GREENING

Your BC Golf Course

A Guide to Environmental Management

Fisheries and Oceans Fraser River Action Plan
Pêches et Océans Plan d'action du Fraser

Canada

Environment Canada Fraser River Action Plan
Environnement Canada Plan d'action du Fraser

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Acronyms Used in this Report:
DFO = federal Department of Fisheries and Oceans
BC MELP = BC Ministry of Environment, Lands and Parks

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1.0 Introduction

1.1 Environmental Management: A Win-Win Solution

Golf is rapidly emerging as one of British Columbia's most popular sport and leisure activities. BC's 230 golf courses draw an estimated 450,000 golfers each year from across Canada and around the world, and the number of courses increases by two or three each year. It's easy to understand what attracts golfers to the province — the scenic and diverse BC environment, combined with a moderate climate, provides an unparalleled range of golfing experiences that can be enjoyed year-round.

As the number of golf courses continues to grow, so does the need for prudent environmental management. Golf courses are often constructed near streams or rivers for aesthetic reasons and to meet irrigation requirements. Their proximity to environmentally sensitive areas means that golf course development and maintenance can impact aquatic and wildlife habitat. Construction activities, herbicide and pesticide use, irrigation withdrawals and other routine golf course procedures can harm fish and wildlife habitat if performed without consideration for these values.

Responsible environmental management offers numerous advantages not only to the environment and the public, but also to golfers, golf course superintendents and owners. Specifically, it:

- may reduce the potential for opposition to a new or expanding course;
- facilitates course management by defining objectives and responsibilities;
- provides a progress record for future planning;
- creates healthier turf;
- reduces chemical use, thereby reducing the chances of chemical dependence, kill-off of non-target species, turf stress due to chemical misapplication, and exposure of staff and players to toxic substances;
- lowers operating costs through reduced chemical use;
- averts costs associated with developing

environmentally sensitive areas (e.g., approval and habitat reconstruction costs);
- avoids repair and maintenance costs in areas prone to seasonal flooding (e.g., side channels, floodplains and wetlands) and costs associated with the loss of agrochemicals;
- protects water quality for downstream users;
- reduces erosion problems;
- increases course aesthetics by maintaining natural vegetation, which also provides natural boundaries for play; and sustains fish and wildlife populations, increasing a course's contribution to the liveability of a community and making it a more desirable constituent.

In contrast, poor environmental practices can lead to:
- higher long-term management costs;
- habitat fragmentation and loss;
- contaminated soil and sediment;
- poor water quality;
- excessive erosion;
- reduced water levels; and
- fish kills.

Many superintendents already incorporate good stewardship practices into golf course management through Integrated Pest Management (IPM). IPM forms an essential component of good management, but environmental management must also consider other practices that can impact the environment, such as stormwater management, pesticide and fertilizer storage, equipment washing and composting.

This document is intended to guide managers in the design and management of golf courses that benefit both course owners, operators and golfers; *and* fish and wildlife. If you're still in the planning stages of your golf course, section 2.0 describes design and construction considerations that minimize habitat disturbance, enhance course aesthetics and may help smooth government approvals. Section 3.0 describes management options to maximize the environmental performance of both new *and* previously existing golf course facilities and practices.

Many of the approaches outlined in this guide are relatively simple, while others may require professional advice from an environmental consultant or government representative. Section 4.2 lists a number of contacts that can provide help and guidance. In addition, sources for additional information are highlighted throughout the guide.

1.2 Fish and Wildlife Habitat: What to Look For

Effective environmental management requires some knowledge of key habitat features and how they function. This section describes the features of healthy stream, **riparian** and upland habitats, and how they work together to support fish and wildlife while maintaining the aesthetic appeal of your golf course.

riparian: relating to, or located on the bank of a watercourse, such as a river, lake, stream or a tidewater

1.2.1 Streams

Most streams provide valuable fish and wildlife habitat, even those that are very small, modified or that run dry at times. A variety of in-stream features support fish and wildlife in different ways. The following text describes a few of the more important features of stream habitat:

photo courtesy of DFO

Riffles are relatively shallow, swift and turbulent sections of a stream. They add life-sustaining oxygen to the water and support a diverse array of aquatic insects upon which fish prey. Riffles are excellent sites for fish spawning, egg incubation and overwintering.

Pools are slower, deeper sections of a stream. They provide resting, rearing and cover habitat for all stages of fish life.

Undercut banks provide juvenile fish with cover from predators, and serve as rearing and winter refuge areas. Overhanging vegetation on the banks supplies additional cover and helps to keep the water cool.

Substrate is the collection of materials that makes up the stream bottom, including sand, mud, bedrock and gravel. Salmon and trout require clean, unsilted gravel beds for spawning and egg survival. Clean gravels allow stream water to flush through, and provide incubating fish eggs with a steady source of cool, clean water.

Good water quality is a central element of fish habitat. In general, water must be cool, clean and well-oxygenated to support healthy fish populations.

Adequate water flow is extremely important. Low flows can leave fish stranded in pools or make them more susceptible to predators, contaminants and higher water temperatures.

Large natural debris (such as boulders, logs and rootwads) add diversity to stream habitat by contributing to streambank stability, trapping gravels and scouring pools. The diversity of stream habitats will support a greater number of species and contribute to the stability of ecosystems. Large woody debris also provides fish with a place to hide from predators.

Access is important in developed and developing areas. Fish must be able to pass through migration corridors and can be blocked by poorly placed culverts and other obstructions.

1.2.2 Riparian Zones

Riparian zones are the bands of land surrounding lakes, wetlands, streams and rivers. These areas only occupy a small portion of the land in a watershed, but are wetter and more productive than upland areas. Their lush, diverse vegetation provides habitat for numerous species of mammals, birds and reptiles. Marshy wetlands in riparian areas are often removed for aesthetic reasons when golf courses are developed. However, these wetlands are a critical asset to a healthy watershed.

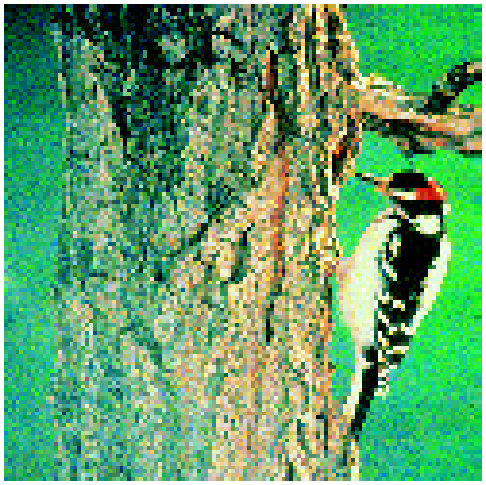


photo courtesy of CWS

Wooded riparian zones are great habitat for birds.

Specifically, riparian vegetation provides:

- **Breeding and feeding grounds** for fish, birds and wildlife. Lush riparian vegetation provides great bug habitat. Insects dropping from overhanging vegetation or munching on submerged organic material are a significant source of fish food. Many birds (such as songbirds, red-tailed hawks and great horned owls) nest in mature or dead trees of the riparian zone. Others stop in riparian areas to “fuel up” on berries and

seeds during their annual migrations. Wetlands and their riparian zones are also essential breeding areas for waterfowl.

- **Wildlife corridors** that connect larger habitats together. These sheltered routes allow animals to migrate from one area to another with some level of protection.

- **A natural water filter** that helps to keep the water clean. Trees, shrubs and grasses filter eroded soil from runoff water. This helps to keep sediment on land instead of on stream bottoms, where it can smother spawning gravels. Plant roots are also effective at removing excessive nutrients which can result from fertilizer application near water. High nutrient levels in streams stimulates the growth of algae to harmful levels, which damages fish habitat and degrades water quality.

Erosion control by stabilizing the stream banks. The dense vegetation reduces sediment runoff and minimizes disturbances to fish habitat.

A study of several small BC rivers showed that only 14 per cent of vegetated bends eroded, while 67 per cent of non-vegetated bends eroded during the same flood event.

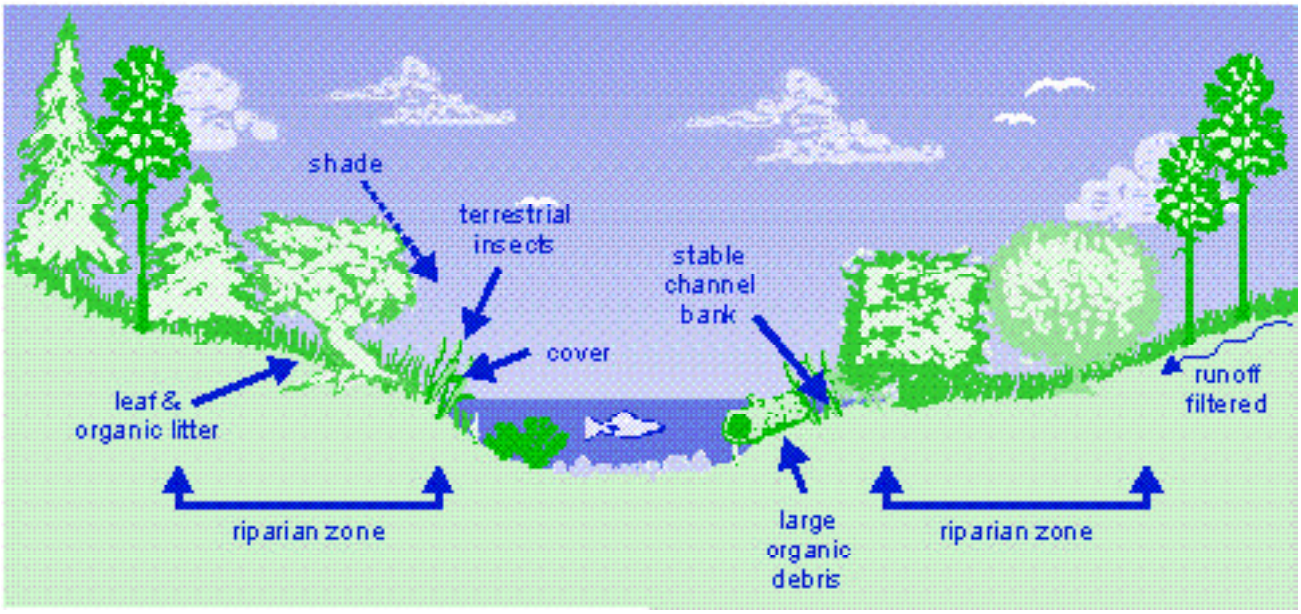
Shelter and Cover from predators and adverse environmental conditions. Wetlands and side channels provide refuge for fish during high flow periods. Large natural debris (such as fallen trees and rootwads) provide fish with protection from predators.

Shade that moderates water temperature. Fish are very sensitive to variations in water temperature. Water temperatures greater than 20°C can be fatal to salmon and trout.

1.2.3 Uplands

Upland wooded areas provide perches for raptors and nesting habitat for songbirds. They also serve as additional buffer areas that help prevent contamination of stream waters through surface runoff, and help moderate seasonal flow patterns. Roughs and out-of-play areas that are not wooded are excellent habitat for small mammals (such as voles) and their predators. Larger mammals also benefit from natural areas on the golf course — many golf courses report deer, foxes and raccoons on their grounds.

Figure 1.1
Image of a Healthy Riparian Zone



2.0 Designing & Building An Eco-Friendly Golf Course

Golf course designers must consider numerous issues during the initial planning stage, many relating to course layout and playability. This stage also provides an excellent opportunity to develop a layout and implement cost-effective controls that are sensitive to the natural environment and enhance the aesthetic appeal of the course. A good design also demonstrates environmental stewardship, which fosters good community relations and may help expedite approvals.

From an environmental perspective, a good golf course design:

- protects streams and streamside vegetation;
- manages runoff to maintain water quality and quantity for recreation purposes, drinking water supplies and fish survival;
- minimizes erosion and sedimentation;
- protects or enhances bird and wildlife habitats; and
- protects natural wetlands.

photo by O. Langer

A good environmental design enhances a golf course's scenic qualities.

This section discusses the elements of good environmental design. Many elements may require assistance from a reputable environmental consultant. General guidance is also available through regional offices of the federal Department of Fisheries and Oceans (DFO), or the fisheries and wildlife branches of BC Ministry of Environment, Lands and Parks (BC MELP). The telephone directory blue pages list contact numbers for these government agencies.

There are three main steps to achieving a good environmental design. The first is to record existing fish and wildlife habitat on the proposed site. This information is then used for the second phase, which involves developing a plan to protect critical habitat through a well-designed course layout. Finally, measures should be taken to protect sensitive habitats during construction of the golf course.

2.1 Documenting Fish and Wildlife

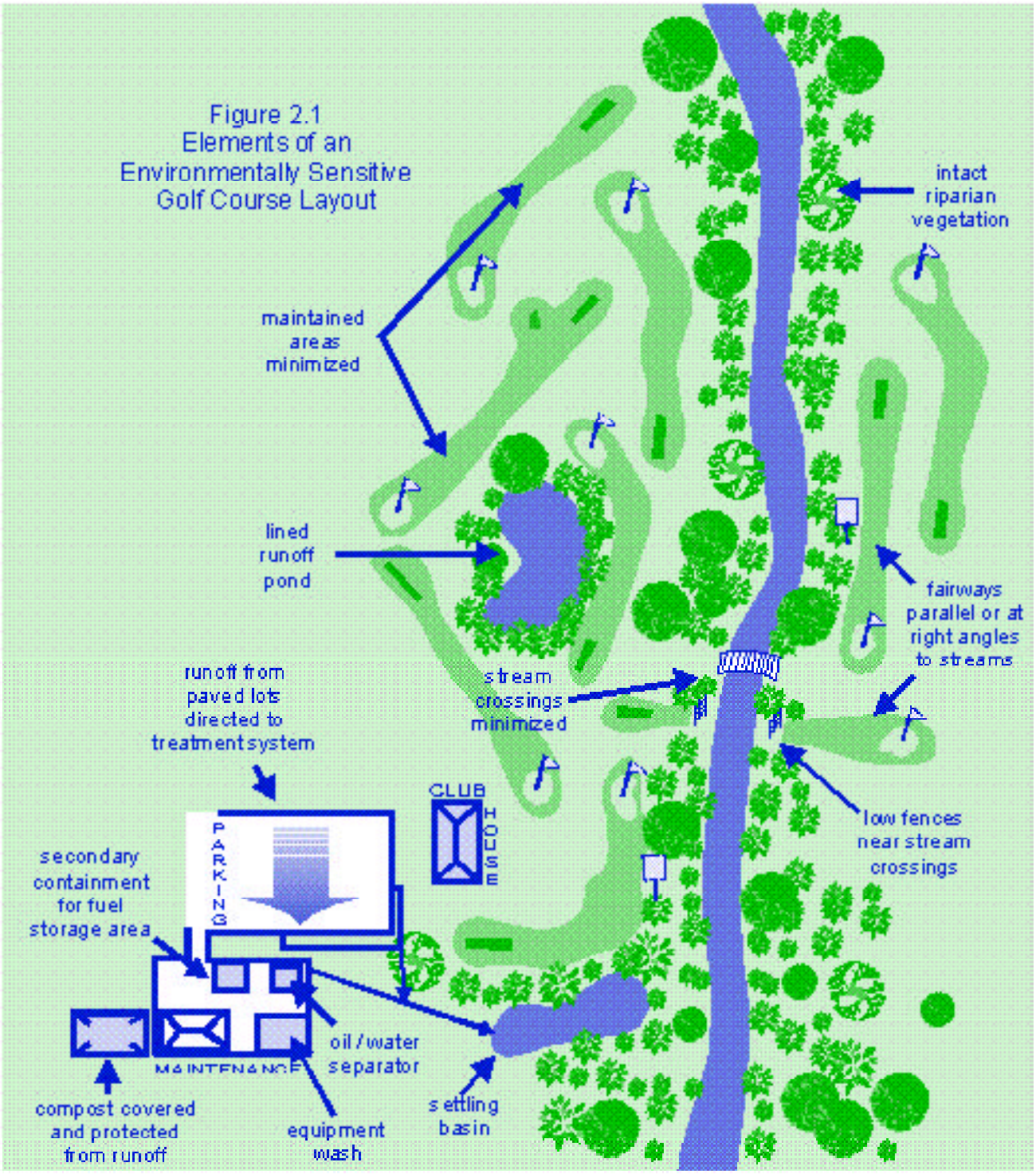
A careful survey of fish and wildlife on the proposed site can reveal sensitive or critical habitat areas that should be preserved. Information gathered at this stage will help to guide course layout and determine which species should be the focus of habitat management. This, in turn, determines the kinds of habitats that will be preserved, created or enhanced during golf course design. Remember, the federal DFO has a "no-net-loss" policy for exiting fish habitat.

A biologist can identify significant flora and fauna.

2.2 Designing an Eco-Friendly Layout

Using the information gathered during step one, prepare a detailed plan showing how critical fish and wildlife habitats will be preserved, created and maintained on the golf course. As much as possible, the golf course should be designed to maintain the same wildlife species that inhabited the site before development. The plan should identify the habitat requirements of each species or group of species and indicate how these requirements will be addressed. It should also consider all applicable environmental acts, regulations and guidelines (these are listed in Section 4.1).

A reliable environmental consultant can provide useful advice during this planning stage to guide golf course layout and construction. Some of the following design principles may be included in the golf course layout to minimize habitat disturbance. Figure 2.1 illustrates how some of these considerations can be incorporated into the layout of a golf course.



Avoid alterations to floodplains and watercourses.

Filling floodplains or modifying watercourses often results in reduced water storage capacity or channel conveyance, channel obstructions or increased erosion. Modifications of this nature require prior written approval from DFO, BC MELP and possibly local governments. Some jurisdictions require that course construction not change the floodplain storage characteristics below the 25 year floodplain.

Avoid developments near wetlands.

Due to their high ecological value, development in the vicinity of wetlands should be avoided. Any runoff from golf courses should be directed away from naturally occurring wetlands. If courses are to be located near

wetlands, the course design should recognize and avoid disrupting the hydraulic connections between the course and the wetland, and consider the impacts of surface water alterations, diversions and course contouring. This will help avoid damaging or destroying wetlands by interrupting the connections between the wetlands and their water supply.

Development around wetlands can disturb ecosystem processes or impact habitat use by making the wetland less attractive to wildlife. Golf course design should aim for no-net-loss of wetland function and values as defined in the *Federal Policy on Wetland Conservation*. A buffer zone of at least 15 m (preferably 30 m) should be maintained around existing wetland areas on the golf course. Constructed wetlands for stormwater management should not disrupt the functioning of natural wetlands.

Minimum areas for habitats are discussed in *Working Guidelines for Golf Course Development* by the Canadian Wildlife Service.

Incorporate or preserve wildlife habitat areas.

Golf course development will inevitably change existing habitat conditions. Good golf course design can preserve many aspects of the existing habitat and much of the fauna. In some areas, management might involve leaving the original habitat intact. In other areas, it might be desirable to create wildlife habitat. Scalloped edges and a gradual increase in shrub and tree height can be incorporated in the design to maintain ideal turfgrass growth conditions while retaining or adding to habitat values.

More information on native vegetation is found in *Native Tree and Shrub Cover Recommended to Enhance Fish and Wildlife Habitat* by BC MELP.

Wildlife habitat areas must be of a significant size to support wildlife and provide adequate food (e.g., seeds, nectar or invertebrates), nest sites, perches, and nearby water sources. Large continuous habitat areas are more useful to wildlife than the equivalent area in small pieces. Some wildlife, particularly terrestrial species, need continuous cover to facilitate migration, movement from nesting to foraging habitat or dispersion of young into new areas. Golf course design should strive to connect habitat areas by providing corridors at least 15 m wide. These corridors may be vegetated with tall grass and herbaceous or woody species. They may include wetlands or stream and lake banks, but should not be cut by paths, fairways or greens.

Utilize native plant species in habitat areas and for landscaping.

Some wildlife species require native vegetation. Where possible, existing vegetation should be left undisturbed. Where existing vegetation cannot be preserved, but wildlife habitat is desirable, native grasses, herbs, shrubs, and trees should be planted. Native vegetation should also be used in landscaping around golf course buildings, parking lots and roadways.

Retain roughs and grassy out-of-play areas.

Roughs provide foraging habitat for raptors feeding on voles and other rodents. Where possible, these areas should be allowed to grow to a height of 25 to 30 cm and kept as "old-field" habitat. Old field habitats are excellent sites for voles and other rodents that nest and feed in the thatch that accumulates near the ground. If the grass is allowed to grow any taller, the raptors will have difficulty detecting their rodent prey. Where the rough is to be planted, select grass species that are relatively deep rooted and climate tolerant and let them grow to the maximum acceptable height.

Avoid soil compaction.

Avoid the disturbance or compaction of the soil's upper layer interflow network. Areas that have been compacted should be tilled prior to seeding or turf placement. In areas where

Figure 2.2
Minimum Leave Strip for a
Well-Defined High Water Mark

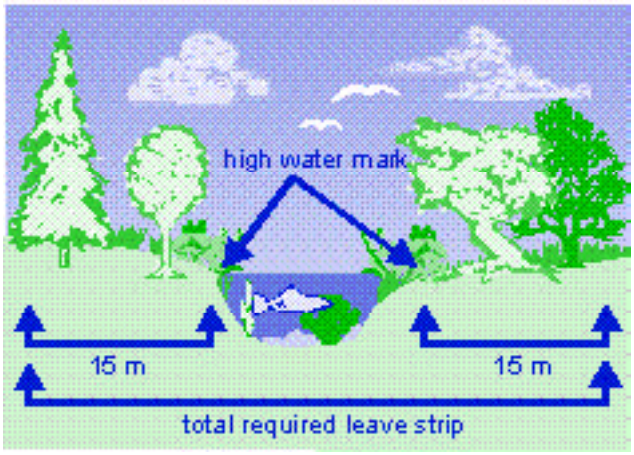


Figure 2.3
Minimum Leave Strip for a
Poorly-Defined High Water Mark

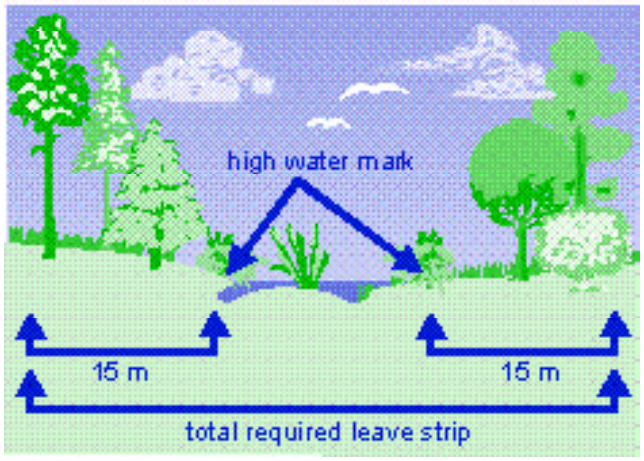
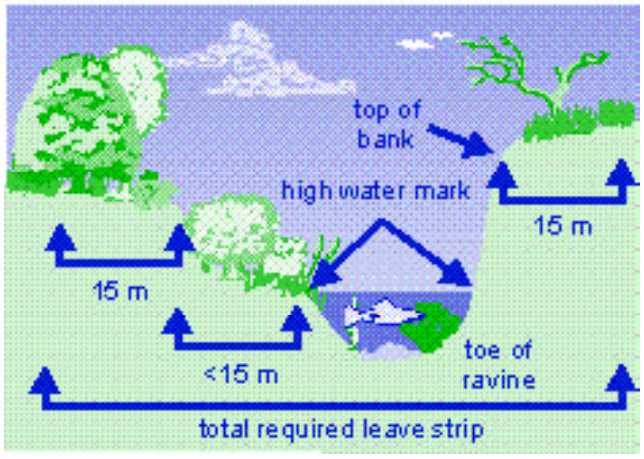


Figure 2.4
Minimum Leave Strip for a
Ravine or Steep-Sloped Banks



excessive soil compaction has occurred, a sandy loam material should be placed on top of the tilled soil.

Protect streams from contamination. There should be no direct discharge of course runoff to streams or wetlands because golf course runoff may contain fertilizers and pesticides. Runoff should be directed to either retention ponds or vegetative filter strips prior to release to a receiving environment that directly or indirectly supports fish.

Riparian vegetation should be left intact to protect bank stability, water quality, shading of the stream and valuable habitat. If revegetation is necessary, only native species should be used. A minimum 15 m leave strip is recommended for streams used directly by fish and larger streams which flow into fish-bearing streams. A 5 m minimum is recommended for small streams that provide food and nutrients to fish-bearing streams. Figures 2.2 to 2.4 provide examples of leave strip definition.

High maintenance areas (e.g., tees, greens and fairways) typically experience the most significant alterations to natural conditions and usually receive the most intensive chemical treatments compared with other areas of a golf course. By keeping these areas to a minimum, the overall change in runoff quantity and quality can be minimized. High maintenance areas located near streams and wetlands should be lined to ensure that chemicals do not infiltrate to the groundwater and gain access to streams and wetlands. Drainage from greens and tees should be directed away from surface waters. It may be possible to return this drainage to the irrigation system through the use of ponds, after treatment has improved water quality. Pesticides and fertilizers should not be applied in close proximity to water bodies or watercourses. Applications made too close to open water may enter the aquatic environment, with potential impacts on fish, wildlife, vegetation and downstream water users.

It is desirable to locate low maintenance areas (e.g., roughs) near streams and wetlands. Roughs survive well without fertilizers and pesticides, and require less mowing. Therefore,

they generate lower risks of impacts to streams and wetlands than high maintenance areas.

See Section 3.4 for further information regarding pesticide and fertilizer-free zones

- ***Design ponds to minimize seepage and runoff.***

Figure 2.5 illustrates a recommended design for ponds that do not discharge into streams. The ponds should provide habitat diversity and maintain acceptable water quality. The design should include a random distribution of the following elements: 40 per cent emergent aquatic vegetation; 40 per cent submergent aquatic vegetation; and 20 per cent open water of at least three metres in depth.

In areas with permeable soils, ponds should be lined with either a synthetic or clay liner to prevent seepage into groundwater and nearby aquatic systems. The water may be used for irrigation purposes if there is sufficient volume.

If a pond discharges into a stream, it should be designed to maintain fish passage, provide habitat diversity, and achieve acceptable water quality. In this case, pond design and management should encourage several habitat zones. Figure 2.6 shows a sample design that includes: 20 per cent emergent aquatic vegetation; 30 per cent submergent aquatic vegetation; and 50 per cent open water (including the outlet channel) of at least three metres in depth. The quality of existing water should be tested.

As an additional benefit, ponds can be designed to discourage non-compatible species that are not threatened or endangered. Some wildlife species (e.g., widgeon and Canada

Figure 2.5
Recommended Vegetation
for Ponds Not Connected to Streams

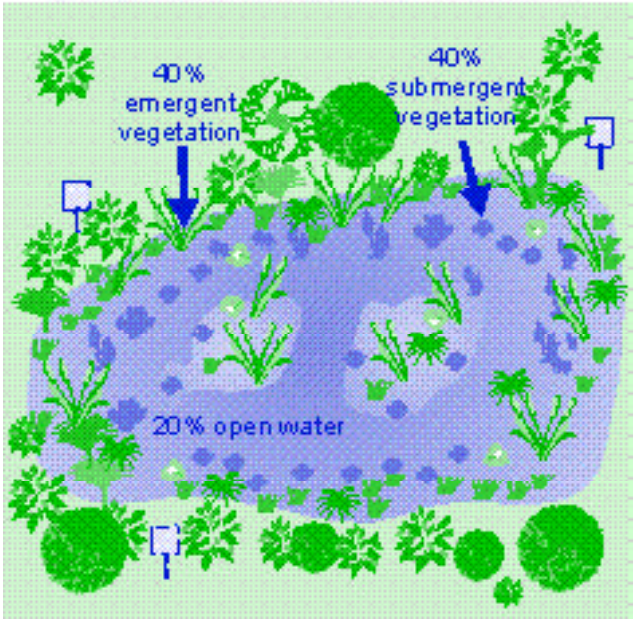
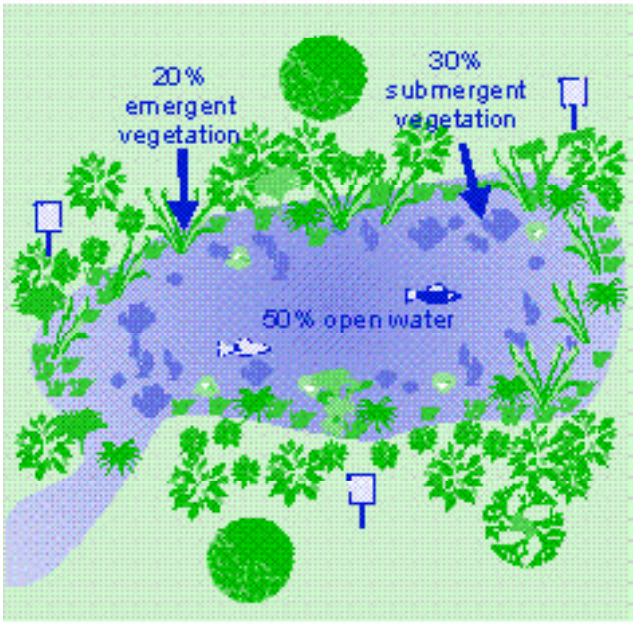


Figure 2.6
Recommended Vegetation
for Ponds Connected to Streams



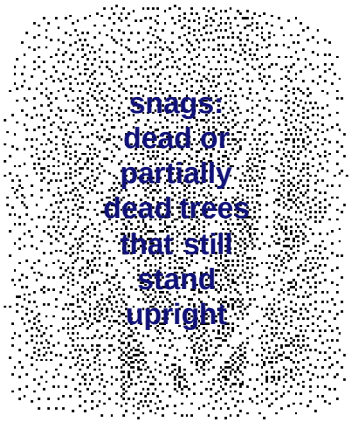
geese. Nesting islands should not be created unless the pond is surrounded by very tall trees. Marshy areas in the centre of ponds should not become dry during nesting season.

Limit stream crossings.
Stream crossings should be avoided, especially in fish-bearing streams. Fairways located parallel to streams, but separated from the stream by a buffer of riparian vegetation, reduce the need for crossings. Where fairways cross streams, they should cross at right angles. Rather than removing riparian vegetation to create a visual pathway between the tee and the green, it is recommended that either the tee, green or both be elevated.

Where approval is obtained for stream crossings, bridges are recommended over culverts or fords. If a culvert must be installed, fish passage must be ensured during periods of both high and low flow. A variety of culvert designs are available, some of which are more suitable to fish passage than others (e.g., those that maintain natural substrate). Steel or pre-stressed concrete are the preferred building materials. If wood is to be used for a bridge, it should ideally be untreated. If treated wood is to be used, the preferred preservative is chromated-copper-arsenate.

Protect forested areas.
Significant areas of forested habitat on a golf course, especially if linked with forested areas outside the golf course, can provide excellent habitat for many wildlife species. Mature trees and shrubs are also more effective at intercepting water and evapotranspiration than grasses, and are particularly useful in erosion-sensitive areas, where their extensive root systems help hold soils together. If the golf course site supports mature forest, design the course to retain as much of the original forest as possible. For example, if a mature tree is located near a green, trim it to get more sun rather than cutting it down. Consult a biologist to identify areas with the greatest ecological value.

Where they do not pose a danger, retain wildlife trees and snags as nesting habitat for cavity nesting birds and perches for **raptors**. Wildlife trees are mature trees that have special importance for certain species of wildlife. For instance, large cottonwood trees are a food source for woodpeckers and provide excellent nesting site. Mature conifers are often used as roosts by owls. Trees containing raptor nests are protected under the provincial *Wildlife Act* (see Section 4.1). The tree itself and a buffer of a given size must be retained during construction. Consult BC MELP to determine the appropriate buffer size.



Snags are an integral part of forest and riparian ecosystems and should be left standing whenever possible. They provide excellent perches for raptors and their decaying wood is often full of the insect larvae upon which woodpeckers feed. Consult a professional arborist if safety is an issue. They may recommend topping a tree, leaving a stump of four of five metres still standing. This will reduce the safety hazard and still provide some of the habitat values for wildlife. Consider installing perching poles for raptors, in association with smaller trees.

Put up nest boxes to encourage nesting by cavity nesting species.
Many bird species will utilize nest boxes for breeding. Nest boxes can be designed to attract particular species such as swallows, wood ducks and barn owls. Success at attracting birds with nest boxes often depends on attention to the details of design and finishing touches that will deter predators or competitors. There are many good books on nest box design. Alternately, consult a local naturalist group or the Canadian Wildlife Service.

Minimize human intervention.
Maintaining the integrity of habitat areas is important to ensuring their continued use by wildlife. Golfers should be encouraged to enjoy wildlife sightings, but not to enter or disturb habitat areas. Planting densely branching non-invasive species of shrubs, such as black gooseberry, or thorny species such as black hawthorn, can provide excellent habitat for passerine birds that feed on berries. These plants also deter humans from entering ecologically sensitive areas. Signage explaining the habitat values on the golf course and requesting patrons to keep to the playing areas can provide effective public relations and protect habitat areas.

photo by B. Galbraith

Signs and fences ward off golfers from environmentally sensitive areas.

Where an existing fairway crosses a stream, a low fence can be installed on either side of the watercourse to intercept stray golf balls and discourage golfers from entering the riparian zone to retrieve balls. Vegetation may be used to disguise the appearance of the fence. Higher fencing can be installed near watercourses that parallel fairways.

2.3 Protecting Sensitive Habitats During Construction

Whether you are constructing a new golf course or modifying an existing course, an erosion and sedimentation control plan is an essential step in the design phase. Unmitigated development can result increased erosion, potentially impacting both water quality and aquatic habitat.

Erosion is a function of soil types, geologic materials and slope. When developing a control plan, identify and map the erosion hazards. Use this information to develop a course layout which avoids erosion-sensitive areas. Construction in areas with high erosion potential is best avoided. In areas with moderate to high erosion potential, implement erosion control and stabilization practices and monitor prior to and during construction. The sensitivity of terrain to erosion is typically categorized as follows (slope ranges may vary, depending on the native materials and type of cover):

Erosion Sensitivity	Slope
High	>40%
Moderate to High	15-40%
Moderate	8-15%
Low to Moderate	<8%
Low	<1%

Technical aspects of land development are discussed in *Land Development Guidelines for the Protection of Aquatic Habitat*.

Sediment control management practices are required to reduce the sediment loads in stormwater runoff from areas under construction. The principles behind minimizing sediment release include: minimizing the extent of disturbed areas, protecting exposed soil surfaces from runoff and stabilizing disturbed areas as quickly as possible. Key erosion and sediment control practices to be implemented during construction are discussed below:

Schedule earthworks appropriately.
Avoiding clearing, grubbing and heavy construction during wet periods, and stage development so that any new vegetation has time to become established prior to the end of the growing season. Clearing and grading should be conducted in stages to limit the total soil area exposed at any one time.

Divert surface runoff away from erosion-sensitive areas.
Cleared and grubbed areas should be isolated with swales and overland flows should be directed away from downslope development. The slopes of the swales should be minimized to reduce erosive energy. The erosive energy of runoff from a steep, long slope can be minimized by creating interceptor ditches. Interceptor ditches with high gradients can be lined with filter fabric, rip rap or polyethylene.

photo by B. Galbraith

A settling pond used during construction.

In areas susceptible to erosion, preserve existing vegetation as much as possible.
Careful planning of the construction process will minimize the needless disturbance of vegetation. In particular, vegetative cover should be preserved in erosion-susceptible areas (e.g., steep slopes and sensitive soils). A corridor of existing vegetation between construction areas and watercourses traversing the site can provide a buffer zone for streams.

Place a sod buffer strip around newly seeded areas.
In comparison to newly sodded areas, newly seeded areas are much more susceptible to soil erosion and fertilizer runoff. A sod buffer strip acts as a protective sediment and nutrient filter.

Establish silt fencing below construction zones.
Cleared fairways should have silt traps or enviro-fencing (protective fencing with filter cloth placed 150 mm into the soil and 600 to 900 mm above the soil) established on the downslope side to prevent sediment migration. These fences can also be used to protect other erosion-prone areas or areas sensitive to the impacts of erosion.

Protect soil stockpiles and exposed soils from erosion.
Top soils are often stripped and stored for re-application once grading and sculpting is complete. Stockpiles of top soil and earth should be covered with waterproof materials to prevent the generation of sediment-laden runoff. Temporary covers (e.g., grasses, mulches, matting and plastic sheets) can be used to minimize erosion in temporarily exposed soils.

Use constructed sediment control measures when necessary.
It is not always possible to control sediment generation at its source. Where stormwater runoff contains sediment, employ structural methods to reduce sediment loads, including check dams, sediment ponds, and enviro / silt control fencing.

Regularly inspect and maintain sediment control measures.
A maintenance and inspection schedule should be prepared for all sediment control measures. Sediment control materials should be readily available, if necessary.

Fence off sensitive habitat during construction to ensure protection.
Leave strips adjacent to watercourses should be flagged and enclosed by a temporary fence prior to construction to ensure that there is no encroachment into these areas.

3.0 Managing An Eco-Friendly Golf Course

Sound environmental management practices are equally as important as a good golf course design. Good management practices allow you to maximize the environmental benefits of a new course or existing facilities. They can also lead to lowered maintenance costs and good community relations.

This section discusses the general elements of an effective management plan. It also outlines best management practices for specific operations such as stormwater management, irrigation management, integrated pest management, and maintenance area management; that might be incorporated in your management plan. The concepts are directed towards the protection of surface water quality and aquatic habitat, but they also have relevance to the protection of other areas of environmental concern such as groundwater quality and fish / wildlife habitat.

The Cooperative Sanctuary Program was developed by the Audobon Society, in conjunction with several golf associations, to promote ecologically sound land management. Through this program, the Society provides assistance on environmental planning issues. Call (518) 767-9051 for more information.

This guide is not intended to be an exhaustive review of all management issues. Management decisions must consider numerous factors, often of a very site-specific nature. It is recommended that this guide be used by the superintendent in conjunction with good educational background and experience. Further information regarding the practices described in the guide can be obtained from the guidelines listed in Section 4.1 or the agencies listed in Section 4.2.

3.1 Components of an Effective Management Plan

A documented plan is a prerequisite for a successful management endeavour. While a number of routes may be taken to develop a plan, the essential procedures remain the same. They are as follows:

1) Identify people / agencies affected by the management plan.

It is important to establish routes of communication and seek input from those affected by the management plan. Key persons and agencies will include:

- course owner(s);
- course superintendent and assistant superintendent;
- employees;
- golfers; and
- government agencies (e.g., BC MELP; BC Ministry of Agriculture, Fisheries and Food; Environment Canada; and DFO).

2) Define the management areas and gather background information.

Management areas include turfed or non-turfed areas, natural areas, the maintenance area and environmentally sensitive areas (i.e., ponds, streams, wetlands and any other areas with high habitat value or sensitivity). Relevant background information includes soil types, plant types, pest pressure histories (e.g., pest type, location, season, development conditions), prior successful and unsuccessful pest control methods, prior cultural practices and impacts on environmentally sensitive areas.

3) Define the goals and objectives of the golf course (e.g., course quality expectations).

4) Develop a monitoring program to identify threshold conditions at which specific actions are to be taken and evaluate the effectiveness of management practices.

5) Develop plans for operations that could have negative environmental impact.

For example, plans could be developed for:

- storm water management (e.g., settling and treatment);
- irrigation management;
- integrated pest management (e.g., cultural and non-cultural management practices);
- maintenance area management (e.g., equipment washing, fuelling, chemical storage and composting).

6) Prepare a contingency plan for emergencies (e.g., pesticide or fertilizer spills).

7) Prepare record keeping procedures.

8) Define the responsibilities of people affected by the management plan.

While the responsibility for overall plan implementation falls primarily to the superintendent, the equipment operators, labourers, mechanic, irrigation technician and others are responsible for carrying out the daily activities. They must, therefore, clearly understand management goals. The roles of golfers and owners should not be overlooked. Golfers must be understanding of any changes to the appearance of the course and owners must be supportive of the superintendent's initiatives.

9) Publish the plan and its goals.

3.2 Stormwater Management

Stormwater on golf courses should be managed to protect surface watercourses from deleterious impacts to water quality and aquatic habitat. The objectives of a good stormwater management program should be to minimize:

- interference with the natural surface runoff rate and volume;
- soil erosion and sedimentation;
- changes to surface runoff quality;
- changes to intact riparian areas;
- disturbance of the stream channel; and
- impact on existing wetlands.

Two approaches are typically used for minimizing impacts to watercourses and, in turn, aquatic habitat: 1) stormwater management through runoff control or treatment, and 2) appropriate chemical (fertilizer and pesticide) use. This chapter focusses on stormwater management. Chemical management is discussed in Section 3.4 under Integrated Pest Management.

A variety of management practices can be employed to protect surface water and aquatic habitat. The choice, design and implementation of these practices should be considered throughout the life cycle of a golf course.

This section discusses the factors that influence stormwater runoff and then examines several specific management options; namely: surface water infiltration, filtration and detention. All of these measures can be incorporated into new golf courses, and several can also be installed as retrofits to existing facilities. Other management practices which do not strictly fall into these categories, but can also protect the surface water environment, are noted at the end of this section.

3.2.1 Stormwater Management Considerations

Important factors influencing the production and discharge of stormwater runoff are precipitation, soil type and land use.

Rainfall

Climatic conditions are quite different among regions, with implications for golf course management. High annual precipitation is common along the coastal areas of BC and the lower Fraser River basin. The high annual rainfall volumes (typically in winter) require excellent underdrain systems to prevent soil and root waterlogging. These underdrains may discharge to ponds, surface swales, infiltration trenches or pump stations. In lowland areas, effective drainage management may also include management of the water table.

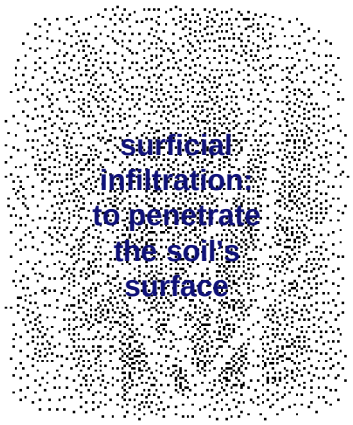
Climatic conditions are quite different in the interior. The South Thompson River valley has a low annual precipitation, averaging 300 mm. Most precipitation occurs in the late fall and early spring, however, intense short duration rainfall events do occur in the summer period. Stormwater management considerations may involve moderating the peak runoff flows and ensuring that sediment generation and release is minimized.

More information on stormwater management is found in Land Development Guidelines for the Protection of Aquatic Habitat, Stream Stewardship: A Guide for Planners and Developers and Guidelines to Protect, Maintain and Enhance Fish and Wildlife Habitat On and Adjacent to Proposed Golf Course Developments and Existing Course Re-Developments on Lowland Areas.

The Prince George region experiences a low mean annual temperature (4°C) and moderate rainfall (600 mm). Rainfall events can range from intense thunderstorm activity to longer duration events associated with frontal weather systems. In this region, surface runoff systems must be designed to convey the runoff associated with summer thunderstorms as well as snowmelt and rainfall / snowmelt events.

Soils

For many soil types (e.g., sand through to sandy loams), **surficial infiltration** rates usually exceed rainfall rates. In cases where the soil absorption capacity is limited, the ground may become saturated during periods of prolonged rainfall resulting in surface ponding and / or surface runoff from usually pervious areas. Soils with a high proportion of silt may compact severely and further contribute to surface runoff.



Some surficial soils (such as till, bedrock, marine clays, glacio-marine deposits or glacio-lacustrine deposits) may have a high permeability, but are underlain with impermeable materials. Where this occurs, the impermeable soils restrict the downward movement of water. Runoff then either moves laterally across the impermeable till layer through the upper (permeable) soil zone or as surface runoff.

Land Use

For golf courses being constructed in previously undeveloped areas, course designers must be sensitive to the drainage characteristics of the natural system. It is important that the subsurface flow rate and quantity are not significantly altered. For example, forest cover removal in areas adjacent to streams can lead to more severe flooding during storms and less water between storms, affecting fish and fish habitat. The intent with new courses is to reduce the extent of soil disturbance (i.e., minimize upset of existing water pathways) and develop new pathways through the fairways and roughs. It is important to understand the hydraulic connections between the golf course and any nearby wetlands, since surface water alterations / diversions and course contouring can affect water flow to and from a wetland.

Removal of the tree canopy is an important consideration in forested areas. Forested areas typically produce little runoff. The tree canopy intercepts rain and concentrates water flow down the tree stem and trunks. This dissipates the energy of rain drops, reducing the risk of surface erosion. In addition, tree roots help to bind soil together. Trees should be maintained wherever possible, but particularly in erosion sensitive areas.

The removal of the natural vegetation adjacent to watercourses can dramatically affect water quality and aquatic habitat. This vegetation moderates water temperatures, protects stream banks against erosion, provides food for aquatic life, protects fish against floods and predators and filters contaminated runoff. In contrast, golf courses can benefit streams in developed areas if stormwater is retained and released slowly.

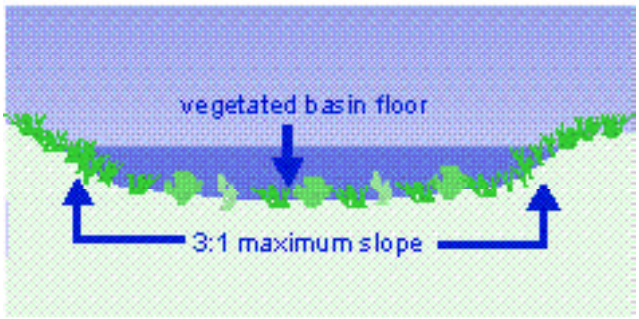
3.2.2 Infiltration Practices

Infiltration reduces surface runoff by directing collected stormwater into the ground. Infiltration helps to maintain pre-development recharge to watercourses, treats runoff, controls streambank erosion and recharges the water table. For infiltration to be effective the water table or the impermeable layer should be approximately 1 m below the bottom of the infiltration trench or other device. In addition, the upper soil layers should have a permeability between 12 and 75 mm/hr. The following text discusses several different infiltration techniques:

Infiltration Basins

Infiltration basins are typically constructed with grass side slopes and grass or gravel bottoms (see Figure 3.1). They are designed to receive stormwater runoff from paved or reconstructed areas and are effective where the soil permeability is relatively high. Discharge occurs primarily to the ground, but an overflow system should be provided for extreme events. Tile drains are often installed in the bottom of the basins to aid infiltration. At a golf course, this type of basin could be constructed at the downstream end of a parking lot or alternatively, storm drains, ditches or swales could convey site runoff to an infiltration basin.

Figure 3.1
Cross Section of an Infiltration Basin



Infiltration Trenches

These trenches convey stormwater runoff through a gravel bed, past a filter medium (such as sand) and into the groundwater (see Figure 3.2). During larger storm events the trenches will overflow and stormwater may be carried by a drain to a surface ditch or swale. Prior to entering the trench, runoff should pass through a grassed vegetated buffer (1 to 5 m in width) to filter out suspended solids. Infiltration trenches can be constructed around the perimeter of parking lots so that runoff passes through the trenches prior to entering a piped drainage system. Infiltration trenches are typically used to retain initial runoff and assist with groundwater recharge.

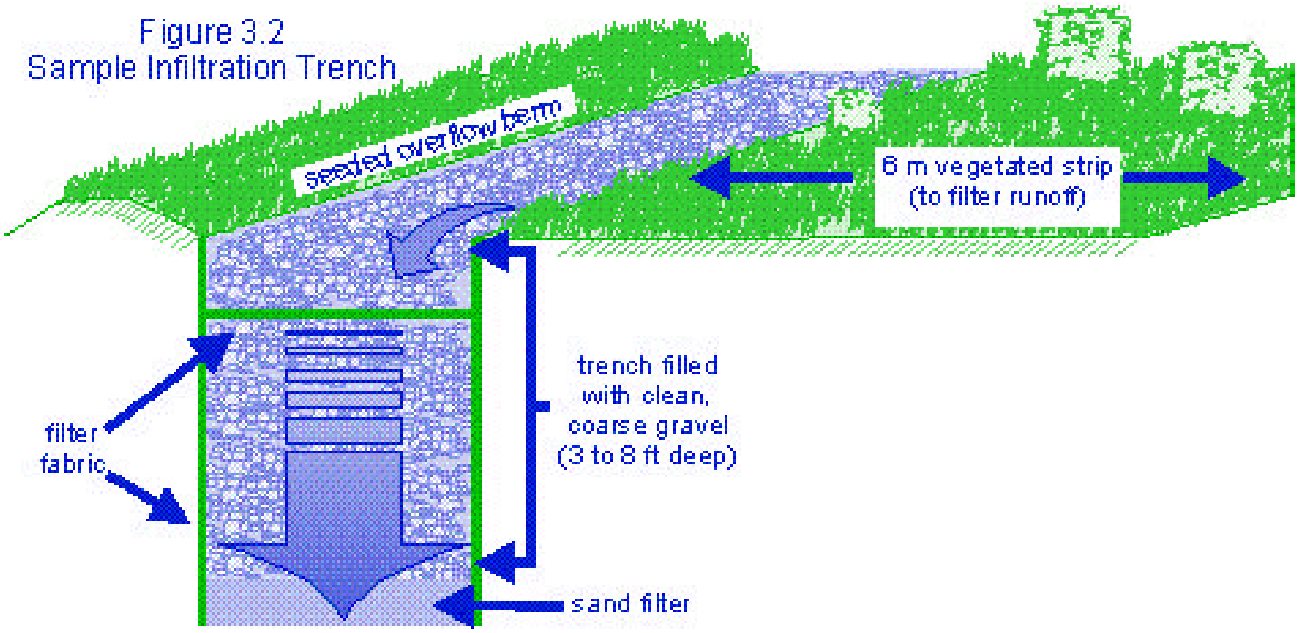
Dry Wells / Soak Away Pits

A standard drainage technique involves directing surface runoff to a catchbasin, where it is conveyed via a storm pipe to a watercourse or ditch. To encourage infiltration of initial runoff volumes, catchbasins can be constructed with perforations and surrounded with a clean, evenly-sized stone. This arrangement is known as a dry well or soak away pit. Dry wells / soak away pits encourage the dispersion and diffusion of stormwater into the surrounding soil. This technique may be appropriate around the perimeter of greens and tee areas where the subsoils have good permeability.

Sand Peat Filter

A layered filter system can more effectively improve water quality than other infiltration

Figure 3.2
Sample Infiltration Trench



systems. A variety of configurations are possible, one of which consists of:

- a 15 cm gravel layer to act as a water spreader and to prevent the migration of coarse particles;
- a 60 cm layer of fine sand for filtering finer particles;
- a 10 cm layer of a peat / sand mixture; and
- a 45 cm peat layer for removing nitrates and other nutrients.

In some circumstances, peat systems have been found to be effective in the removal of nitrogen compounds. This type of filtration / infiltration system may be appropriate for receiving and infiltrating drainage from greens.

photo by R. Russell

Vegetation can be used to filter runoff.

3.2.3 Filtration Practices

Vegetation removes pollutants, primarily through filtration and sedimentation, but also through nutrient uptake. Filtration (or vegetative) management practices are very compatible with golf course environments and can be integrated into the design in a relatively non-obtrusive manner. A number of approaches are described below:

Grassed Swales

Grassed swales provide an open channel conveyance system, which can easily be constructed in roughs adjacent to the fairways. Channels should be lined with deep rooted and water tolerant grasses so that runoff velocities are controlled and the runoff duration is increased. Grassed swales may also promote infiltration.

Filter Strips

Filter strips are vegetated buffers designed to accept sheet flows rather than concentrated flows. While they can remove particulate pollutants from the runoff, they are not effective at improving infiltration or at providing significant water detention.

Constructed Wetlands

Constructed wetlands can be effective at removing pollutants from stormwater runoff (see Figure 3.3). This is achieved through filtration, settling and uptake by vegetation. Emergent plant species (e.g., cattails, rushes, reeds and water tolerant grasses) augment filtration and nutrient uptake. Short duration water level fluctuations of up to one meter can be tolerated by the emergent species. In the golf course environment, these facilities could be located on the course periphery or integrated into the rough area. Constructed wetlands should not disrupt the function of existing wetlands. In addition, existing wetlands should not be used to treat stormwater as this could disrupt wetland functions and discourage use by fish and wildlife.

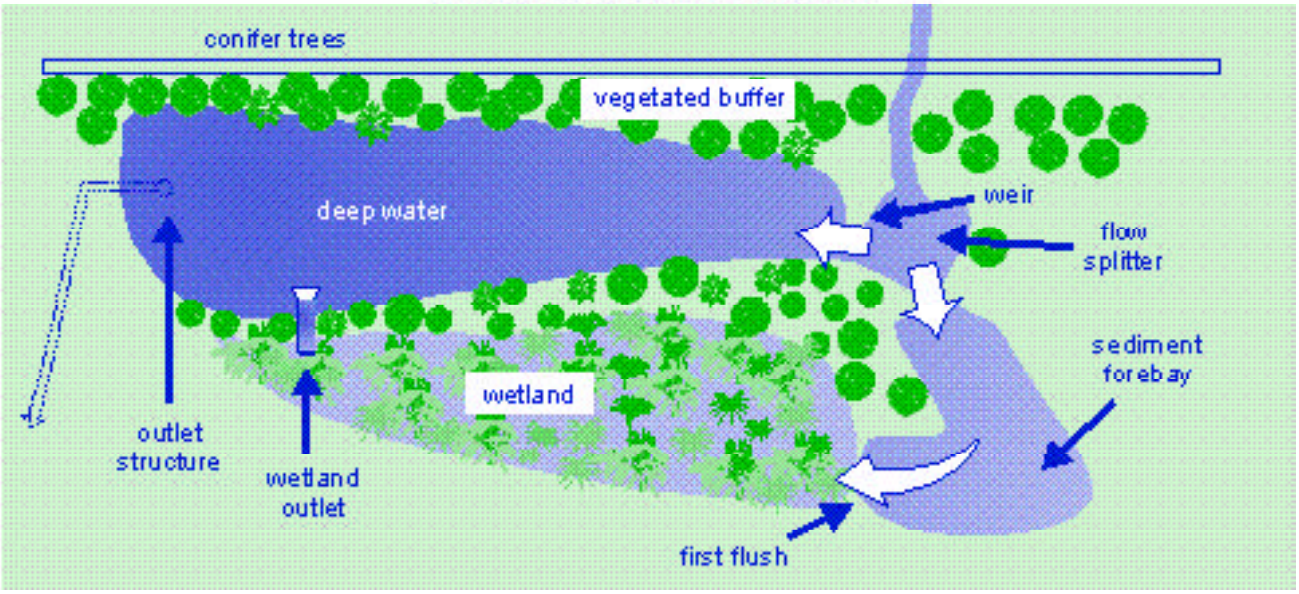
3.2.4 Detention Practices

Temporary stormwater detention stabilizes flows and improves runoff quality. Appropriate measures for golf courses include extended detention wet ponds and storage tanks.

In all of these endeavours, it is important to carry out good pond management. Good pond management includes a number of tasks such as:

- ensuring that the integrity of the pond's side slopes is maintained;
- ensuring that flow control structures are operating correctly;

Figure 3.3
Plan of a Constructed Wetland



- managing plant growth, which may require harvesting at selected time intervals; and
- controlling algae growth through aeration.

Extended Detention Wet Ponds

Wet ponds consist of permanent pools and temporary storage to detain runoff and achieve water quality and quantity control. Wet ponds help to remove numerous pollutants, including sediment, organics, nutrients and trace metals. A proper pond design creates wildlife habitat, adds to the landscape character of the course and provides an overall benefit for stormwater management.

Low outflow rates and long residence times can remove up to 90 per cent of particulate pollutants from the water column. This improves water quality for fish and protects habitat. A good wet pond design consists of three zones: open water (2.5 to 3m deep), submergent plants (1 to 1.5 m deep) and emergent aquatic plants (0 to 0.9m deep). A sample wet pond design is illustrated in Figure 2.6.

Storage Tanks

Large underground storage tanks can be used to retain contaminated water. The water can then be passed through a treatment process or pumped and disposed of at an off-site waste water treatment plant. Tanks may be appropriate in maintenance yards where oil and grease, grass clippings, chemicals and fuels pose a potential source of environmental contamination.

3.2.5 Other Practices

The following stormwater management practices do not necessarily fall into the categories described above, but are beneficial for the protection of water quality and aquatic habitat. They pertain to practices that can be initiated during the construction phase of a new golf course, the retrofit of an existing course or daily course management.

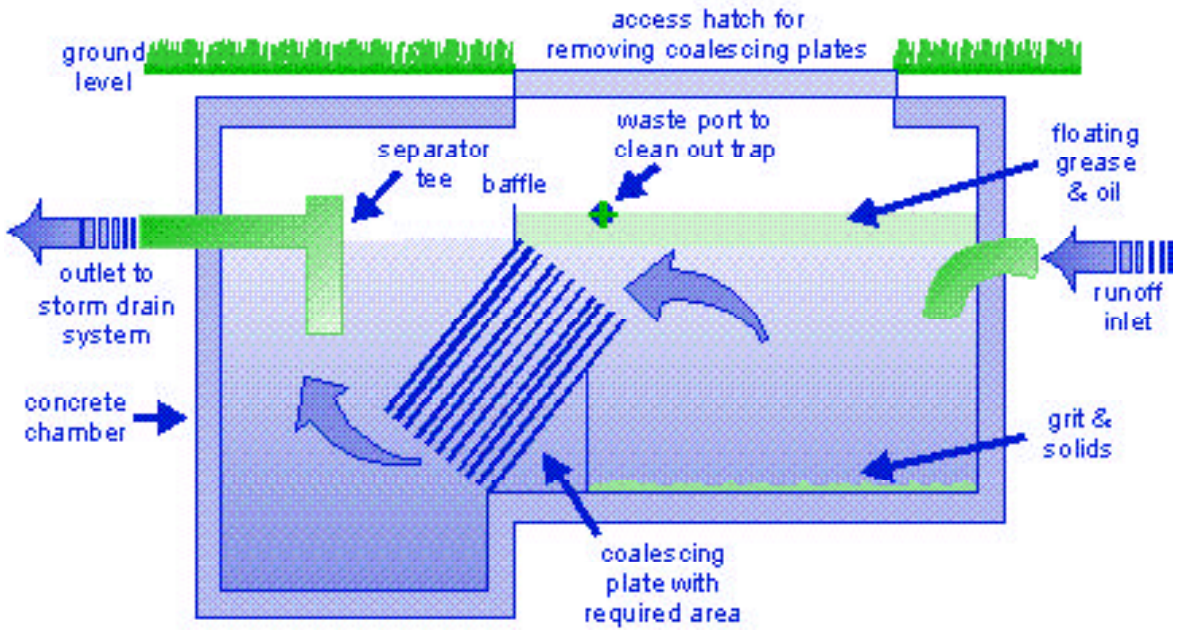
- ***Use construction products that minimize environmental impact.***

Avoid the use of creosote treated railway ties and wood chips adjacent to open water. Concrete blocks could replace railway ties, and gravel or porous pavement on pathways. Hog fuel and other wood wastes generate toxic leachate and should not be used on construction sites, especially near fish bearing streams.

- ***Control stormwater discharge from parking lot areas.***

The quality and quantity of runoff from parking areas should be controlled. Depending on the location of the lot, infiltration, storage or

Figure 3.4
Coalescing Oil / Water Separator



an oil / water separation unit may be appropriate. Coalescing plate oil / water separators (see Figure 3.4) have proven to be effective.

Install surface drainage improvements. Areas requiring surface drainage improvement become more evident as a course matures. Drainage improvements such as French drains are still relatively easy to install, even after turfgrass is established.

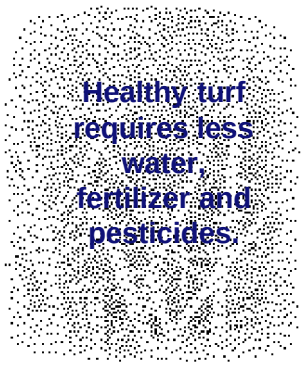
Plan in-stream works well in advance, in consultation with government representatives and in accordance with the appropriate guidelines.

If in-stream work cannot be avoided, it should be planned and completed in consultation with the DFO and BC MELP, and in accordance with the *Land Development Guidelines* and the *Water Act*. General guidelines include:

- carrying out work during periods of low fishery sensitivity;
- protecting the natural aquatic habitat (e.g., stream banks and riparian vegetation);
- providing for unhindered fish migration during and after construction;
- isolating construction activities to prevent sediment from entering the stream; and
- ensuring that hazardous substances do not enter the stream (e.g., wood preservative, paint or adhesives).

3.3 Irrigation Management

Appropriate irrigation management is essential to promote healthy turfgrass that is better able to tolerate stress and resist pests. Healthy turfgrass requires less water, fertilizer and pesticides, resulting in reduced runoff and leaching. More efficient water use reduced the amount of water removed from streams, resulting in less disturbance to aquatic systems.



Good water management depends upon design considerations such as layout, grass selection, irrigation system design and control, and the use of treated sewage effluent. Operational considerations affecting water management will include irrigation quantity and frequency, fertilization, weed management, infiltration management and mowing. Most new

courses are designed with water conservation and water quality protection in mind. Improved irrigation technologies can benefit new courses but are often not suitable for existing courses, where opportunities for reduced water use or water quality protection may arise from assessing management practices.

This section illustrates design and operational practices that may reduce water use, improve turfgrass health and benefit surface water quality. It discusses general tactics to reduce irrigation needs, examines options for managing irrigation supply and timing, and provides information to help you choose an irrigation system that suits the particular needs of your golf course.

Water withdrawals from streams, lakes or other waterbodies require a license from BC MELP's Water Management Branch.

3.3.1 Reducing Irrigation Needs

Golf Course Layout

Course layout has a large impact on water use. Conventional courses are generally 75 to 85 hectares (180 to 210 acres) in total size and have approximately 30 hectares (80 acres) of irrigated area. In contrast, courses in semi-arid regions average less than 55 hectares (140 acres) in total area, with approximately 25 hectares (60 acres) being irrigated.

Today, courses are often designed with a smaller proportion of the total area requiring irrigation. Narrowing fairways and roughs, and incorporating native vegetation between holes reduces water use. However, savings are not always proportional to the irrigated area. For example, a 20 per cent reduction in irrigated area will likely not achieve a corresponding 20 per cent decrease in irrigation requirements.

deficit irrigation: applying a fraction of the water required to maintain well-watered conditions.

The movement of warm, dry air from non-irrigated to irrigated areas results in a higher water requirement in the irrigated portion.

Turfgrass Selection

Significant water savings are possible with the appropriate selection of turfgrasses. Water use rates of grasses differ between species and between the cultivars of a single species. Grasses also differ in their response to **deficit irrigation**.

Deficit irrigation, combined with slightly different approaches to irrigation scheduling, can maintain turfgrass quality and achieve substantial water savings. For example, tests conducted with tall fescue in Colorado showed that with short irrigation intervals (two days), tall fescue could be maintained at 50 per cent deficit irrigation without a loss of quality. However, increasing the irrigation interval resulted in loss of turf quality.

A summary of the water use and drought tolerance ratings for various cool season grass species used on golf courses is presented in Table 3.1. However, water use is only one factor in turfgrass choice. The best approach is to identify species and cultivars that perform best under the intended use and investigate water use data to make the final selection. This combined approach will lead to grasses that require less fertilizer, pesticide and water.

Certain characteristics appear to be common to cultivars with low water use rates. Two of the most important are considered to be high verdure and low vertical growth rate. Both increase canopy resistance, which reduces evapotranspiration rate and thus water demand.

The advantages and disadvantages of various common cool season turfgrass species are

Table 3.1
Water Use Requirements and Drought Injury Rankings for Cool Season Turfgrass Species

Turfgrass Species	Evapotranspiration Rate (mm / day)	Evapotranspiration Rate Ranking	Deficit Irrigation Requirements	Susceptibility to Drought Injury
hard & sheep fescues	2.0 - 4.0	medium	0 - 50	very low
chewings & creeping	3.0 - 4.5	medium	0 - 60	low
perennial ryegrass	3.5 - 6.0	high	60 - 80	medium / high
colonial bentgrass	3.0 - 6.0	high	40 - 80	medium / low
Kentucky bluegrass	3.0 - 6.0	high	60 - 80	medium
annual bluegrass	4.0 - 6.5	very high	90 - 100	high
tall fescue	4.0 - 6.5	very high	20 - 80	low

discussed below. The focus is primarily on their response to irrigation management, but reference is also made to other significant factors such as their competitive ability and suitability to certain geographic regions and areas of a course.

Fine leaf fescues

- use the least water and suffer the least permanent drought damage
- maintain acceptable quality under severe deficit irrigation
- low wear tolerance
- appropriate for roughs and other low maintenance areas

Perennial ryegrass

- relatively high water requirements
- moderate drought sensitivity that can be improved by appropriate nutrients
- well adapted to climate of the Lower Fraser basin
- low cold tolerance
- widely used on fairways, tees and roughs
- not appropriate in northern climates

Colonial bentgrass

- lower water requirements and higher drought injury recovery than perennial ryegrass
- well adapted to the climate of the south coastal region
- appropriate for fairways in south coastal region (area may expand as improved cultivars become available)

Kentucky bluegrass

- high water requirements
- well adapted for areas outside BC's south coastal region
- a prime candidate for general turf areas outside BC's south coastal region.

Tall fescue

- extremely drought tolerant
- very high water use rate
- new dwarf varieties maintain acceptable quality with less fertilizer and pesticide
- more flood tolerant than fine fescues
- not used extensively on BC golf courses, but new dwarf varieties show promise

Table 3.3 on page 34 lists turfgrass cultivars suitable for the different management areas of a golf course.

Annual bluegrass

- extremely high water use
- little drought tolerance
- extremely competitive
- inevitably becomes the dominant species on golf greens due to competitiveness and lack of available control measures

Creeping bentgrass

- relatively high water use, but less than annual bluegrass
- new cultivars may be able to compete against annual bluegrass
- converting existing greens from annual bluegrass to creeping bentgrass may result in moderate water savings

Fertilizer Management

Nitrogen and potassium can be applied at rates that provide adequate nutrition while minimizing water use. In general, lower nitrogen application rates reduce water use. Heavily fertilized plants experience greater growth rates, are denser, have wider leaves and often shallower root systems — all of which lead to greater water use.

Potassium can improve turfgrass resistance to drought injury, but its effect on water use is relatively minor. Higher potassium application rates may be advantageous when deficit irrigation is practiced.

Infiltration

Low infiltration rates reduce irrigation efficiency and increase runoff. Turfgrass cultivation promotes higher infiltration rates and deep, vigorous turfgrass root zones.

Traditional hollow tine core cultivation of greens and tees should occur twice per year to control compaction and the accumulation of thatch — both of which restrict water infiltration rates. Water injection cultivation, solid tine cultivation and spiking are other methods which can be used throughout the summer to maintain good infiltration rates on greens and tees.

Cultivation of fairways, especially by spiking, can be an effective, relatively rapid method of maintaining fairway infiltration rates. Drum aeration can improve both infiltration rates and other physical characteristics such as compaction.

Mowing

Mowing height and frequency affect water use. Mowing at greater heights and less frequently results in greater evapotranspiration than mowing at shorter heights and more frequently. However, as described under Integrated Pest Management, higher canopy heights are desirable for improved infiltration, decreased surface runoff, improved soil moisture retention and deeper root systems. Selecting cultivars that are adapted to the proposed mowing height and frequency so that only one-third of the leaf area is removed at one time will help balance water use with the other aspects of stress resistance and water quality protection.

3.3.2 Irrigation Supply

If irrigation water is to be drawn from surface waters, a licence is required from the Water Management Branch of BC MELP. In addition, water intakes must adhere to the federal *Freshwater Intake End-of-Pipe Fish Screen Guideline*. In general, irrigate using stored water (i.e., from stormwater detention ponds) where possible to leave natural waters for fish, and look for an water source that will have a minimal impact on fish and wildlife.

Sewage Effluent Use

The use of treated sewage effluent for golf course irrigation is an important development in meeting the water needs of golf courses. The replacement of potable or surface water with treated effluent offers a number of advantages to golf courses in specific, but also to the community in general. Advantages include:

- effluent is not discharged directly to surface waters;
- effluent contains plant nutrients,
- resulting in lower fertilizer requirements;
- effluent supply is relatively constant;
- effluent is generally a less expensive water source than potable water; and
- potable water is conserved for other users.

Concerns regarding the use of treated effluent water include the potential for various compounds to accumulate in soils and harm turf plants.

Treated effluent use is more viable in hot, dry regions with high irrigation requirements and low water availability. The shorter irrigation season in south coastal BC makes effluent use less desirable, due to the high costs associated with conveying the effluent to the course relative to the benefits.

3.3.3 Quantity and Frequency

Water that infiltrates into the soil and remains in the root zone can be used by turfgrass. Irrigation systems delivering inappropriate quantities of water or water at inappropriate frequencies result in runoff or leaching — a waste of water that can jeopardize ground and surface water quality.

Table 3.2
Typical Available Water Storage Capacity

Soil Texture	Available Water (cm H_2O / cm soil)
medium sands	0.06
sand loam	0.08
fine sandy loam	0.10
loam	0.11
silt loam	0.14
clay loam	0.11
clay	0.08

Determining appropriate turfgrass irrigation quantities and frequencies requires an understanding of soil water capacity and turfgrass evapotranspiration rates. Data regarding potential evapotranspiration rates is available from Environment Canada. Typical water storage capacities for a number of soil textures are presented in Table 3.2. This table is intended as a guide and is not a replacement for actual testing. Irrigation designs produced by certified designers will account for soil water storage capacities.

Irrigation normally occurs when one-half of the soil's available water storage capacity over the depth of the root zone has been depleted.

The rate at which this quantity of water is supplied will depend on the soil infiltration rate. Infiltration rates are affected by slopes, soil compaction and the development of hydrophobic soil layers. Minimizing the impact of slopes is an issue that should be addressed during the design of irrigation zones.

Working Scenario

Given:

- a 20 cm root zone (typical of many turfgrasses);
- a silty loam soil;
- an irrigation system which can apply approximately 1.4 cm of water; and
- an evapotranspiration rate of 0.3 cm per day (typical of perennial ryegrass during Lower Fraser basin summers),

the turf could be irrigated every 4 to 5 days to maintain maximum quality.

Correction of soil compaction or hydrophobic layers is a regular management issue and is discussed under Infiltration.

Irrigation timing is a balance of competing concerns. Night irrigation minimizes evaporative losses but may promote disease problems. Early morning irrigation can reduce disease pressure by removing dew and avoiding high moisture conditions at night, but soil compaction and evaporative losses are greater.

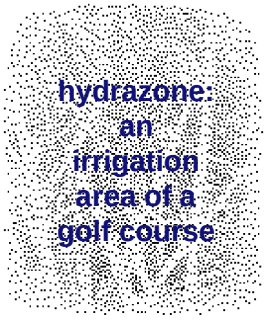
The presence of weeds can indicate water imbalances. Weeds that are indicative of high soil moisture include annual bluegrass, common chickweed, mouse-ear chickweed and velvetgrass. Because climatic conditions in south coastal BC are ideal for the growth of these weeds eight to nine months of the year, the presence of these weeds in this region is not necessarily indicative of over-irrigation. Weeds that are indicative of drought situations include prostrate knotweed, buckhorn plantain, yarrow, dandelion and white clover.

3.3.4 Irrigation Systems

The following text discusses the relative benefits of various alternatives for designing and controlling irrigation systems. It also identifies ongoing maintenance practices to ensure the continued efficiency of your irrigation system.

Design Alternatives

Appropriate water distribution is important to maintain healthy turf and minimize water use and chemical reliance. Modern irrigation design is a complicated process that is best left to qualified designers. It requires the ability to interpret information on the golf course soils (texture, structure and stratification) and turfgrasses, water sources, prevailing winds and typical wind speeds. This information is incorporated into the design and operation of a system to meet the needs of each **hydrazone.** Following installation, the system should be audited to ensure that design criteria are met.



Standard irrigation designs involve double row systems using equilateral triangle spacing or, where water requirements are minor, single row spacing of irrigation heads. This latter approach minimizes irrigated acreage, but lowers water use efficiency. A number of irrigation design alternatives are emerging in this rapidly changing and highly competitive sector of the industry. A brief review of some of the more significant new design practices is presented below with a discussion of their impact on water use.

Perimeter Irrigation

Perimeter irrigation is a strategy whereby part circle heads are used to isolate areas with different water requirements and ensure uniform water application rates within each area. This approach is appropriate for greens, fairways and roughs.

Perimeter irrigation allows more control over the watered area. For example, irrigation of the greens can be separated from the surrounds when the surrounds contain soils with a different water holding capacity or turfgrasses with different water requirements.

Perimeter irrigation is also employed to meet the different irrigation needs of fairways versus roughs. Turfgrass areas may contain different grasses or the grasses may face different levels of stress depending on mowing height and traffic.

Finally, perimeter irrigation is beneficial where effluent water is being used for irrigation. A perimeter irrigation system for non-effluent water may be desirable to confine the effluent water within the golf course. This may be necessary due to aesthetic considerations (e.g., if the course borders on a housing development) or environmental protection issues (e.g., if the course borders on wetland areas).

Low Pressure / Low Precipitation Rate Heads

Low pressure / low precipitation rate heads effectively prevent runoff in areas where infiltration rates are low. Reducing operating pressures lowers the energy and pumping capacity requirements of an irrigation system. However, reduced precipitation rates also permit the slower application of water, providing better infiltration and more efficient water use.

Due to system design differences, the replacement of traditional heads with low pressure / low precipitation rate heads may not be appropriate. Existing designs should be reviewed by an expert before a change is implemented.

Micro-Irrigation of Ornamental Plantings

There is an increasing trend to create complex landscape designs around clubhouses. Micro-irrigation systems can lower water use and reduce runoff or leaching.

Specific advantages include:

- ❒ low runoff losses on slopes because of lower application rates;
- ❒ higher water efficiency because of the precise placement of water; and
- ❒ lower water pressure requirements and energy costs.

Potential drawbacks include:

- ❒ expensive equipment;
- ❒ higher maintenance labour costs;
- ❒ greater fragility of the system as compared to traditional irrigation methods;

❒ the need for filtration and treatment of irrigation water under most circumstances.

Control Alternatives

Computers are becoming a popular means to control irrigation systems. Computers can utilize information from weather stations, soil moisture sensors and turfgrass canopy temperature sensors to determine water use requirements. They can also be programmed to manage water flows, control irrigation timing and to maintain a water supply database. A computer-controlled irrigation system coupled with the appropriate irrigation hardware can conserve water and electricity, and reduce the potential for nutrient and pesticide runoff or leaching. Some options for the manual or computerized operation and scheduling of irrigation systems are described below.

Irrigation Head Control

Individual valve in head (VIH) sprinklers can be controlled manually. While the control of single heads is not efficient for the overall control of water use, the manual shutoff of individual VIH sprinklers can be of value under special circumstances.

A VIH sprinkler

Satellite Control

Zones of VIH sprinklers connected to a particular on-course satellite may be shut off at the satellite. While this level of control is effective for managing an irrigation system, it still does not offer efficient control of overall water use.

Master Control Station

Sophisticated irrigation systems use a computer for coordinating control. All major irrigation manufacturers offer some form of this design. Advantages include:

❒ greater control of water distribution and timing

❒ easier scheduling (e.g., adjustment to timing and sequence of operation);

❒ enhanced flow management to maximize pumping efficiency;

❒ centralized system control that provides a single shutoff point in case of emergency;

❒ two-way communication between the computer and the satellite to inform the operator of the station's performance;

❒ telephone link-up to remote locations;

❒ radio remote control, allowing the superintendent to alter irrigation scheduling in response to course conditions; and

❒ monitoring of total water use and shutdown (e.g., in case of a break in the irrigation lines).

Scheduling Control

Irrigation scheduling can be determined by visual observations or by interpreting sensor and weather station information. Optimal scheduling promotes efficient water use, healthy turf and decreased opportunities for pesticide and fertilizer runoff and leaching.

Weather Stations

Weather stations provide information regarding air temperature, relative humidity, rainfall, sunlight and wind speed. Evaporation rates predicted from weather station data can be used to determine irrigation requirements.

Evapotranspiration sensors can collect much of the same information as weather stations and are less expensive to install. Rainfall data obtained by weather stations also permits adjustments to irrigation scheduling or system override during a rain event.

Information from weather stations, in conjunction with sensor data, is beneficial for pest management. For example, air temperature data and soil temperature data can be used to determine the accumulation of "growing degree days," valuable for the effective application of pre-emergent herbicide for the control of crabgrass. Weather station data augmented by leaf wetness meters have also been incorpo-

rated into models for disease prediction. At the time of publication, these models have not been calibrated for conditions within BC.

Soil Water Content Monitoring

Superintendents can monitor moisture content by the feel of the soil. There are also a number of commercially available methods.

Indirect moisture measurements can be made by gauging the soil water potential with tensiometers or electrical resistance blocks. Soil water content is subsequently determined by knowledge of the water content / potential relationship. Tensiometers work best at water potentials less than -0.1 Mpa, which generally covers the range of water potentials corresponding to when irrigation is necessary. Tensiometers tend to work best in medium or fine textured soils, and can be connected to controllers. Electrical resistance blocks require relatively low maintenance once calibrated to the appropriate soil type.

Two other commercially available soil water monitoring methods are frequency domain meters and time domain reflectometers. Both measure the volumetric water content of the soil, but are not widely used at golf courses, due to their higher cost and more sophisticated set-up requirements.

The newest irrigation systems offer soil moisture sensors as integrated components of a control system. Soil moisture sensors can also be retrofitted to most automated systems. The points to consider when selecting a moisture sensor system for an existing system are:

- ❒ compatibility with the existing system;
- ❒ trenching or disturbance required for installation;
- ❒ multiple sensor options and central computer capability;
- ❒ full-range adjustment for plant water requirements;
- ❒ durable sensors; and
- ❒ use of existing valve wires to transmit signals to the controller.

Plant Response Measurement

Drought stress is indicated by three distinct symptoms: footprinting (a loss in resiliency or elasticity evident in high traffic), darkened turf, and wilting.

Turf can recover from footprinting or darkening without serious injury, although its long-term performance will deteriorate. Syringing or lightly watering turf when these symptoms occur reverses drought stress and allows turf to recover. Hand watering is also used to control heat stress and minimize the water requirements of greens. Hand watering is necessary when the turf's root system has been damaged or restricted. Wilted turf won't recover.

Canopy temperature provides another means to assess plant response. Infrared thermometers that measure canopy temperature can detect water stress before the visual symptoms become obvious. At its simplest level of use, an infrared thermometer allows for faster and more effective use of hand watering. At a more sophisticated level, turfgrass canopy temperature monitors may eventually be connected to data collection systems for scheduling regular irrigation cycles.

System Performance Audits

Irrigation audits are part of good management practices. Yearly inspections can improve efficiency by identifying any physical problems. Audits typically assess distribution uniformity, pressure fluctuations and the condition of nozzles, gaskets and sprinklers. The efficiency of a system which has been appropriately designed and is operating correctly should be around 85 per cent. The tasks which should be carried out as part of an irrigation audit are outlined below:

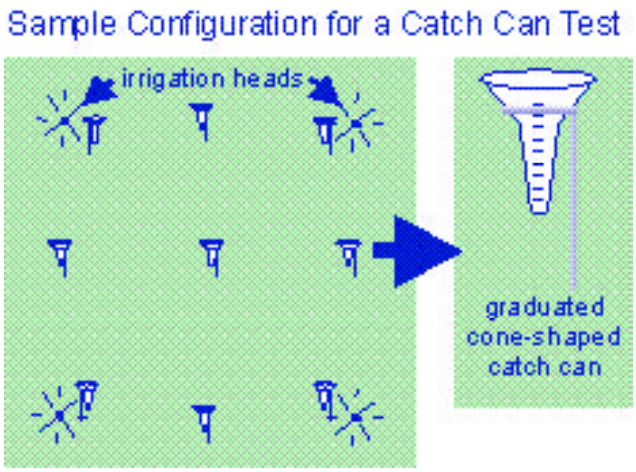
Inspect sprinklers, gaskets and nozzles.

Sprinklers should be checked for plugging, spacing, and head rotation and alignment. Gaskets and nozzles should also be checked.

Test for pressure fluctuations.
One procedure for assessing pressure fluctuations involves testing the pressure at the beginning, middle and end of a zone. If the pressure difference is greater than 20 per cent, further evaluation should be conducted by an irrigation hydraulics expert. The pressure at the irrigation heads can be measured using pilot tubes or pressure gauges.

Irrigation system analysis is discussed in the article "Adjusting Irrigation Systems for Greater Efficiency" published in Issue 64 of *Golf Course Management*.

Measure the precipitation rate of the heads in a zone and the distribution uniformity of the system.
If all equipment is in good condition and operating pressures are adequate, this next stage of the audit can be performed. A single catch can test can be used to determine both precipitation rate and system uniformity. Cone-shaped catch cans are commercially available, but any matching set of collection devices are acceptable (e.g., tin cans). The cans can be laid out in a variety of patterns — the minimum arrangement places cans near each head and half way between overlapping heads. Ideally, the station should run for its normal time during the test, however, a minimum of 25 mL must be collected and large rotor sprinklers should make at least five rotations. The run time and volume of water in each can should be recorded.



Review the data from the precipitation rate / distribution uniformity test.
The data from catch cans should be inspected for cases in which the water collected is much greater or much less than the average. Data extremes may indicate a mechanical problem with the heads in the zone. Problems may include incorrect operating pressures, improper sprinkler head alignment, partially plugged nozzles, mismatched precipitation rates (especially where part and full circle heads are in one zone), broken equipment or thatch or turf blocking the operation of one head.

Calculate irrigation system efficiency.
The standard measure of application efficiency is distribution uniformity (D.U.). The D.U. is calculated by dividing the average water collection of the lowest 25 per cent of the cans by the overall average. A D.U. of 0.85 means the system is operating at 85 per cent efficiency. The D.U. can also be used to determine the amount of time required to supply a minimum amount of water to the turf in a zone. Other coefficients used to make adjustments in run time include the scheduling coefficient and the mid-point uniformity coefficient.

3.4 Integrated Pest Management

The overall goal of Integrated Pest Management (IPM) is to promote healthy turfgrass that can withstand higher levels of pest pressure without significant damage. IPM prevents unacceptable levels of pest damage by economical means and with the least possible hazard to people, property and the environment. The information presented in this guide is based on standard recommendations from current literature.

Further information on IPM is available through golf associations, academic institutions, government agencies, reference texts and the Internet. Michigan State University manages a database devoted to turfgrass research.

The starting point for an Integrated Pest Management program is a thorough understanding of turfgrass growth, pest biology and factors that favour pest infestation. This is followed by the definition of treatment thresholds for determining when action is to be taken, the development of a scouting strategy for pest identification and the development of a monitoring program for evaluating the effectiveness of control methods. Pest management methods and their success will vary by geographic region and among areas of one golf course.

cultural pest control: using management techniques to minimize pests

non-cultural pest control: using biological controls or pesticides to minimize pests

Appropriate pest control methods can be both **cultural** and **non-cultural** in nature. Cultural management offers pest-specific methods for blocking or reducing the extent of a pest problem. Non-cultural management employs biological controls or pesticides to control pests posing an economic threat to turfgrass resources.

3.4.1 Problem Identification

Pest Biology

Pests, in the present context, are those diseases, fungi, weeds, insects and animals that destroy or reduce turfgrass quality. The correct selection and effective implementation of IPM techniques relies upon a thorough knowledge of pest biology, including:

- pest identification features;
- the life cycle of regional pests known to occur; and
- factors favouring the development and propagation of pest problems.

Scouting

A successful IPM program relies on effective scouting and diagnosis. Scouting identifies early pest conditions and evaluates treatment effectiveness. Pest populations can then be compared with established threshold levels to determine appropriate treatment.

Pointers for an effective scouting program are listed below:

- ***Base the scouting program on pests known to occur in the region.***

- ***Perform regular, systematic inspections to identify pest problems.***

Standardized methods for survey patterns, sample numbers and sizes, and turf descriptions will permit effective comparisons of recorded information. Initial scouting should entail a detailed hole-by-hole survey, with any problems noted on a map. In the case of disease outbreaks, weather conditions should also be recorded.

Further information regarding scouting protocols can be found in the US EPA publication, entitled *Integrated Pest Management for Turfgrass and Ornamentals.*

- ***Base scouting frequency on pest occurrence.***

Scouting frequency depends on the type and extent of the pest problem. Regular scouting may be done weekly, but daily checks may be required during outbreaks or periods that favour pest establishment. Pay particular attention to areas that experienced previous outbreaks.

- ***Accurately identify pests.***

Damage caused by different pests is often similar in appearance. If in doubt, submit samples of the pest, turf or soil to a specialist for analysis. Further assistance can be obtained through the BC Ministry of Agriculture, Fisheries and Food. Immunoassay kits are available to help identify plant diseases.

- ***Accurately diagnose the stage and severity of the pest problem.***

Treatment decisions rely on accurate diagnoses. Once damage has occurred, it is often appropriate to facilitate turfgrass recovery and prevent recurrence of a particular pest rather than target the pest itself.

- ***Monitor pest problems to determine the effectiveness of treatments.***

Use a standard method to describe the outcome of management decisions and treatments. For example, the point quadrat method can be used to quantify weed populations, irritants can be used to extract insects, and soil cores can be taken to inspect for insect larvae.

Record Keeping

Accurate record keeping is necessary to evaluate management effectiveness and plan future strategies. Record scouting observations, weather conditions, management decisions, control methods and the effectiveness of various strategies.

3.4.2 Cultural Management

Healthy turf is the goal of cultural management practices. Healthy turf is better able to propagate, resist disease, ward off insects and compete against weeds. A good cultural management program recognizes that cultivar selection, soil improvement, mowing, irrigation and fertilization will all affect each other and must be coordinated to produce healthy turfgrass and control pests. This section describes general cultural management techniques to prevent or mitigate diseases, weeds, insects, animals and aquatic pests.

Cultivar Selection

- ***Select turfgrass cultivars adapted to the local climate and growing conditions.***

Poorly adapted species have higher maintenance requirements, are more stress prone and may inevitably require more fertilizer and pesticides. Information on new cultivars can be

obtained from trade journals, seed companies and academic or governmental turfgrass specialists. Most of these sources will use National Turfgrass Evaluation Program (NTEP) data. When evaluating these data, ensure that:

- ❒ data were collected in regions with a similar climate;
- ❒ turfgrass cultivar is of good overall quality;
- ❒ pest ratings are common to the golf course; and
- ❒ data are compared to those of familiar cultivars.

Conserve native grass species or establish diverse grass species wherever possible.

Native or more diverse grass species are less susceptible to pest outbreaks but not adapted to high traffic areas, so they can be maintained in rough areas. Fairways and roughs can be seeded with a mix of turfgrass species and cultivars. When using species and cultivar blends, all components should be well adapted to local environmental and pest pressures. Turfgrass species appropriate to the different management areas of courses located in various geographic regions are listed in Table 3.3.

Soil Improvement

Conduct soil testing early in the construction or renovation process.
This allows time to review the results and plan amendment strategies. Also, soil acidity and phosphorous adjustments are more effective if lime and / or phosphate can be cultivated throughout the root zone.

In areas where organic matter is low, incorporate peat moss, compost, or other organic soil amendments.
This improves the soil's water and nutrient holding capacity, enhances drainage, promotes aeration and facilitates pesticide application.

In areas of compacted soil, use core cultivators or similar soil aerators.
This improves infiltration, reduces runoff and improves root zone development. Cultivation techniques are discussed under the Infiltration section of this guide.

Mowing

Raise mowing height and reduce mowing frequency.
Slightly higher turf improves infiltration, decreases surface runoff, improves soil moisture retention, encourages deeper root systems, reduces mowing frequency and discourages weeds. Mowing frequency will ultimately be determined by the growth rate of the grass. Ideally, no more than one-third of the leaf tissue should be removed at one time.

Mow with sharp blades.
Mowing with dull blades tears and bruises the leaves, slowing recovery and making the grass susceptible to disease. Mowing with sharp blades enhances the decomposition rate of grass clippings.

Return grass clippings to grass areas, wherever possible.
This provides a natural source of organic matter and nutrients, potentially reducing the need for fertilizers. Grass clippings should be removed during disease outbreaks to prevent spreading. If grass clippings cannot be left on certain parts of a course, they should be collected and dispersed in the rough or other undeveloped, non-buffer areas.

Fertilizer Management

Fertilizers may be required to maintain healthy turfgrass. The most common fertilizer nutrients are nitrogen, phosphorous and potassium. Excessive application can harm plants and result in fertilizer migration to ground or

Table 3.3
Suitable Turfgrasses for Golf Courses in the Fraser River Basin

Management Area	South Coast (Lower Fraser)	Southern Interior (Thompson Region)	Northern Interior (Upper Fraser)
greens	Creeping bentgrass	Creeping bentgrass	Creeping bentgrass
collar	Creeping bentgrass	Creeping bentgrass	Creeping bentgrass
tee & green surrounds	Perennial ryegrass, fine fescue[1] mixtures Perennial rygegrass, fine fescue[1], Kentucky bluegrass[2] mixtures	Perennial ryegrass, fine fescue[1] mixtures Kentucky bluegrass, fine fescue[1], perennial ryegrass mixtures	Creeping bentgrass Kentucky bluegrass blends Kentucky bluegrass, fine fescue[1], perennial ryegrass mixes
tees	Creeping bentgrass Perennial ryegrass blends Perennial ryegrass, Colonial bentgrass mixes	Creeping bentgrass Perennial ryegrass blends Perennial ryegrass, colonial bentgrass mixes Kentucky bluegrass blends Kentucky bluegrass, perennial ryegrass mixes	Creeping bentgrass Kentucky bluegrass blends Kentucky bluegrass, perennial ryegrass mixes
fairways	Perennial ryegrass blends Perennial ryegrass, Colonial bentgrass mixes Perennial ryegrass, fine fescue[1] mixes Perennial ryegrass, fine fescue[1], Colonial bentgrass mixes Colonial bentgrass, fine fescue[1] mixes Creeping bentgrass	Kentucky bluegrass blends Kentucky bluegrass, perennial ryegrass mixes Kentucky bluegrass, fine fescue, perennial ryegrass mixes Perennial ryegrass blends Colonial bentgrass, fine fescue mixes Creeping bentgrass	Kentucky bluegrass blends Kentucky bluegrass, fine fescue[1], perennial ryegrass mixes Creeping bentgrass
primary rough[4]	Perennial ryegrass blends Perennial ryegrass, Colonial bentgrass mixes Perennial ryegrass, fine fescue[1], hard fescue mixes Perennial ryegrass, fine fescue[1] Fine fescue[1], colonial bentgrass mixes Fine fescue[1], hard fescue, perennial ryegrass	Kentucky bluegrass blends Kentucky bluegrass, perennial ryegrass mixes Kentucky bluegrass[5], fine fescue, perennial ryegrass mixes	Kentucky bluegrass blends Kentucky bluegrass, perennial ryegrass[3] mixes Kentucky bluegrass, fine fescue, perennial ryegrass[3] mixes
secondary rough[4,6]	Perennial ryegrass blends Perennial ryegrass[1], Colonial bentgrass mixes Perennial ryegrass, fine fescue[1], hard fescue mixes Perennial ryegrass, fine fescue[1] Fine fescue[1], colonial bentgrass mixes Fine fescue[1], hard fescue, perennial ryegrass	Kentucky bluegrass, hard fescue blends Hard fescues, sheep fescues Fairway wheatgrass	Kentucky bluegrass blends Kentucky bluegrass, perennial ryegrass[3] mixes Kentucky bluegrass, fine fescue, perennial ryegrass[3] mixes Kentucky bluegrass, hard fescue mixes Hard and sheep fescue mixes
ornamental lawn	any primary rough mix	any primary rough mix	any primary rough mix

Notes:
1. Fine fescues are combinations of chewings, creeping red and slender creeping red fescues.
2. Kentucky bluegrass should be a minor component of seed mixes, especially in wetter areas.
3. Perennial ryegrass should be should be a minor component of mixes in northern regions due to poor cold tolerance.
4. Where shade tolerance is required, seed mixes should contain 40% singly or combined fine fescues and rough bluegrass. In shady, moist areas, rough bluegrass may be necessary; otherwise, the use of this grass is not recommended.
5. A wide variety of Kentucky bluegrass cultivars are available. Select aggressive, low growing cultivars for use on tees and fairways and select lower maintenance varieties for rough areas not generally in play.
6. Secondary rough includes areas generally out of play. In these areas, sheep fescue, crested wheatgrass or native grass and herbaceous plant mixes could be used.

surface waters. In addition, elevated concentrations of nitrate is a health concern in drinking water.

Surface runoff from established, healthy turf does not usually carry significant quantities of nitrogen and phosphorus. The potential for nitrogen and phosphorus runoff increases in newly seeded areas, in erosion-sensitive areas, and during the reclamation of damaged turfgrass. Certain climatic and topographic conditions, such as heavy rainfall or irrigation on steep slopes, can also contribute to increased nutrient runoff.

The main objective of a fertilizer program should be to apply fertilizers in the appropriate quantities, where and when they are needed. Best management practices for a fertilizer program are listed below. The properties of various commonly used fertilizer types are summarized in Table 3.4.

Develop and document fertilizer programs for each area of the golf course.

Nutrient requirements will vary according to grass type, growing conditions, natural fertility and playing pressure. A fertilizer plan should address the different needs of each area of the course. Application frequency, timing and concentration should be documented for future planning.

Table 3.4
Nitrogen Fertilizer Characteristics

Type	Classification	Availability	Water Solubility	Leaching Potential	Runoff Potential	Comments
ammonium nitrate	inorganic salt	rapid	100%	high	high	-
amonium sulphate	inorganic salt	rapid	100%	minimal	minimal	used to reduce soil pH
urea	synthetic organic	rapid	100%	minimal	minimal	volatilization losses can be high
methylol urea	synthetic organic	rapid	100%	minimal	minimal	-
urea-formaldehyde	synthetic organic	slow	40% max	high	high	some formulations less useful under low soil temps., good N management possible using UF products
composted sewage sludge (i.e., Milorganite)	natural organic	very slow	6 - 10%	high	high	poor availability under low soil temps., many organic fertilizers have some disease suppression
composted manures (i.e., Sustane)	natural organic	very slow	6 - 10%	high	high	poor availability under low soil temps., many organic fertilizers have some disease suppression
IBDU	synthetic organic	slow	15%	low	moderate	a low density material, so runoff may be a problem, as well as removal by mowers; good low-temperature, slow-release N source
sulphur-coated urea	coated	med.	variable-low	low	low	uniform response
plastic coated urea	coated	med.-slow	variable-low	low	low	products with a wide range of availabilities are obtainable

Periodically conduct a soil sampling program for each area of the golf course.
Soil analysis should include phosphorus, potassium, acidity, texture and organic matter content for representative areas of the course. This information will establish nutrient requirements and help characterize the soil matrix for determining cultural management needs. Texture and organic matter measurements can be used to assess the risk of agrochemical runoff or leaching.

When low or unbalanced nutrient levels are suspected, soil testing should be carried out each year until the problems are remedied. When optimum nutrient levels are achieved, soil testing every two to three years should be sufficient. On sand, greens or tees, plant tissue tests are more indicative of nutrient conditions than soil tests.

Manage fertilizer applications based on weather and soil conditions.
Fertilizer application should be avoided during dry soil conditions prior to rainfall events. At any time, heavy applications of soluble nitrogen fertilizers should be avoided, especially during cool, wet periods. Under optimal circumstances, no more than approximately 1.0 kg of soluble nitrogen per 200 m^2 should be applied. Ideally, only one-half of this rate should be considered. On highly leachable, coarse textured soils (e.g., sandy soils), a system of more frequent but smaller fertilizer applications should be used.

Conduct light fertilization during late fall or early winter (after turfgrass has gone dormant but before the ground freezes) to promote good greening in the spring and reduce the need for early spring fertilization. It also prevents the decline in turfgrass density common during coastal region winters. Recent research discourages fall fertilization in cool, moist climates due to water quality concerns. Use slow release, temperature-sensitive nitrogen fertilizer for late season applications. These fertilizers remain insoluble in cold temperatures, thereby reducing runoff and leaching during wet winter seasons. Ideally, slow release fertilizers should supply 50 per cent of the nitrogen requirements.

Maintain transition zone grasses around surface waters, including detention facilities.
Transition zone grasses requiring little or no fertilizer act as runoff filters or barriers. This intact riparian zone may consist of long grass, trees and shrubs.

Establish a fertilizer-free zone around waterbodies and adjacent to watercourses.
Fertilizer application equipment should not be permitted in this zone. Fertilizer runoff, drift or leaching into this zone should be prevented.

Maintain transition zone grasses with higher nitrogen requirements around greens and tees and maintain these grasses under minimal nitrogen conditions.
This practice will hasten absorption of any nitrogen lost from greens and tees.

Use moderate levels of fertilizer on newly seeded areas.
A balance is desired between high fertilizer levels (that increase the growth rate and decrease the high runoff period, but also increase the quantity of fertilizer available for runoff) and low fertilizer levels (that slow the growth rate and lengthen the high runoff period, but decrease the amount of fertilizer available for runoff).

Other Cultural Management Practices

Use fencing to prevent turfgrass injury from winter traffic.

Consider protective covers to reduce the damage and disease problems that occur in winter months.
Protective covers can act as a greenhouse for greens and tees in the winter and early spring. They prevent desiccation, stimulate growth and help grass recover from snow mould. While a preventative fungicide treatment may still be required, re-application of fungicide is generally not necessary.

- ***Improve surface drainage in poorly drained areas.***

Improved drainage reduces excess moisture in the fall that could later freeze, suffocating the grass and its root systems. To improve drainage, consider the use of dry wells on greens. (For example, an 8 cm diameter, 2.5 m hole filled with gravel can be constructed at the lowest point of the green. In the summer, the well can be capped with turf; in the fall, the turf cap is removed and excess water may infiltrate via the well.)

3.4.3 Treatment Thresholds

Cultural management is intended to reduce pest populations and strengthen the turf's ability to withstand pest pressure. Despite these techniques, pest populations may cause economic damage related to the marketability of the course and the cost to control an established pest and reclaim an affected site.

More information about treatment thresholds may be found in the U.S. EPA document, entitled *Integrated Pest Management for Turfgrass and Ornamentals*.

Treatment thresholds take into account population, damage and economic thresholds. Vigorous turf, for example, can withstand higher pest populations and roughs can sustain more damage than greens without affecting aesthetics or playability. It may not be economical to treat a pest problem where the damage is minimal and the problem is not expected to intensify or spread.

Input and agreement from owners and golfers is essential for the successful implementation of treatment thresholds. In determining treatment thresholds, managers must define:

- ❒ population thresholds for each potential pest;
- ❒ damage thresholds for each area of the golf course, especially the greens, tees, fairways and roughs; and
- ❒ unit costs of standard cultural and non-cultural control methods.

Disease Control

Biological or parasitic turfgrass diseases are a result of fungi, bacteria, viruses and nematodes. Other diseases may be caused by unsuitable soil and climate conditions. Damage from pedestrian or vehicular traffic increases susceptibility to disease. Cultural controls should be the first and primary line of defense against turfgrass disease.

The following cultural practices are intended to reduce the threat posed by a range of fungal diseases. Again, successful disease control relies on a well organized scouting program for early and correct identification.

- ***Select turfgrass that is least susceptible to prevalent local diseases.***

- ***Use disease-free and disease-resistant seed varieties.***

- ***Manage soil fertility, weed control and irrigation to help maintain a strong healthy grass stand and increase disease resistance.***

- ***Schedule early morning irrigation in areas that are susceptible to disease.***

Moist overnight soil conditions favour disease inception. Early morning irrigation removes dew, helping turfgrass to dry faster and reducing the potential for disease outbreaks.

- ***Properly drain depressions.***

Facilitate Good Turf Aeration

Turf aeration may include spiking, coring, aerifying or brooming greens and tees to help drain snow-melt and precipitation. Aeration reduces the high moisture conditions favoured by some diseases.

- ***Thin tree stands on the windward sides of greens and tee boxes to promote adequate air circulation.***

- ***Minimize shade in areas susceptible to disease.***
This may involve pruning or selectively removing trees.

- ***Avoid green slopes with a northern aspect.***
The reduced sunlight on northern facing gradients results in cooler surface temperatures and moisture conditions favouring fungal growth.

- ***Spread dark organic material on greens and tees to accelerate snow melt, but not substances that could generate toxic runoff or sedimentation.***
Snow mould tends to grow at the snow / green interface during periods of melting.

- ***Use snow blowing equipment and snow fencing to distribute snow evenly.***
Clearing snow, or distributing it more evenly, will promote melting, reducing the likelihood of snow mould.

- ***Prevent the spread of disease by equipment or personnel.***
Disease can be spread by moving infected equipment or personnel to uninfected areas. Turf showing disease symptoms should not be mowed or the affected turf should be mowed last. Equipment and shoes should be cleaned after working in infected areas.

Weed Control

Weed control is based on recognizing the biological differences between weeds and turfgrass and focusing control measures at the weaker phase of the weed's life cycle. To reduce the potential for weed encroachment, it is important to promote strong turfgrass. The following are a number of cultural weed control practices:

- ***Till exposed soil at new courses or new areas within existing courses to kill growing weeds.***
In areas experiencing cold winters, areas planned for turf can be tilled late in the fall to expose weed roots to freeze-kill.

- ***Use high quality seed stock.***
Canada Certified #1 seed is not weed free, but comes with an analysis of the types and numbers of weed seed contained in the product.

- ***Prevent the spread of weeds by equipment.***
If possible, clean equipment in a dedicated area before moving to a new site.

- ***Prevent weed seed production by scheduling control operations before production occurs.***
Such control measures vary with the type of weed. For example, timely mowing of certain weeds will help prevent seed production and can starve plant roots. This is ineffective for low growing weeds that flower below the mower blade.

- ***Hand pull weeds growing in small patches.***
Hand pulling removes roots or can starve root systems. While labour intensive, this technique may be feasible for small areas or light infestations, such as dandelions on green collars. Hand pulled weeds that are flowering should be bagged and disposed of to prevent seed spread.

Insect Control

Insect pests do not normally pose a significant risk to turfgrasses within BC. In general, insecticides are more toxic to fish and wildlife than other pesticides. Consequently, chemical insect

control should be avoided. The following are cultural management practices that can be employed to prevent or mitigate insect damage:

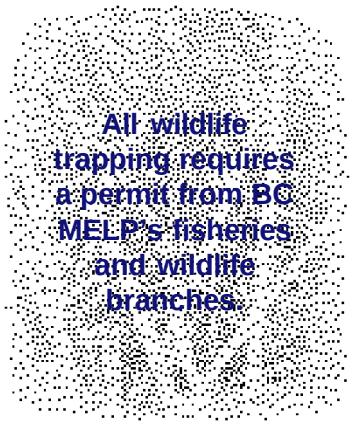
- ***Select native or pest-resistant trees, shrubs, and ornamentals.***

- ***Avoid the use of insecticides on ornamentals, shrubs and trees.***

Consider non-chemical alternatives such as insecticidal soaps, *Bacillus thuringiensis* (a bacterium that infects the larvae of some moth and butterfly species) or diatomaceous earth (kieselguhr or infusorial earth — hydrated silica from the skeletons of minute organisms known as diatoms).

- ***Avoid the use of insecticides to control mosquitoes.***

Mosquito breeding sites within the course's property can be discouraged by encouraging flow in waterbodies. Golfers should also be encouraged to use personal methods against mosquitoes, such as long sleeved shirts and pants and repellents.



Animal Control

Certain wildlife can pose problems to golf courses or their users. Only non-chemical control measures should be considered, since poisons for terrestrial wildlife are highly toxic and can affect non-target wildlife.

- ***Use traps or repeated flooding of burrows to control gophers and ground squirrels.***

- ***Use tree guards for rabbits and porcupines that occasionally girdle shrubs and trees during the winter.***

Girdling (eating a complete ring around the base of a tree or shrub) cuts off nutrient supply to the roots, killing the plant.

- ***Use traps to control beavers, or remove their dams and lodges.***

Beavers may fell deciduous trees and woody shrubs along streams and block tributaries and channels bordering or running through a golf course. Again, wildlife trapping requires a permit. Beaver dams and lodges cannot be removed without obtaining written approval from DFO and BC MELP.

- ***Focus on the early recovery of turfgrass areas affected by mice.***

Turf damage caused by mice usually occurs in winter beneath the snow and is difficult to control.

Aquatic Pest Control

Golf course developments often use ponds as part of landscape design and for irrigation water sources. Excessive growth of undesirable vegetation can reduce oxygen levels, produce noxious smells and discolour the water as the vegetation decays. The following practices can be employed to prevent or eliminate undesirable aquatic vegetation and algae:

- ***Aerate ponds.***

Fountains or compressors with underwater perforated air lines will maintain dissolved oxygen levels and help eliminate the need for aquatic herbicides to control algae.

- ***Use mechanical methods for removing vegetation, taking care to remove roots and plant debris.***

- ***Control aquatic vegetation.***

Products that colour the water impede the transmission of sunlight and the growth of aquatic vegetation. Make sure you only use products that are not toxic or harmful to fish, birds and wildlife.

3.4.4 Non-Cultural Management

Non-cultural techniques for pest management include biological controls and pesticides. Due to the potential environmental implications, management efforts should concentrate on cultural practices. Non-cultural management should be considered when cultural techniques fail to maintain pest populations below threshold levels.

Biological Controls

Pests can thrive in single species grass communities. Biological controls involve the introduction of control organisms or the promotion of existing, natural enemies. Control organisms include pathogens (disease-causing viruses, fungi, bacteria, nematodes and protozoa), predatory or parasitic insects, bats and birds. While biological controls show promise, their application is relatively new and should be carefully considered. Important points to remember with respect to biological control practices are listed below:

pesticide: any substance or mixture of substances intended to prevent or reduce the damage caused by a pest, including herbicides, insecticides, fungicides and bactericides.

- ***Maintain diverse populations by preserving endemic vegetation and wetlands within and adjacent to the golf course.***
  This requires knowledge of the biology and habitats of the natural enemies of turfgrass pests.

- ***Carefully implement biological control techniques, such as the introduction of weed eating fish, midge larvae, weevils or snails into aquatic environments.***
  Introducing these organisms to aquatic environments can have serious implications for fisheries and requires prior written permission from DFO and / or BC MELP, depending upon the species and the location.

- ***Consult with a biological control specialist.***
  Biological control specialists should be consulted to determine the best options for a particular IPM program.

Pesticide Use

Pesticides can reduce damage to turfgrasses, but can have adverse environmental effects. To protect surface water resources, careful consideration must be given to pesticide selection and application. IPM programs should incorporate the following principles:

- ***Avoid chemical use through cultural control measures, if possible.***

- ***Select the least toxic, least persistent, least mobile and most target-specific registered pesticide.***

- ***Apply the pesticide at the pest's most vulnerable stage.***

- ***Apply the pesticide at the minimum required rates to the minimum area necessary.***

- ***Use the pesticide in strict accordance with the product label directions and guidelines.***

- ***Conduct regular tests for pesticides and nitrates in areas where water quality is regarded as particularly critical (i.e., fish habitat or drinking water).***

- ***Avoid agrochemical application during the winter months (November to March) in areas susceptible to flooding.***

Pesticide Selection

There will likely be more than one type of pesticide that is effective and registered for a specific use. Pesticide selection must consider environmental factors, as well as the pesticide's toxicity, persistence, tendency to bioaccumulate, soil adsorption capability and water solubility. These factors all play an important role in the movement of pesticides runoff and leaching.

Environmental criteria for profiling and selecting pesticides are listed below. Some informa-

tion may not be readily available, but a reasonable effort should be made to obtain the necessary information from the appropriate agencies (Agriculture Canada or BC MELP) or pesticide manufacturers.

Profile important physical environmental factors affecting chemical mobility for each area of the golf course.
Several factors (including soil organic matter, clay content, texture, permeability, subsoil texture and drainage) affect pesticide movement and should be factored in chemical management plans. For example, the higher the percentage of organic matter and clay content in soil, the greater the soil's ability to adsorb chemicals and decrease leaching. In contrast, sites featuring coarse textured soils offer high permeabilities. allowing mobile chemicals to leach. Courses built over fluvial, sandy-gravely substrates also enhance pesticide runoff.

Avoid pesticides that are toxic to birds and wildlife.

Avoid pesticides that are toxic to aquatic life in any areas where there is potential runoff or leaching to water bodies.

Eliminate chemicals that are toxic, persistent or bioaccumulate.
Such substances, which may include some pesticides or their metabolites, pose the most ecological risk. Environment Canada has recently developed criteria by which persistence and bioaccumulation may be measured:
Persistent: having a half life of 6 months in water, 6 months in soil and 1 year in sediment
Bioaccumulative: having a bioconcentration factor or bioaccumulation factor greater than 5 000. This critical value is derived from bioconcentration factors for freshwater fish.

Use, with caution, pesticides with a soil persistence of greater than 21 days, a soil adsorption value (Koc) of less than 300 or a solubility of greater than 30 mg / L.
These general guidelines are especially important in areas with coarse textured soils and soils low in organic matter. It should be noted that pesticides exceeding these guidelines need not necessarily be of concern. For example, water-soluble glyphosate is strongly adsorbed to soils, so it is less likely to leach but could enter surface waters via runoff from exposed soils.

Avoid applying wettable powders in potential runoff areas.
Wettable powders exhibit relatively high runoff rates (5 per cent of amount applied). More suitable alternatives are water soluble powders or emulsifiable concentrates.

Cross-reference pesticide names with their registration number.
Slight differences in trade names can represent significant differences in pesticide content and chemical formulations.

Avoid applying pesticides during winter in flood-prone areas.
Some waterfowl species are attracted to flooded fields, and can be poisoned through ingestion of persistent pesticides, particularly granular formulations.

Pesticide Application

It is the applicator's responsibility to take appropriate precautions to protect bystanders, non-target vegetation, aquatic life and wildlife from exposure. Procedures for pesticide application follow:

Use well trained, licensed staff to apply pesticides.
Applicators should be able to accurately follow pesticide manufacturer directions, interpret the management plan and understand the factors that lead to potentially negative impacts on people and the environment.

Read product labels carefully and apply chemicals according to the manufacturer's recommended usage and only for registered uses.
Pay close attention to delivery rate or spray volume per unit area.

Properly calibrate all pesticide sprayers prior to use.
Accurate calibration will assure better pesticide

performance and reduce the risk of chemical drift, runoff and turf stress caused by misapplication.

Employ techniques to minimize pesticide drift.
There are a number of techniques that can be employed:

❒ *Closely monitor weather conditions and forecasts to comply with application guidelines.*
Do not spray pesticides when the soil is saturated with water, when heavy rainfall is anticipated or when the temperature exceeds 27°C. Do not spray pesticides when winds exceed 8 km / hr or when winds are blowing towards sensitive vegetation or water bodies. Avoid conditions of "dead-calm" or temperature inversions — they can lead to vapour cloud formation.

❒ *Use low pressures (200-250 kPa) and nozzles that produce large droplets.*

❒ *Consider the use of drift inhibitor or retardant additives.*

❒ *Mix a spray pattern indicator with pesticide to where there is potential risk of drift or when spraying near a buffer area.*

❒ *Use wind skirts, shrouds or other wind guards on all sprayers.*

Do not fill pesticide sprayers in the vicinity of watercourses or drains.

Do not leave sprayers unattended while filling.

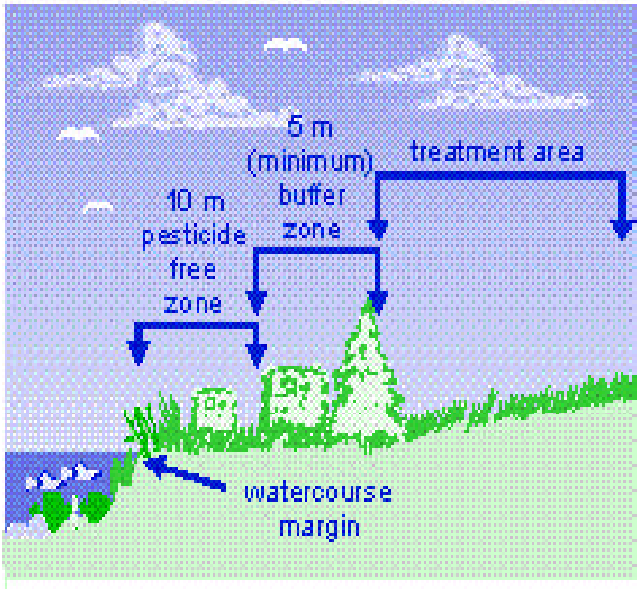
Dedicate spraying equipment to specific chemicals, if possible.
This practice will minimize cross-contamination of pesticides that could result in damage to turf or non-target vegetation or biota.

Maintain application equipment.
Regular cleaning will stop chemicals from corroding or plugging equipment.

Pesticide-Free Zones

Pesticide-free zones reduce the chance of pesticide drift, runoff or leaching into sensitive areas and reduce the likelihood of excess treatment or accidental spills adjacent to surface waters. Surface waters to be protected by pesticide free zones include: i) watercourses such as rivers, streams, creeks and ditches; ii) waterbodies such as ponds, lakes, marshes or sloughs; and iii) seasonal watercourses or waterbodies that are frequented by fish or flow directly into fish-bearing waters or domestic water supplies. Considerations for pesticide-free zones are described below:

Figure 3.5
Relationship Between a Pesticide Free Zone and a Buffer Zone



Maintain a minimum 10 m pesticide-free zone adjacent to watercourses or water bodies.
In BC, most applicable permits and guidelines specify a minimum 10 m pesticide-free zone, but it can be wider depending on site characteristics and the significance of water resources. No pesticide or application equipment should enter the pesticide free zone.

Set a buffer zone along the pesticide-free zone.
A buffer zone is usually required between the pesticide-free and treatment zones to inhibit pesticide drift, runoff or leaching into the free zone. The buffer width will depend on the pesticide application method, weather conditions and terrain. For example, steeper slopes

and applications using boom sprayers may require wider buffers. The relationship between the pesticide-free zone and the buffer zone is depicted in Figure 3.5.

In areas of sensitive aquatic resources, consider conducting a risk assessment.
In areas where there is significant public concern or significant potential for negative impacts to water resources, a risk assessment should be considered. This may require computer modelling to calculate the leaching and surface runoff potential or spray pattern monitoring (Kromekote paper can be used to help identify where a pesticide and dye mixture have landed).

3.5 Maintenance Area Management

The maintenance area is the main storage site at any golf course. It is also used for mixing chemicals, servicing equipment and composting. The goal of the management practices in this section is to prevent the release of maintenance area substances to the outside environment, especially to surface waters.

Extensive guidelines exist for storing and handling pesticides, fuel and equipment maintenance materials. This section highlights general management practices relating to these items, but managers should also review local, provincial and federal requirements (e.g., health and safety regulations, standard practices for pesticide applicators, and pesticide control regulations).

3.5.1 Pesticide and Fertilizer Storage

Maintain a well designed pesticide storage area that includes the following features:
- ❒ distinct / separate facilities (a cabinet for small pesticide quantities or a detached building for larger quantities);
- ❒ fire-resistant construction materials;
- ❒ sealed surfaces (to prevent chemical absorption);
- ❒ spill containment measures (For a separate room or building, this can entail commercial containment flooring and recovery system or a sealed concrete floor encircled by a curb. In all cases, spill containment / clean-up materials should be available.);
- ❒ no floor drain;
- ❒ protection from extreme temperatures;
- ❒ stable storage shelving;
- ❒ materials stored in original containers, with clearly legible labels;
- ❒ liquids stored below dry, bagged materials;
- ❒ good lighting;
- ❒ good ventilation
- ❒ locks; and
- ❒ warning signs.

Designate a covered area solely for the purpose of pesticide mixing and storage with the following features:
- ❒ proximity to the storage building;
- ❒ spill containment and recovery measures;
- ❒ no floor drain; and
- ❒ emergency wash facilities.

Keep a running inventory of all pesticides and fertilizers in stock.

Avoid generating or accumulating unused pesticides.
Pesticide needs should be carefully planned. Only buy pesticides for immediate use or, at most, one year's supply. BC MELP should be contacted regarding the disposal of unused and unwanted pesticides.

Empty pesticide containers should be disposed of as follows:
- ❒ rinse containers as appropriate for the container type;
- ❒ do not rinse empty pesticide containers in surface waters;
- ❒ crush or puncture rinsed containers so they cannot be reused; and
- ❒ dispose of containers at an approved landfill or contact BC MELP about recycling options.

Properly dispose of rinse water produced from rinsing containers or application equipment:

❒ drain container rinse water into spray tanks and apply to the treatment area (also treat equipment rinse water as product); and

❒ if rinse water cannot be applied to the treatment area, apply it to the ground as long as the ground is flat, not in a wet lowland, does not consist of porous materials, and is located at least 200 m from any surface water or wells.

Directions for rinsing pesticide containers can be found in the *BC Handbook for Pesticide Applicators and Dispensers*.

3.5.2 Maintenance Equipment and Fuel Storage

Design a covered equipment maintenance area that incorporates the following features:

❒ located away from surface waters;

❒ protected from outside runoff;

❒ no floor drains;

❒ concrete floor;

❒ spill containment measures (e.g.; absorbent materials such as cat litter or absorbent pads or booms);

❒ dry housekeeping procedures (e.g., avoid the use of water for clean-up: use a broom or a damp mop); and

❒ drip pans for leaking / dripping fluids.

Incorporate the following features into the fuelling area:

❒ located away from surface waters;

❒ paved, with concrete and not asphalt;

❒ stormwater directed away from fuelling area; and

❒ spill containment and recovery features and / or materials.

Direct equipment wash water to an oil / water separator or a storage tank prior to discharge and avoid the use of solvents or detergents.

Washing general maintenance equipment (i.e., equipment not having contained fertilizers or pesticides) can release detergents, solvents, oil and grease to the environment. Ideally, avoid the use of detergents or solvents. Equipment wash water should flow to an oil / water separator prior to discharge (e.g., to the ground or a storage tank for eventual pump out). The oil / water separator can also be used to collect and treat runoff from the parking lot. At a minimum, equipment washing should be conducted as follows:

❒ wash with water only (e.g., pressurized water can help remove debris);

❒ use a flow control device (e.g., on / off trigger) on the water supply; and

❒ wash on grassy or gravelled areas with sufficient soaking capacity, away from surface water or wells.

3.5.3 Composting

Design a composting area that is:

❒ located away from surface waters and downwind from residential areas;

❒ lined to prevent leaching;

❒ covered to prevent saturation and rainfall runoff; and

❒ protected from outside runoff.

3.5.4 Spill Contingency

A spill contingency plan is a must for any maintenance area. To minimize the potential for pesticides or other hazardous materials from the maintenance area (e.g., coolants, oil and fuel) to be discharged to the outside environment, maintenance staff should be educated regarding spill contingency measures. Appropriate personal protective equipment, absorbent materials, neutralizing agents and / or other containment and recovery materials should be readily available.

4.0 Appendices

4.1 Acts, Regulations and Guidelines

Acts, Regulations and Guidelines are the primary standards to which golf course management practices must comply. While there is no legislation in BC or Canada that specifically addresses golf courses, there are a considerable number of Acts, Regulations and Guidelines pertaining to typical golf course practices. There are also a number of government sponsored fact sheets, newsletters and reports that provide valuable information.

Applicable acts, regulations, guidelines and information sources are listed below with brief descriptions of their most relevant aspects. On a municipal or regional district level, bylaws may indirectly or directly apply to golf course activities.

Federal Acts & Regulations

Fertilizers Act / Regulation:
The Act and Regulations pertains primarily to product registration. Products containing only a nitrogen, phosphorous and potassium combination or these primary nutrients in combination with micronutrients need not be registered. However, fertilizer products containing pesticides must be registered under both the *Pest Control Products Act* and the *Fertilizers Act* and products containing only micronutrients (without nitrogen, phosphorous and potassium) must be registered under the *Fertilizers Act*.

Fisheries Act
This act is used to protect fish, fish habitat and water quality.

Migratory Birds Convention Act / Regulation:
Under this Act, it is an offense to allow the release of any substance harmful to migratory birds into waters or areas frequented by these birds.

Pest Control Products Act / Regulation:
Under the Act, every pesticide product for sale or use in Canada must be registered by Agriculture Canada. A key stipulation is that dispensers cannot sell and applicators must not use pesticides for purposes not described on the label, unless otherwise authorized by provincial authorities.

Transportation of Dangerous Goods Act:
The primary relevant requirement of the this Act states that the transport of potentially hazardous quantities of dangerous goods should only be conducted by those appropri-

ately trained and with the required shipping documents, safety markings, vehicle placards and safety procedures. The transport of 5000 L or less of pesticide by road is considered exempt.

Provincial Acts & Regulations

Environmental Management Act
This Act gives the Environment Minister the power to prevent detrimental impact to the environment. For example, in the case of a pesticide accident, mitigation costs can be charged to the person responsible.

Pesticide Control Act / Regulation
This Act and Regulation apply to the safe transportation, storage, preparation, application and disposal of pesticides.

Waste Management Act / Special Waste Regulation
This Act prohibits the discharge of waste without a permit, approval or compliance with the applicable regulations. Pesticide container disposal and pesticide contaminated rinse water are regulated under the Act's Special Waste Regulations.

Water Act

Weed Control Act
Inspectors under this Act can require the control of noxious weeds.

Wildlife Act
This Act makes it an offense to use a poison to kill certain birds, threatened or endangered animals, or fur bearing animals.

Workers' Compensation Act / Industrial Health and Safety Regulations
These regulations stipulate the protective procedures to be followed when handling harmful substances such as pesticides.

Federal Guidelines

Freshwater Intake End-of-Pipe Fish Screen Guideline

Land Development Guidelines

Stream Stewardship: A Guide for Urban Planners and Developers

Provincial Guidelines

Guidelines to Protect, Maintain and Enhance Fish and Wildlife Habitat on and Adjacent to Proposed Golf Course Developments and Existing Course Re-Developments on Lowland Areas

Land Development Guidelines for the Protection of Aquatic Habitat

Provincial Fact Sheets

Integrated Pest Management in BC

Provincial Newsletters

BC Pest Monitor

Other Information Sources

Handbook for Pesticide Applicators & Dispensers

Safe & Sensible Pest Brochures: Aphids - Yellowjackets

Standard Practices for Pesticide Applicators

4.2 Contact Numbers

Listed below are contact numbers for further information on the environmental considerations associated with golf course operation.

Federal

Agriculture Canada
(BC Regional Office)
202-620 Royal Ave.
New Westminster, BC
V3L 5A8
(604) 666-6513

Environment Canada
Climate Information - Historical & Statistical
(604) 664-9156

Environment Canada
Suite 700, 1200 W 73rd Ave.
Vancouver, BC
V6P 6H9
(604) 664-9100

Fisheries & Oceans
Regional Headquarters
400-555 W. Hastings Street
Vancouver, BC
(604) 666-3545

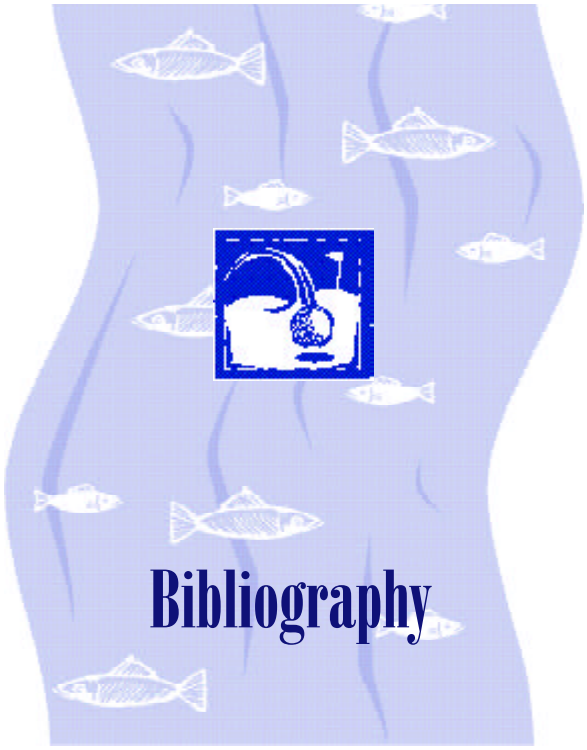
Provincial

Ministry of Agriculture, Fisheries and Food (BC)
Crop Protection Branch
1767 Angus Campbell Road
Abbotsford, BC
V3G 2M3
(604) 556-3001

BC Environment, Lands and Parks
Pesticide Management Branch
4th Floor, 737 Courtney Street
Victoria, BC
V8V 1X5
(604) 387-9415

Other

Audobon Society (New York)
Cooperative Sanctuary Program
Hollyhock Hollow Sanctuary
Rt 2, Box 131
Selkirk, New York
12158
(518) 767-9051



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