gosselink 2000, 128). The hydrological response coefficient for the small catchment of the Richards Creek Farm is estimated to be

0.3, based on the conditions of flat pasture land and clay/silt loam soils (Marsh 1992, 150). This means that 30% of precipitation falling on the catchment becomes immediate surface runoff.

Runoff volume and flow are used to calculate many aspects of a restoration design. Water control structures are usually sized based on the runoff flow from a 1-year 24-hour storm event (Hammer 1992, 171). Ponds or water-holding structures are designed for the 10-year 24-hour event flow; or if large in area, the 25-year 24-hour flow (Soil Conservation Service 1982).

The 1-year 24-hour storm event for the small catchment has not been measured directly at Richards Creek. A reasonable approximation can be estimated from the 2-year 12-hour storm intensity for the Victoria climate station (Lalonde and Hughes-Games 1997). From equation 8.3 (Box 8.2), and with the following values,

I = 2.9 mm/h (8.05x10-7 m/s) (Lalonde and Hughes-Games 1997),
R_c = 0.3, and
A_w = 4.05 ha,

the peak streamflow is given as 0.0098 m^3/s (almost 100 L/s).

Similarly, the 10-year 24-hour storm event is approximated based on the closest available data: the 10-year 12-hour storm intensity for Victoria of 4.2 mm/h ($1.12x10^{-6}$ m/s) (Lalonde and Hughes-Games 1997). Again using equation 8.3, peak streamflow for the 10-year storm is calculated as 0.014 m^3/s.

b. Flooding of outlet creek

Little is known about the flooding characteristics of Richards Creek, as it is primarily the fault of backwatering due to flow reversals in the low-gradient creek that floods the surrounding land, and not streamflow from its own upstream watershed. Personal accounts of flooding during the past 2 years at the Richards Trail farm have described two floods of 3 to 4 feet (0.9 to 1.2 m) between January and April, lasting for approximately two weeks each. A summary of the estimated water balance is given in Table 8.2.

8.3.1.1 Sizing the wetland design to the site's hydrology

Once the water budget is known or reasonably estimated, some simple calculations can be done to size the design wetland to the water balance of a particular site (Table 8.3).

Table 8.2. Summary of water balance evaluation at the Richards Trail farm.

Data	Parameter	Site condition
Observational assessment	primary water sources	• winter precipitation and storm runoff • winter/spring overbank flooding and backwatering from adjacent creek
Climate	monthly average precipitation	• mean annual precipitation = 1042 mm (range 647-1263 mm) • 80% occurs in winter months • monthly values in Table 8.1
	monthly average evapotranspiration	• annual estimate between 789-860 mm • peak evapotranspiration = 4.1 mm/day • monthly estimated values in Table 8.1
Surface flow from catchment	watershed area	approximately 10 acres (4.05 ha)
	1-yr 24-h storm event	estimated at 0.0098 m^3/s (equation 8.3)
	10-yr 24-hour storm event	estimated at 0.014 m^3/s (equation 8.3)
	hydrological response coefficient	$R_c = 0.3$ (flat, pasture, clay/silt loam)
Outside stream flooding	stream capacity	unknown at the site; downstream cross-sectional area is 15.66 m^2
	bank elevation	2.9 m
	flooding stage and frequency	unknown; anecdotal accounts estimate annual floods at ~1 m levels
Groundwater	seasonal water table levels	unknown
	hydraulic gradients	
	infiltration rate	

Table 8.3. Calculations required for sizing the wetland design to a site.

Habitat	Calculation	Data required	Important hydrological parameters
Horseshoe marsh	Width	spacing of tile drains	
	Depth	depth of tile drains	
	Length	minimum water volume available	water balance in catchment during seasonal lows
	Number of cells	length of drainage ditch	
Ditch channel	Dimensions of weir in ditch plug	2-year flood stage of stream into which it empties	stage of overbank flooding of adjacent watercourse
	Dimensions of stoplogs	1-year 24-hour storm flow	runoff flow from catchment
Ponds	Forebay volume	10-year 24-hour storm flow	peak volume of flood flow from catchment
	Backbay volume	10-year flood stage of adjacent watercourse	peak overbank flooding of adjacent watercourse

The two remaining habitats, the shrub buffer and the wet meadow ridges, are planted on the raised ground surrounding the constructed areas and do not require additional calculations.

Horseshoe marsh construction

The width of a wetland cell is constrained by the distance between parallel drainage tiles, which can vary between 8 to 20 m (Lalonde and Hughes-Games 1997). To allow space for a ridge of meadow planting between horseshoe wetlands, the total width of the horseshoe should be approximately 2/3 the distance between drain tiles. The depth of excavation should be level with the tile drain to allow water to drain onto the wetland surface before coming in contact with surface water in the ditch. This depth is typically in the range of 0.8 to 1.5 m (Lalonde and Hughes-Games 1997). Excavating deeper than this level will likely be counter-productive, as exposing too much groundwater may create greater evaporative losses than before (see Chapter 5).

The length of the wetland cell is then the dependent variable: it can be calculated based on local water balances, so that the system can maintain its hydrology using the natural water balance of the area. The wetland surface area (equation 8.4, Box 8.2) should be able to retain the minimum water requirement for marsh species during times of low water storage. The preferred water depths for target species are given in Table 8.4.

Table 8.4. Maximum and minimum growing season water depths for selected marsh plants.

Water depth (cm)	Galingale	Slough sedge	Sweetflag	Arrowhead
Minimum	0	0	15	15
Maximum	10	50	50	60

Therefore, the minimum water depth retained by the marsh cells during the dry season should be 15 cm.

The length and number of cells can be adjusted according to the constraints of local topography, the length of the collecting drainage ditch, or farmer preference. The total size of the wetland complex should be at least 0.4 ha to draw wildlife, however. In this area, existing tile drains are 1.5 m deep and spaced at 15 m intervals. If the cells are selected to be 40 m long, creating a series of 4 marsh cells on either side of the drainage ditch gives a total wetland area of 0.48 ha. (The wetland complex includes the wet meadow ridges along with the marsh cells.) A larger area would probably not be feasible at this site given that the farm acreage is only 3.2 ha in total.

Taking 2/3 of the spacing between tile drains gives a width of 10 m for each horseshoe wetland cell. Using this value in equation 8.4, the surface area of each marsh cell is approximately 314 m^2. Retaining 15 cm of water depth across this surface area therefore requires water storage of 47 m^3, or 329 m^3 for a wetland complex of 7 marsh cells (Figure 7.2). For comparative purposes, surface runoff from the catchment based on average precipitation in April (Table 8.1) is 651 m^3 (equation 8.2, Box 8.2). However, when the average precipitation for July is used, surface runoff only produces 255 m^3. This water source alone is insufficient to meet minimum water requirements; thus, retaining floodwater through use of the control structures is important at this site.

8.3.1.2 Ditch channel modifications

Ditch plug with weir

Without physical data on the flood stage of Richards Creek, the height of the weir in the ditch plug can be approximated based on anecdotal accounts. According to the farmer, the land in upper Richards Creek floods to a level of approximately 1 m at intervals between January and March. Backwatering up the drainage channel occurs during this time. Building a weir with its sill at a 0.8 m height would allow floodwater to enter the ditch and spread out into the wetland cells, but would also permit water to drain out if it threatens to overtop marsh plants immediately adjacent to the ditch channel.

Additional water control structures

Stoplogs are recommended for use at this site because they are one of the most resistant water control structures to beaver and rodent damage (Hammer 1992). The slot openings will be set at a metre or less in width, so that one bank of slots can be used to cut down on costs.

Like the height of the weir, the height of the stoplogs can only be an educated estimate as the water flow in the drainage ditch needs to be monitored prior to wetland construction. In the absence of accurate data, runoff from the catchment can be used as an estimate. The opening would therefore have to handle a flow rate of 0.0098 m^3/s based on the estimated 1-year 24-hour storm event (Table 8.2).

Using the manual from the U.S. Department of Agriculture (1997), a 15 inch (38 cm) diameter pipe should be used for a flow rate of 0.0098 m^3/s (0.35 cfs). This corresponds to a cross-sectional area of 1138 cm^2. A rectangular stoplog slot of 80 cm long by 15 cm high gives the required area for water flow. These dimensions are also sufficient to allow full wetland cell drainage of a group of 4 marsh cells (total surface area 1256 m^2 and a water height of 60 cm) within 5 days.

8.3.1.3 Pond construction

The capacity of the forebay pond should be large enough to handle runoff from the catchment, while the capacity of the backbay should be calculated from the flood stage and volume of floodwaters expected from the rising creek levels.

Since evaporation levels exceed 7.6 cm during the summer months, the pond depth needs to be greater than the minimum recommended depth of 1.5 m (USDA 1997). Because the agricultural catchment is so small (<8 ha), the 10-year 24-hour estimated storm flow of 0.014 m^3/s (Table 8.2) can be used to calculate a reasonable approximation of the required forebay volume. The U.S. Department of Agriculture (1997) provides a detailed set of instructions and calculations for sizing the pond to a given storm flow.

The dimensions of the backbay depend primarily on backwatering flood volumes coming from Richards Creek. After measurements of the flood stage and stream capacity are taken during the pre-construction monitoring phase, dimensions for the required volume of water can be calculated using the equation from the U.S. Department of Agriculture (1997) manual.

8.3.2 Soil characteristics

The soil on the farm has a high organic matter content and a low pH. Much of the surrounding region consists of silty clay 20 to 60 cm in depth over peat, with interlaying strata of clay and peat (Williams 2001). The water table is typically at 20 to 70 cm on these soils, although specific data are unavailable for the farm site. The soil structure is therefore quite amenable to wetland restoration.

Little is known about the soil communities or invertebrates on the farm site. The primary site-specific parameter to examine is the degree of agricultural pesticide use in the catchment. The farm is in its first year of organic farming and most of the catchment area is within farm boundaries, therefore little threat is expected from pesticide runoff.

The closest local natural wetland is a Ducks Unlimited and Nature Trust conservation site on Somenos Lake. Plugs of soil and water can be taken from this site in order to develop a healthy wetland microbial and invertebrate community as quickly and effectively as possible.

8.3.3 Common vegetation, disturbance patterns and threats

Within the Somenos Basin, vegetation types indicate a range of wetlands in the lowland regions. There are tree and shrub riparian areas, willow/shrub areas, and seasonally flooded agricultural fields with a mixture of coarse grasses (Madrone Consulting 2001). Regionally, concerns about vegetation in the area include the loss of wetlands, conservation of Garry oak woodlands, and general biodiversity protection (Madrone Consulting 2001). Willow-shrub wetlands are succeeding many of the marsh areas, reducing habitat for Great Blue Herons, wintering swans, geese, and ducks (Madrone Consulting 2001). Creating marsh habitat out of marginal farmland is therefore beneficial for counteracting biodiversity loss in the region.

The farm currently produces a selection of potted greenhouse herbs, a half-acre of field vegetables, and 5-1/2 acres of reed canary grass forage. Dock is the major invasive plant in the field and garden. Vegetation growing in the streams includes reed canary grass, sedges, iris, and smartweed (Lanarc Consultants 1999). Therefore, there is potential for natural colonization at the site, although invasion by reed canary grass should be monitored.

Other invasive species are also becoming more of a problem along with the increased development pressures and disturbance. These include broom, purple loosestrife, yellow flag iris, Japanese knotweed, and Himalayan blackberry (Madrone Consulting 2001). However, the blackberries do provide good cover for small birds, and current thought allows that some patches are beneficial (Madrone Consulting 2001). These do not necessarily need to be a concern unless they start to take over an area.

8.3.4 Wildlife value

The Somenos Basin is part of the Pacific flyway, a region used by many migrating birds (Williams 2001). Trumpeter swans are a common sight on the Richards Trail farm during the winter months.

The decline of biodiversity in the area has been identified as a management issue due to the increase in human impacts on natural habitat (Madrone Consultants 2001). Maintaining high waterfowl values, especially for Trumpeter Swans and Great Blue Herons, has also been identified as a priority by local conservation authorities (Madrone Consultants 2001). The issues are complex, as wildlife managers working on winter food management are often in conflict with farmers to whom waterfowl are a nuisance on agricultural land (Madrone Consultants 2001).

Waterfowl include Canada geese; Trumpeter and Mute swans; Great Blue, Green, and Night Herons; and many species of dabbling and diving ducks (widgeon, mallard, ring-necked duck, green-winged teal, bufflehead, shoveller, and hooded merganser) (Madrone Consultants 2001). Some shorebirds such as sandpipers and yellowlegs are also found between midsummer to October.

Somenos Lake, marsh, and tributary streams are important rearing areas for coho salmon and trout, also providing important winter fish habitat (Lanarc Consultants 1999). Eutrophication and increased summer temperatures in the creeks have decreased rearing habitat (Madrone Consultants 2001); however, the watershed is still considered to have high fish habitat potential (Lanarc Consultants 1999).

An agricultural design that restores habitat for these priority species while helping farmers to remain viable can be an alternative solution for problems of competing land use in this region.

9.0 Assessing challenges and opportunities: Evaluation, monitoring and future directions

This study investigates a possibility for integrating conservation and production into a system of land use that generates a sustainable income from wet marginal farmland while contributing to species conservation on a landscape scale. There are many social, economic, and ecological parameters to be explored in order to make this kind of wildlife-friendly land-use system a restoration alternative.

The future for this restoration alternative is encouraging: interest was high from study participants, and the technical ability to create the project exists. Preliminary results indicate that creating an integrated agricultural wetland is ecologically feasible. There are some challenges involved, some unknowns to be explored, and some interesting opportunities to follow up.

9.1 Physical and ecological aspects

Some sites may be more amenable to the proposed design than others. Some difficulties that can be foreseen include managing highly fluctuating water levels; possible poor water quality including high rates of sedimentation; herbivory by insects and wildlife; and competition from invading native terrestrial plants and wetland dominants, or alien invasives.

9.1.1 Unpredictable water supplies

Water supplies can be quite variable from year to year. Unpredictable water supplies may cause management difficulties, since manipulation of water levels is the main factor determining species composition and habitat in the wetland. Having the extra water retention provided by the forebay and the spillway pond may help mitigate against drought years, while routine maintenance of the water control structures should keep them functioning well during high storm events. Recording water balances as part of a long-term monitoring scheme will test the flexibility of the design with respect to different water conditions.

Climate change may have implications for the future of the design, if summers become much drier in coastal British Columbia. However, according to climate change scenarios developed by the Canadian Institute for Climate Studies at the University of Victoria, the annual water budget in both Nanaimo and Victoria is actually projected to show a slight increase in annual water surplus by 2070, with winters becoming wetter and summers showing only a minor decline (Murdoch 2002). The impacts of climate change should not affect the overall feasibility of the design.

Looking at the broader picture, water supply can limit the replicatability of the design within a catchment.

9.1.2 Water quality

The design may be impacted by too high nutrient levels in runoff water, too few nutrients available in the wetland, or too high or too low acidity levels.

Keeping sediment loads down is also critical to proper wetland function. If sediment loads are too high, the maintenance required to deal with it may compromise the feasibility of the project. A buffer such as a grass barrier can help control sedimentation rates by trapping incoming sediments (Prato et al. 1995); thus, the wet meadow ridges may be effective enough to handle the sediment load of a small catchment. The system's ability to handle increasing sediment loads should be assessed.

The opportunity with respect to water quality is that the restoration of the wetland may ameliorate water quality in the adjacent stream. This is very important in regions such as the Somenos watershed.

9.1.3 Insect management

Insect pests were identified among the greatest problems affecting local food producers, along with weeds, disease, and high seasonal flooding (Figure 4.7). However, the diversity of crops present in the wetland may actually provide opportunities for integrated pest management. Maintaining diversity provides a range of habitats that harbour beneficial pest predators and makes food items harder for the pests to locate (Fern 2000, 4).

9.1.4 Acceptable levels of herbivory

The primary purpose of this research is to have wildlife and crop production occurring on the same land. Herbivory must therefore be expected and allowed. Levels of herbivore damage that would be economically acceptable must be determined in future studies. Muskrats and geese are able to completely devour some newly planted sites (Middleton 1999, 49); this is obviously not acceptable if some sort of a crop is to be produced each year. Even geese feeding on the shoots and leaves of emergent plants can indirectly affect their rhizomes by reducing oxygen transport and photosynthesis (Keddy 2000, 378). Plant densities are lower and there is less tuber production in grazed areas (Evers et al. 1998). However, a moderate level of grazing actually increases diversity by opening up dominant stands (Middleton 1999, 50). Herbivores can help to reset succession (Evers et al. 1998).

There are many economic threshold models in the agricultural literature that can be modified for this purpose. However, 30% herbivory is expected for aquatic macrophytes in restoration sites (Keddy 2000, 371). The effect that taking a 30% level of acceptable damage would have on the economics of the site would need to be assessed in future work.

An opportunity associated with wetland production arises where the presence of water helps protect plants against herbivores. When surrounded by a water barrier, emergent aquatic plants have a lower rate of herbivory than their counterparts on moist soil (Warren 1993).

9.1.5 Interspecific plant competition

Invasive plants are a constant threat in restored or agricultural systems. Weeds are among the greatest hindrances to production described by study participants (Figure 4.7).

On the other hand, plant facilitation may provide good opportunities for this system. Some species of sedge help stabilize the substrate during winter floods and protect neighbouring plants from herbivores (Levine 2000). The benefits of intercropping wetland plants with tussock-forming plants like the sedge appear to be higher than the negative impacts of competition (Levine 2000). Including *Carex obnupta* or another sedge intercropped as part of the restoration design may actually benefit neighbouring plants.

9.2 ECONOMICS

Overall, participant response was extremely positive with respect to integrated wetland agriculture, and interest was expressed in viewing a demonstration project. Demonstrated financial viability was a strong positive incentive expressed during the interview process.

The length of time over which investment into the project is recouped can be an important concern for many landowners. There are models available that help in predicting the timespan of such projects. First, the cost of land conversion can be estimated by taking the opportunity cost of the lost land. This should be small, as the farmland to be restored to wetland is marginal for conventional production.

One model measures the loss of net agricultural income from converting cropland to wetland over a finite time horizon:

$$L = \Sigma^{T}_{t=1} [(1/n)\Sigma^{n}_{i=1}(P_iY_i-C_i)] / (1+r)^t] \qquad \text{(Prato et al. 1995)}$$

where

L = present value of loss in net agricultural income;

t = time index;

T = length of time horizon (years);

n = number of crops in rotation;

i = crop index;

P_i = price of the *i*th crop in the rotation;

Y_i = yield per ha of the *i*th crop in the rotation;

C_i = cost of production per ha of the *i*th crop in the rotation; and

r = discount rate (10% is often considered an appropriate rate for evaluating losses in private agricultural income).

Then, construction and maintenance costs for wetlands are given by:

$$CM = CC + \Sigma^{T}_{t=1} MC_t/(1+r)^t \qquad \text{(Prato et al. 1995)}$$

where

CM = construction cost plus present value of maintenance cost;

CC = construction cost; and

MC = maintenance cost.

The economic benefits to the landowner generated from the wetland are equal to the income generated from the wetland minus the lost agricultural income and costs of constructing and maintaining the design.

Another element to be explored is the lower operational costs of maintaining agriculture in a flooded setting because of natural pest control. Pest and weed control in the restored area is aided by periodic flooding (Snyder 1987; Porter et al. 1991).

A current economic challenge may be the actual marketing of wetland produce. However, markets for alternative products and alternative growing practices are growing; the specialty crops industry in British Columbia is expanding rapidly. Pre-mixed salad or spice blends may be able to command premium prices. Increasing the reputation of the farm by emphasizing wildlife-friendly farming may be a good farm advertisement as well. Targeting British Columbia's growing agrotourism industry may also be an option: there may be potential for additional income from bird-watching or ecological education outings.

Market studies on a test plot will include testing different creative marketing and advertising strategies to take advantage of the opportunities for new crop plants.

One thing must be kept in mind when considering economics: the intention of the design as a compromise solution between creating income and restoring an ecology. Thus, while it is possible for the design to be modified to maximize profit by focusing on certain crops, this would degrade its value as habitat.

9.3 Social marketing factors

The crops grown in the system must be more easily grown than wild harvested for the design to be desirable. Many plants are currently collected or picked from the wild. However, the growing concern for biodiversity conservation and the protection of wild resources has created a demand for the cultivation of popular wildcrafted plants (Small and Catling 1999, 5). Cultivation decreases the pressure on wild resources when the market price of a particular plant rises. Ginseng and Pacific yew are two examples of Canadian species that have been overcollected to the point of being threatened in the wild (Small and Catling 1999, 5).

Operationally, the unfamiliarity of the suggested plants as agricultural crops may also be a challenge. No fact sheets or easy references are available as yet for farmers wanting to grow arrowhead tubers. Experimentation on best practices must necessarily be a part of the planned demonstration project.

From a social marketing perspective, achieving buy-in to such a project may be an interesting project in itself. However, many agricultural innovations were looked at sceptically for many years before they became widespread.

9.4 Evaluating the opportunities

There are many unknowns associated with creating this design. Variables such as on-the-ground feasibility, crop production, and the conservation potential of the design can be tested and monitored on a trial basis. While the monitoring plan is an outline only, it should be able to provide baseline information about the quality of the habitat in a way that is easily measurable by most landowners.

An evaluative monitoring plan assesses different variables in the created wetland to create a measure of success or failure of the design with respect to project goals. The plan given here is meant to be a baseline guide; monitoring is often most successful as an iterative process where selection of indicators and definition of critical limits for success are permitted to adapt based on changing needs (Keddy 1999).

9.4.1 Evaluative monitoring

A newly planted site takes years before nutrient retention, soil development and wildlife usage are optimized (Mitsch and Gosselink 2000, 684). During this time, monitoring can provide the information needed for remedial action and to track the success of the system. Data should be collected annually for the first five years after planting, and then reduced to every two to three years (Galatowitsch and van der Valk 1994, 93).

Feasibility

The feasibility of the design will be appraised first on its implementation. A qualitative narrative account can document the ease of obtaining the required resources, the degree of land alteration needed to effect the design, the subsequent maintenance needed, and any other unanticipated difficulties. All costs, in money and labour-hours, are tabulated.

Vegetation success and productivity

A stratified random sample of five quadrats measuring 1 m x 1 m is designated for each wetland cell and wet meadow sub-area. First, a vegetation census is taken of each quadrat to determine the proportion of each species present on the site based on percent cover. Success is determined by the relative frequency of cropped species within the plots. A census is taken in May, July, and September to indicate successional processes (Galatowitsch and van der Valk 1994, 96).

The crop productivity is evaluated at the end of the growing season by calculating the biological yield and harvestable crop yield within the set of quadrats. Biological yield is defined as the weight of dry matter biomass accumulated by a species per unit area per growing season, while crop yield refers to the proportion of biomass collected in the utilizable components of the plants (Sinclair and Gardner 1998, 77; Tivy 1990, 90). Biological yield is useful for assessing the ecological productivity of the system according to environmental potential, while crop yield is useful for assessing commercial value. The biological yield at each of the experimental plots is assessed at the time of harvest. The harvested material is dried and weighed to obtain an estimate of both biological and crop yield. Extrapolation of average yield per ha will be determined. The yield of the crops can then be evaluated according to appropriate baselines from the literature. For comparative purposes, rice grain yields in California are often greater than 13 t/ha (considered a high yield) with crop residue of 10 t/ha left on the field (van Groenigen et al. 2003).

The cash value of the harvestable crop at the end of the season can also be calculated. The result is compared to the cost of time and resources for design implementation. If the harvested crop value over a given time period is greater than the value of the resources invested, the design can be considered to have productive potential. The amortization time for the design is unknown; a trial plot can test for this.

Conservation

Duelli and Obrist (2003) suggest how to select biological indicators depending on different motivations for monitoring biodiversity. From a conservation standpoint, choosing a wildlife group that includes some abundant and some rare species will give an idea of the ability of the design to support biodiversity at the species level. A pilot site should be able to give an initial indication of whether appropriate conditions for wildlife are satisfied (Block et al. 2001).

Global wetland conservation efforts have often been directed at waterfowl. The effectiveness of bird conservation has even been used as a means of determining success in conservation of biodiversity as a whole (Heath 2002, 24). Birds respond quickly to habitat alterations, reflect changes in other animals and plants, and initiate strong top-down effects in ecosystems (Heath 2002, 24). Data is realistic, easy to collect, and easily understood (Heath 2002, 24). This makes avian censuses feasible as a long-term monitoring strategy that is utilizable by farmers and local groups (Gliessman 1998, 305).

An avian census of each of the plots will be taken initially and on a bi-weekly basis following planting. A census is feasible because of the small size of the plot. A point census, using the same observation point and time of day for each site, will be conducted. A point census is useful because these are most applicable for animals such as migrating birds passing though a site (Underwood 1997, 134).

Alpha diversity of the avian community will be assessed; this measure represents the diversity of species within the habitat (Henderson 2003, 116). Common measures of species diversity include the Simpson Index and Shannon-Wiener Index. These indices are described in practical ecology texts such as Henderson (2003). The contribution of rare species to the Shannon-Wiener Index and Simpson Index of diversity is very small, as these indices account for the relative abundance of each species (Oka et al. 2001). Hence, species richness will be used as a more appropriate measure for conservation. The density of bird individuals within the plot will also be measured as an indication of habitat preference.

Two control sites in the local area will also be designated and surveyed according to the same process; one in the agricultural field surrounding the test plot, and one in the nearest undeveloped wetland. Comparison with these controls will help to determine whether any changes in wildlife presence or abundance occurred only on the test plot or across the local region. Knowledge of natural variations in wildlife use of the area will help guard against false assumptions about plot success or failure to maintain wildlife habitat (Grayson et al. 1999). In past wetland restoration projects, success has been defined as attaining 85% of the species richness of a natural wetland (Grayson et al. 1999). However, in Indonesia, historical polyculture cultivation has resulted in agroforests that contain 70% of the bird species found in natural rainforests of the area (Geno and Geno 2001). Since the created plot is intended to be in cultivation, this more conservative goal will be used to indicate success. Comparison with avian species inventories for the locality will also be conducted to determine which species avoided the created habitat.

If time and resources permit, monitoring other wildlife groups would be beneficial. Frogs are a good measure of water quality, and can be identified relatively easily by recording frog calls over the spring (Galatowitsch and van der Valk 1994, 105). Live trapping can be used for small mammals such as voles, a good indicator of healthy wet meadow and sedge habitat. A procedure for live trapping is given in Galatowitsch and van der Valk (1994, 107).

Water quality

Water levels should be carefully monitored, especially during the first few years, with a staff gauge (Galatowitsch and van der Valk 1994, 94). Monitoring of water quality, begun as part of the preliminary monitoring program, can be continued throughout planting and production years. Levels of nitrogen and phosphate, pH, pesticide residues, and presence of trace contaminants are measured through the monitoring wells. Sedimentation is measured on a seasonal basis to track any changes in rate so that adjustments to structures or maintenance such as dredging can be planned.

Further research will examine economic and social aspects of the production system; results from the experimental plots will be used to refine and modify the design.

9.5 Future vision and opportunities

Achieving greater sustainability in agricultural production systems is possible; opportunity to pursue alternatives is what is required. Providing a design that can restore habitat in wet marginal farmlands can create wetland biological corridors across the landscape. Wildlife can then migrate among wetland habitats (Tilton 1995).

Remedial agriculture can be described as restoring habitat to a farm through naturalized crop systems that re-create the natural habitat, promote wildlife conservation, and benefit the landowner. Using this idea to create an integrated wetland agriculture can contribute an alternative system that may overcome some of the barriers to integrated land use and provide sustainable opportunities for the Canadian small farmer.

Appendix

Additional crop information

Table A.1. Selected characteristics of wetland crop plants relevant to planting design.

	Crop	Planting time	Harvest time	Spacing & size	References
Wet meadow ridges	Anise hyssop	• spring	• spring – 1st cut • summer – 2nd cut	• 25 to 35 cm apart • up to 1 m tall	Anise Hyssop 2001
	Spearmint	• spring – cuttings	• spring to summer – leaves	• 15 to 20 cm apart • up to 60 cm tall	Greenwood 1995
	Aquatic mint	• spring – seed or cutting	• spring to summer – leaves	• 18 to 60 cm tall	Fern 2002 Greenwood 1995
Horseshoe marshes	Galingale	• spring – seed or divided clump	• fall – rhizome	• up to 1.2 m tall	Cyperus 2004 Fern 2000
	Slough sedge	• fall – bare rootstock	• spring – young shoots and leaves • fall – seeds	• average 60 cm tall	Hansen 2003b Thunhorst 1993
	Sweetflag	• spring – roots (divided in fall)	• spring – young shoots and leaves • fall – rhizome (2 years after planting)	• up to 1 or 2 m tall	Trenary 1997 Motley 1994
	Arrowhead	• spring or summer – tubers	• fall to winter – tubers	• 120 cm apart • to 30 cm tall	Missouri Department of Conservation 2004a Thunhorst 1993
Channel	Watercress	• spring – cuttings	• spring and fall – leaves	• up to 60 cm tall	Fern 2000 Thunhorst 1993
Shrub belt	Elderberry	• fall – rootstock or cutting	• spring – flowers • summer – fruit 3 to 4 year after planting)	• 1 m apart in 4 to 5 m rows • from 2 to 4 m tall and wide	Hebda Schooley 1995

*spring is defined as April to June, summer as June to August, and fall as September to November.

Recipes of interest for marketing purposes*

Sedge Seed Energy Bars

12 T margarine	a pinch of salt
1-1/2 C brown sugar	1 C sedge seeds, finely ground
1 egg	1-1/4 C whole wheat flour

Melt butter in saucepan; remove from heat and stir in sugar, egg, and salt. Add flour and seeds and stir until well mixed. Pour evenly into a greased 10 x 12 pan; bake for 10 minutes at 375°. Cool and cut into bars.

Mint Jelly

3 C mint water	8 drops green food colouring
1 box powdered pectin	4 C sugar

Take 1-1/2 to 1-3/4 cups tightly packed mint leaves and stems. Crush in a pan and add about 3 cups water; bring to a boil. Remove from heat and strain after 10 minutes standing time. Add more water as needed to make 3 cups of mint water. Bring mint water, food colouring, and pectin to boiling point. Add sugar, bring to a second boiling point and let boil for one minute, stirring occasionally. Remove from heat and skim with a spoon before pouring into glasses.

Mint Marinade

1/2 C red wine	30 chopped mint leaves
1/2 C red wine vinegar	1/8 t salt
1/3 C water	1/4 t sweet basil leaves
3 cloves minced garlic	1/4 t marjoram
1/2 C minced onion	

Combine and let sit overnight. Makes 1-1/2 cups.

Wapato and Sedge Salad

Wash and slice the inside base of sedge stems and leaves; combine with sliced wapato tubers. Toss with oil, vinegar, and seasoning to taste. Top with sedge seeds.

Watercress Potato Salad

4 or 5 medium potatoes (can use arrowhead tubers)	3 mild radishes
1/3 C minced green onions	1 bunch watercress
2 hard-boiled eggs	

Pickle dressing:

1/2 C mayonnaise or salad dressing	1/2 t fresh ground pepper
1/4 C pickle juice	dash fresh lemon
3/4 t salt	1-1/4 C whole wheat flour

Boil potatoes until tender; drain, cool, peel, and cube. Add onions, eggs, radishes, and dressing to coat. Toss and refrigerate until cool. Chop and add watercress just before serving. Top with rest of dressing. Serves 4 to 6.

Sedge Cereal

Dry seeds and remove hulls if desired. Bring 2 cups water to a boil with 1/2 t salt. Stirring, gradually add 1 cup seeds. After boiling, reduce heat and cook for 30 minutes, stirring occasionally. Serve with honey or sugar and cream.

**Recipes adapted from Furlong and Pill 1980*

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