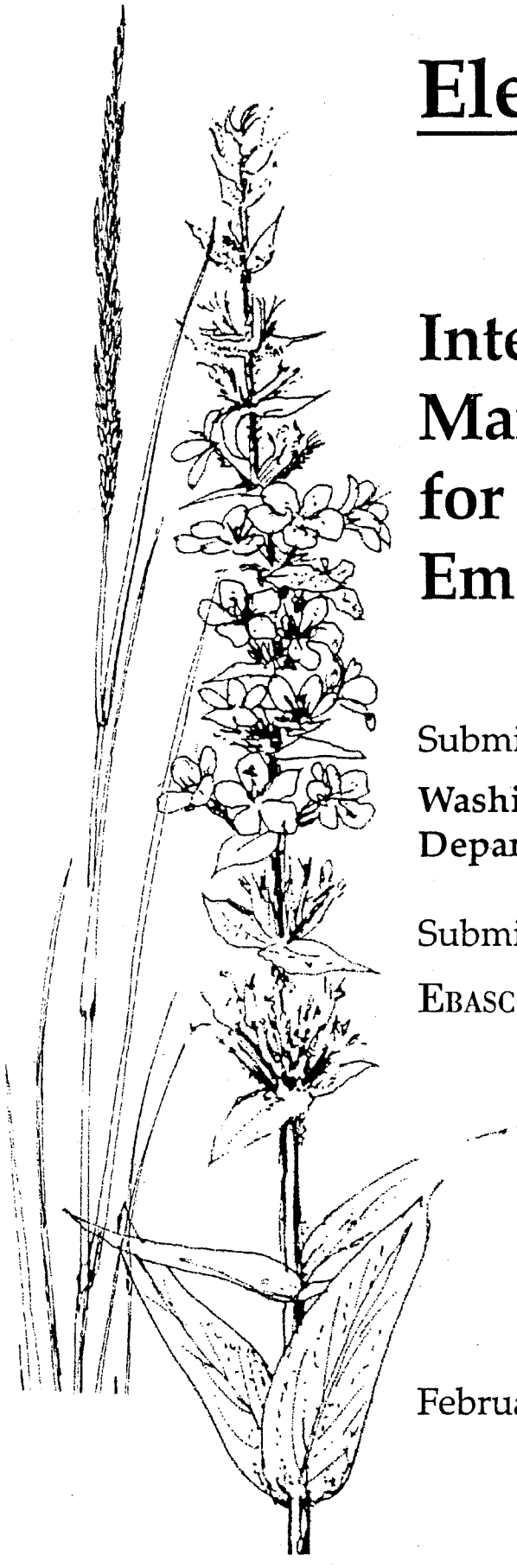
DRAFT REPORT

Element I



Integrated Weed Management Alternative for Managing Noxious Emergent Plants

Submitted to

Washington State Department of Ecology

Submitted by

EBASCO ENVIRONMENTAL

February 1993

ABSTRACT

Infestations of noxious emergent plant species in Washington are raising ecological and economic concerns. The Washington State Departments of Agriculture, Ecology, Fisheries, Natural Resources, and Wildlife, and the Washington State Noxious Weed Control Board, have proposed to develop and implement a management plan for these species. Species of immediate concern include smooth cordgrass (*Spartina alterniflora*), common cordgrass (*S. anglica*), salt meadow cordgrass (*S. patens*), purple loosestrife (*Lythrum salicaria*), wand loosestrife (*L. virgatum*), dotted loosestrife (*Lysimachia punctata*), garden loosestrife (*L. vulgaris*), giant hogweed (*Heracleum mantegazzianum*), and indigobush (*Amorpha fruticosa*). One management option is an integrated management approach, which focuses on the coordinated use of multiple preventive, biological, mechanical/physical, and chemical treatment methods to effect control, containment, reduction, and, in some instances, eradication of these noxious species.

Integrated management involves the deliberate selection, integration, and directed utilization of plant population suppression measures on the basis of predicted economic, environmental, and sociological consequences. When these measures are successfully applied, plant populations are prevented from attaining economically or environmentally damaging densities. Management program activity within Washington must be guided by appraisals of plant invasive status and damage potential. Preventing establishment of potentially new invaders is the top management priority, followed by the containment and suppression of new invader and established invader populations.

This report presents a generalized management program and its components, including information acquisition, damage and action threshold establishment and use, treatment methods selection and implementation, and monitoring/evaluation. Site-specific management plan strategies, objectives, and treatment methods for potentially new, new, and established invaders are also discussed. Generic species-specific integrated management scenarios are provided for selected noxious emergent plants, including the cordgrasses, purple loosestrife, and giant hogweed.

The integrated approach to noxious emergent plant management requires that all affected land/water protection, regulatory, educational outreach, and other agencies effectively work together. Public participation in integrated management program development and implementation is also essential. Various ways to involve interested citizens in inventory, management, and educational activities are described.

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Element I: Integrated Weed Management Alternative for Managing Noxious Emergent Plants

Submitted to:

Washington State Department of Ecology

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CONTENTS

TABLES

FIGURES

1.0 INTRODUCTION

1.1 PURPOSE

The Washington State Departments of Agriculture, Ecology, Fisheries, Natural Resources, and Wildlife, and the Washington State Noxious Weed Control Board, acting as lead agencies, have proposed to develop and implement a management plan for noxious emergent plant species occurring in the state of Washington. Species of concern include three species of cordgrass (*Spartina alterniflora*, *S. anglica*, and *S. patens*), purple loosestrife (*Lythrum salicaria*), wand loosestrife (*L. virgatum*), garden loosestrife (*Lysimachia vulgaris*), dotted loosestrife (*L. punctata*), giant hogweed (*Heracleum mantegazzianum*), and indigobush (*Amorpha fruticosa*). The lead agencies want to determine which management alternative or combination of alternatives would provide the most effective management of noxious emergent plant species with the least environmental impacts. The ultimate goal of the proposal is to develop criteria and approaches for preventing infestations of potential new invader weed species and for managing infestations of both new and established invader species.

Using a public scoping process, the lead agencies have determined that a management program could have significant adverse environmental impacts. Thus, an environmental impact statement (EIS) is required under RCW 43.21C.030(2)(c). Topics to be discussed in the EIS have been identified by the lead agencies, and include biology and ecology of problem species, management alternatives, efficacy and impacts of alternatives, and mitigation strategies. Ebasco Environmental was contracted by the nominal lead agency, the Washington State Department of Ecology, to assemble and synthesize available information on the topics of interest for inclusion in the EIS.

To assist in plan development, this report describes an integrated management approach (the preferred alternative) for the management of noxious emergent plants in Washington.

1.2 OBJECTIVES

The objectives of this report are to:

(1) describe the practice of integrated weed management and the benefits and limitations associated with its use; and,

(2) provide descriptive generic and site-specific integrated management plan design and implementation guidelines, and present generic species-specific integrated management plans for selected noxious emergent plant species.

Information sources for this report were published journal articles, reports, and books obtained from national sources.

2.0 DESCRIPTION OF INTEGRATED WEED MANAGEMENT

2.1 INTEGRATED WEED MANAGEMENT DEFINED

The modern era of managing pests of all kinds, including noxious plants, has emphasized control. Inherent in the concept of control has been the notion that weeds—at whatever population level—are intolerable. In attempts to achieve this objective, herbicides have been utilized extensively during the last four decades. However, mounting scientific and societal concerns about the potential or realized development of herbicide-resistant weed species, groundwater contamination, impact on non-target plants, and realized or perceived health risks to humans and other animals have substantially eroded the confidence once placed in these chemicals.

These concerns have provided impetus for weed scientists and others to re-evaluate past control efforts and to adopt a new philosophy concerning suppression of noxious plant species—integrated weed management (IWM). Integrated weed management is a component of integrated pest management (IPM) (Thill *et al.* 1991), a comprehensive approach to pest control that has received much attention since the mid-1960s (Rabb and Guthrie 1970, Geise *et al.* 1975, Bottrell 1979, Flint and van den Bosch 1981, Horn 1988, Olkowski *et al.* 1991). Integrated management is the deliberate selection, integration, and implementation of weed suppressive measures on the basis of predicted economic, ecological, and sociological consequences (Klassen 1979). The approach is unique because it is predicated on ecological principles and incorporates multidisciplinary methodologies in developing ecosystem management strategies that are practical, effective, economical, and protective of public and environmental health.

Experience has shown that development of effective, long-term weed management solutions requires a thorough understanding of the actions, reactions, and interactions of the various components of the ecosystem to be protected. IWM uses the systems approach and considers the noxious plant as it relates to the ecosystem of which it is a part. Only by studying and understanding these relationships can the weed management practitioner devise ways to suppress noxious vegetation without causing ecological perturbation. Because ecosystems are dynamic, IWM programs must be flexible to accommodate changes within the ecosystems of concern (Bottrell and Smith 1982). IWM organizes multiple noxious plant suppression techniques into a system that maximizes the advantages while minimizing disadvantages or impacts of the component methods.

2.2 MANAGEMENT VERSUS ERADICATION

The IWM concept implies a manipulation of the ecosystem so that noxious plants, particularly well-established species, are maintained at noninjurious population levels, i.e., complete elimination of the target species is not attained. Integrated weed management is not a universal solution for all pest plant problems. For some weeds (new invaders, for example), eradication—not management—may be the desired objective. Eradication and

integrated weed management are not synonymous strategies, as many people erroneously believe. In fact, eradication is the antithesis of weed management. Integrated weed management can often successfully reduce noxious plant abundance to where eradication becomes possible. Eradication implies the elimination of all plants and propagules of the target species from an infestation area, and is only achievable and economically feasible when the noxious plant is geographically confined.

2.3 BENEFITS AND LIMITATIONS OF INTEGRATED WEED MANAGEMENT

Integrated weed management is a systematic, comprehensive approach to the management of noxious plant populations that acknowledges the importance of both economic and environmental perspectives. Implementation of the integrated approach has benefits and limitations. Benefits include:

- coordinated, efficient use of multiple weed management methods;
- continuous monitoring and evaluation of the weed-impacted managed resource;
- reduced adverse impacts to natural, agricultural, and built aquatic environments;
- improved placement and/or lessened use of herbicides;
- reduced human and wildlife exposure to herbicides; and,
- attainment of long-term, reliable weed management not possible from single-method approaches.

Shortcomings of the IWM approach include:

- nonapplicability in some situations (eradication, for example);
- failure among some weed managers to recognize that development and implementation of an effective integrated approach are time-consumptive processes;
- insufficient understanding of the concepts, philosophies, and goals of IWM among policy-makers, management personnel, and the general public;
- shortage of knowledgeable individuals for effecting IWM program development, implementation, and evaluation;
- reluctance among management personnel to administrate integrated program complexity;

- lack of information on noxious plant biology and ecology, damage and action thresholds, and management method efficacies needed for program implementation; and,

- failure to attain specified weed management objectives because of inconsistent, inadequate financial support by responsible management agencies.

3.0 NOXIOUS EMERGENT PLANT MANAGEMENT PROGRAM PRIORITIES

3.1 NOXIOUS WEED SELECTION

3.1.1 Definitions

The management and/or eradication of emergent plant species formally listed as noxious should be considered more critical than management of problem species not listed as noxious. The term "noxious weed" has legal definitions established by the federal government and by the state of Washington. In the amended Federal Noxious Weed Act (Public Law 93-629), a noxious weed is defined as "any living stage (including but not limited to, seeds and reproductive parts) of any parasitic or other plant of a kind, or subdivision of a kind, which is of foreign origin, is new to or not widely prevalent in the United States, and can directly or indirectly injure crops, other useful plants, livestock, or poultry or other interests of agriculture, including irrigation, or navigation or the fish or wildlife resources of the United States or the public health." In Washington, a noxious weed is defined as "any plant which when established is highly destructive, competitive, or difficult to control by cultural or chemical practices" (Chapter 17.10 RCW). An emergent plant is defined as "a rooted plant adapted to grow with most of its leaf and stem tissue above the water surface" (Kurtz 1989).

The Washington State Noxious Weed Control Board (WSNWCB) has designated certain emergent plants as noxious and the Washington State Department of Agriculture (WSDA) provides funding (legislative appropriations) to county noxious weed control boards and districts for the management of such plants. The WSNWCB annually adopts a Washington State Noxious Weed List that classifies non-native plants having potential to cause serious problems because they are difficult to manage and/or are a threat to the state's natural resources.

Noxious species appearing on the state list are categorized as either Class A, B, or C species, largely depending on their distribution within Washington. Class A species are of limited distribution or are unrecorded in the state. Class B species are of limited distribution or are unrecorded in a region of the state and pose a serious threat to that region. Class C species are any other noxious weeds, typically those that are widely established in the state and of special concern to a segment of the agricultural industry.

Control (defined as prevention of all seed production) of all Class A species in counties where they occur is required by Washington state law (Chapter 17.10 RCW, Chapter 16-750 WAC). Control of Class B species is mandated in regions designated by the WSNWCB (Class B-designate species). County weed control boards/districts may select and add to their noxious weed lists Class B species not designated by the WSNWCB for control in their counties. The weed control boards/districts also may include Class C species on their lists. When Class B (non-designate) and C species are included on county lists, control is required by state statutes.

The following emergent plants are included on the current (1993) State Noxious Weed List:

Class A species:

- salt meadow cordgrass (*Spartina patens*)
- giant hogweed (*Heracleum mantegazzianum*)

Class B—designate species:

- common cordgrass (*Spartina anglica*)
- smooth cordgrass (*Spartina alterniflora*)
- purple loosestrife (*Lythrum salicaria*)
- wand loosestrife (*Lythrum virgatum*)
- garden loosestrife (*Lysimachia vulgaris*)
- indigobush (*Amorpha fruticosa*)

One additional emergent plant species of concern, dotted loosestrife (*Lysimachia punctata*), has not been proposed for inclusion on the State Noxious Weed List. A separate report submitted to the Washington State Department of Ecology provides available information on the biology and ecology of this species (Ebasco Environmental 1993c).

3.2 NOXIOUS PLANT MANAGEMENT PRIORITIZATION

The specific type of management response to be undertaken at a particular site is determined by an assessment of the target species's class designation (A, B, or C), invasive status, distribution, and/or density. The following hierarchical priority or action levels should be used:

PRIORITY I, *Potential New Invaders*: Potential new invaders are noxious weeds as yet unrecorded in a site or defined geographic area, but a strong possibility of imminent invasion exists (Hoglund *et al.* 1991). Class A species fall into this category. Management emphasis is prevention, identification, monitoring, and educational awareness.

PRIORITY II, *New Invaders*: New invaders are noxious weeds whose population density and distribution are such that all propagule production can be prevented within a specific site

or area by use of appropriate management methods (Hoglund *et al.* 1991). Class A and B-designate species can be classified as new invaders. Management emphasis is control, containment, and eventual eradication.

PRIORITY III, *Established Invaders*: Established invaders are noxious weeds whose population density and distribution are such that all propagule production cannot be prevented within a specific site or area (Hoglund *et al.* 1991). Class B-designate species could fall into this category. Damage/action thresholds determine the management strategy selected. Management emphasis is placed on control and containment, but taking no action is also a possibility. Eradication is not feasible.

4.0 INTEGRATED MANAGEMENT PLAN DEVELOPMENT GUIDELINES FOR NOXIOUS EMERGENT PLANTS

4.1 NOXIOUS EMERGENT PLANT MANAGEMENT GENERIC PLAN DEVELOPMENT

Because development of a specific IWM plan depends on the target species, the resource to be protected, and economic, labor, and other constraints, it is not possible to provide absolute procedures to be followed in every situation. However, certain general program guidelines are applicable to the management of all noxious emergent weeds.

4.1.1 Information Acquisition

The most important component of an IWM effort is development and maintenance of an information gathering system. Information gathering is essential in order to delineate the problem area, determine damage and suppressive action levels, select and time the most effective and least environmentally disruptive management options, and monitor/evaluate the program upon its implementation. The process includes surveying, monitoring, and record keeping, and represents an ongoing activity in any IWM program.

Surveys are designed to provide information about noxious plant species composition, distribution, abundance, and importance within the resource area to be protected. A list of plant species to be surveyed must be compiled and should include potential and new invaders as well as established species. Survey personnel must be able to accurately recognize designated noxious weeds or know where to seek identification assistance when unfamiliar species are encountered. All infestations should be mapped and maps should be updated annually once a management effort has been initiated. It is imperative that areas subject to repetitive disturbance and intense human activity be prioritized in survey efforts. The survey should be conducted early enough in the season to ensure that identified noxious weeds can be managed at their most susceptible developmental stage(s).

The purpose of monitoring is to compile and record the site-specific information on which decisions about management options for invasive species are to be based. Monitoring provides the weed management specialist with baseline data, reference points for all management decisions, and ways to evaluate short- and long-term program effectiveness. Each monitoring system must be site-specific in character because the level-of-effort needs to be based on consideration of damage potential, monitoring personnel time availability and skill level constraints, among other factors. A monitoring system is valuable only if accurate records are maintained. The format and process by which information is maintained by monitoring personnel should be standardized in order to achieve long-term continuity.

4.1.2 Damage and Action Thresholds

Monitoring noxious plant populations in a resource management system is productive only if the level of weed occupancy can somehow be meaningfully related to potential damage. The principle of using damage and action thresholds to base management decisions upon is an essential element of the IWM approach. Thresholds provide weed managers with definitive ways of determining if and when noxious weed populations warrant manipulative actions in an area of concern.

A damage threshold is the plant population density or growth stage that results in intolerable damage to the affected resource and/or its occupant biota. It is based on: 1) an assessment of the noxious weed's potential to become established and spread off-site; 2) determination of the quantity of sites or extent of a geographic area susceptible to invasion; and 3) evaluation of the affected site's resource management objective(s). To the extent that a noxious weed is capable of damaging site resources, a damage potential exists. The damage potential is simply a subjective or objective (where data exists) estimate of the potential for site damage based upon aspects of weed biology and ecology, propagule transport potential, and site susceptibility.

The action threshold is determined relative to the damage threshold. The action threshold is the plant abundance level at which suppressive techniques must be implemented in order to prevent the population from reaching the damage threshold. An action threshold is established to guide weed management treatment selection and implementation.

In the case of any new invader noxious weed species, the damage and action threshold is considered to be one plant of that species within the area of concern. This determination is based on the potential of any new noxious weed to significantly impact natural resources and increase management costs if it spreads. The low damage and action thresholds indicate immediate action is needed to prevent reproduction.

Thresholds are most useful for decision-making when infestations of well-established noxious weeds require annual management. In such situations, establishment of realistic damage and action thresholds will depend upon species-specific, site-specific, phenological, economic, and other pertinent factors. For an established invader, occasional readjustment of

established damage and action thresholds is usually required because management strategies and objectives change in response to noxious weed population density reductions or increases. Threshold evaluation and modification should be a continuing endeavor in any IWM program.

4.1.3 Weed Management Treatment and Method Selection and Implementation

Suppression of noxious weeds from the perspective of integrated weed management focuses on the harmonious use of several, low environmentally-impactive management methods to reduce the damage caused by noxious weeds. No single management technique can or ever should be expected to effectively control established invaders or deter new invaders (Bottrell 1979). Many factors must be considered when deciding what management options may be most feasible and practicable for use in a resource protection system. Selection of these measures must be based on detailed knowledge of available control options, the resource to be protected, and weed biology and ecology, an understanding of which enables the resource manager to identify maximum vulnerability periods in the highly divergent life cycles of weeds and to apply appropriate tactics at such times to achieve optimum population reductions (Radosevich and Holt 1984). Important consideration should be given to tactics that interrupt weed propagule dispersal, reduce seed longevity, minimize habitat perturbations contributing to undesirable plant occupancy, and avoid or interrupt local and regional weed immigration and emigration.

Management measures applicable for use against noxious emergent plant species can be categorized as being preventive, biological, mechanical/physical, and chemical. Various preventive tactics and the importance of incorporating them into an IWM program are discussed in Section 4.2.4.1. The biological control method involves the importation, conservation, or augmentation of invertebrate and vertebrate animals, plant pathogens, and competitive plants for weed management. It involves techniques such as site revegetation, planting of competitive and site-appropriate vegetation, and animal grazing management to decrease the suitability of the environment to support weed development. Mechanical/ physical weed management methods include hand extraction, cutting, mowing, covering, dredging, rotovating, crushing, flaming, and prescribed burning. Chemical management of noxious plants is achieved by using selective and nonselective herbicides. Descriptive information on these management methods is contained within reports prepared by ACOE (1993) and Ebasco Environmental (1993e, 1993f, 1993g).

4.1.4 Evaluation

The IWM process is as dynamic as the ecosystem in which it is applied. Thus, once an IWM plan has been formulated and implemented, project accomplishments must be regularly reviewed and evaluated. Monitoring of the impacted ecosystem is essential. Information gathering and interpretation through time allows the weed management specialist to detect and respond to changes that develop in the state of the resource. Evaluation findings enter

the management system at all levels in order to refine and improve the system and to provide updated information for the next round of decision-making.

4.2 NOXIOUS EMERGENT PLANT MANAGEMENT SITE-SPECIFIC PLAN DEVELOPMENT

4.2.1 Defining a Site

A "site" can be characterized as a land and/or water area either susceptible to infestation or infested by one or more noxious emergent weed species. Each area is unique and consequently warrants development of an individualized management prescription. Site-specific factors such as the noxious plant species and its invasive status, potential environmental impacts, and the resource management objectives for the site dictate which techniques would be most appropriate. A standardized decision-making process facilitates selection of and integration of all suitable weed management methods into a workable plan. Environmental and human health concerns, accessibility, seasonal, weather-related and possible budgetary and/or labor constraints, and mitigation measures must also be considered during design of the management plan.

4.2.2 Public Participation

Public reaction is another element to be considered during IWM program planning. This is particularly true for large-scale, weed suppression programs where public understanding, acceptance, and support of the effort are indispensable. In general, the public usually supports programs they understand, and protests ones they do not understand. Successful project and risk communication with the affected public thus becomes a critical factor to program success. Unfortunately, this subject is typically given less thought than any other aspect during management program development. A public information effort should be instituted during early IWM project planning stages and be continued throughout the implementation and evaluation phases. All available and effective information dissemination methods should be used to reach the affected public.

4.2.3 Integrated Weed Management Decision Matrix

By following a stepwise, decision-making process, a weed manager can develop and implement a functional, site-specific management plan. This process is described below. A flow diagram of the integrated management plan decision-making process for noxious emergent noxious plants is presented in Figure 1.

(1) Inventory each management site. Designate all identified noxious emergent species as new or established invaders. Develop or review/modify list of potential new invaders.

(2) Determine the potential for damage to the site from noxious weed infestation. Determine the damage and action thresholds for each noxious plant species present.

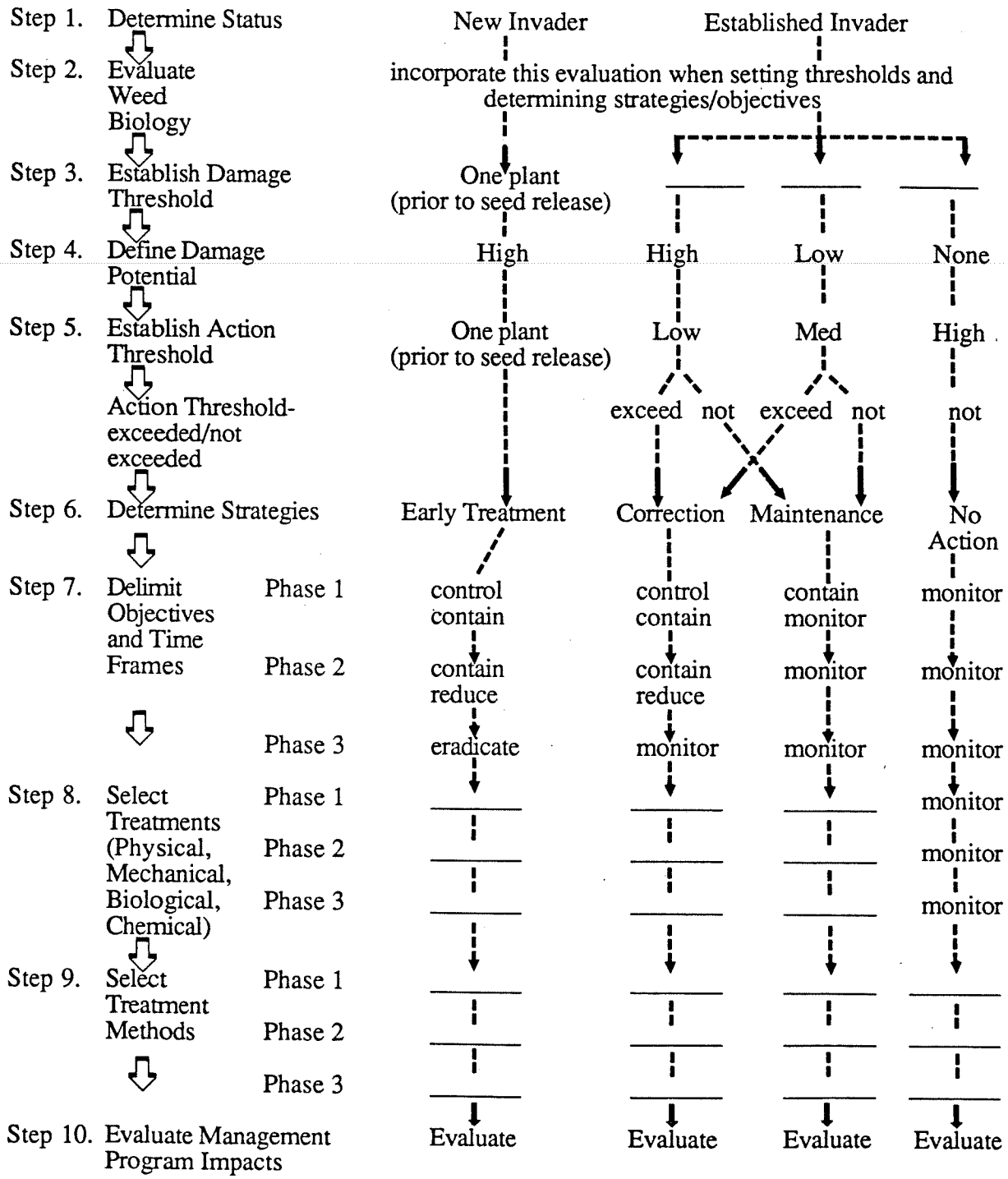

Figure 1. Flow diagram of the integrated management decision-making process for noxious emergent weeds. Modified from USFS (1991).

(3) Develop site-specific weed management strategies based on noxious weed status (new or established invader) and damage and action thresholds. Strategies will include early treatment, correction, maintenance, and no action, as well as prevention.

(4) Determine specific objectives that can be attained within reasonable timeframes for each site. Objectives may include one or more of the following: control (that is, prevention of all propagule production), containment (that is, confinement of the noxious weed to an identified area of infestation), reduction (that is, decreasing population density or the area infested), eradication (that is, complete and permanent elimination of plants and their propagules from the area of infestation), and monitoring (that is, information gathering) through time to identify the efficacy of the implemented management strategy.

(5) Identify appropriate treatments (that is, preventive, mechanical/physical, chemical, and/or biological) and methods and specific treatment tactics (for example, hand removal, burning, insect bioagent release, etc.) based upon a knowledge of weed biology and ecology, operational constraints, and mitigation needs.

(6) Monitor and evaluate treatments to gauge their effectiveness. Identify any use-related constraints and adverse environmental impacts. Ascertain costs involved in the implementation of the treatments. Adjust management program as needed.

4.2.4 Priority-based, Site-Specific Management Plans

4.2.4.1 Priority I: Potential New Invaders

Goal: Prevent or reduce the likelihood of invasion by noxious emergent weed species not yet recorded at a site or geographic area.

Detection

Many species of noxious weeds yet unrecorded in Washington are capable of invading and establishing in aquatic environments throughout Washington (Reed 1977). Some Class A and B-designate emergent weed species occur in certain regions of the state but have not yet spread to infest other regions. This large number of potential new invaders requires constant vigil to prevent them from entering the state or expanding their currently known distributions.

The key to managing Priority I noxious weeds is to identify those species most likely to enter an area from adjacent counties, states, and Canada, and to take steps to prohibit their entry. Likewise, early detection is of paramount importance in the management of these species. Once the presence of a potential new invader is confirmed, it is reclassified as either a new invader or established invader, depending upon whether or not all seed production can readily be prevented. All new invaders must be promptly reported to the WSNWCB and

WSDA upon their discovery in a management area, as these agencies act as clearinghouses for such information.

County, state, and federal noxious weed management personnel must cooperatively compile potential new invader species lists and update the lists annually, document all known distributional data, identify mechanisms that may result in plant or propagule transport into an area, regularly maintain surveillance of those locations determined to be most susceptible to invasion by Priority I noxious weeds, ascertain infestation damage potential, and access information on possible treatment methods. These individuals must also receive training in potential invader identification and biology and learn how and where to submit unrecognizable plants for expert identification. The WSNWCB should play an integral role in developing resource management personnel and general public educational outreach programs and training materials emphasizing identification and prevention (Hovanic 1991).

Prevention Strategy and Methods

A preventive weed strategy must always precede and accompany the management effort. Noxious weed prevention is so critical to an IWM program's efficacy that it should be considered an integral component of the overall vegetation management program in any affected ecosystem. It is more environmentally desirable and highly cost effective to prevent noxious weed infestations than to manage established infestations at later dates.

Prevention is the process of forestalling contamination of an uninfested area by a noxious weed. It is pre-planned suppression. Prevention includes early detection procedures and measures taken to ameliorate the conditions that cause and foster the spread of certain undesirable plants. The success of preventive measures varies with the noxious weed species, the means of weed dissemination, and the amount of effort expended.

Preventive programs may involve enactment and/or enforcement of federal and state laws and regulations restricting noxious weed movement (for example, quarantines such as WAC 16-752-400 through 420 for purple and wand loosestrife), and seed and weed laws. Other preventive methods include:

- detection and expeditious elimination of incipient infestations of newly encountered noxious weed species;

- revegetation of disturbed soils with desirable plant species to inhibit entry of potential invaders;

- curtailment of noxious weed development in wastelands or along transportation and utility line corridors;

- inspection of and/or cleaning machinery, boats, and vehicles prior to their movement from noxious weed-infested to uninfested sites;

- management of livestock and wildlife feed and manure to prevent seed dissemination;
- restriction of weed propagule transport in fill earth;
- restriction of weed propagule transport in irrigation water delivery systems through weed seed screen installation; and
- enhancement of educational awareness among resource managers and users concerning the identification of noxious plants and the detrimental, environmental impacts associated with their spread.

4.2.4.2 Priority II: New Invaders

Goal: Control and ultimately eradicate noxious emergent weeds from a site or geographic area.

Damage and Action Thresholds

The damage and action thresholds for new invaders are one non-reproductive plant in the area of concern. Thus, the damage threshold is exceeded upon the discovery of a single plant. This extreme, low damage threshold is necessary based on the potential of any new noxious weed to significantly impact natural resources and treatment costs if allowed to spread. The low action threshold implies immediate action is required to prevent reproduction.

Treatment Strategy Selection and Objectives

Development of objectives for new invaders is based on the strategy of Early Treatment. Early treatment is characterized by the prevention of seed production during the stage of invasion when species locations and numbers are few. Selected treatments and methods focus on immediate and continued prevention of seed production in the entire infestation. All appropriate, low environmentally-impactive treatment methods should be used to achieve the following Phase 1, 2, and 3 objectives.

(1) effect control and containment during the first treatment year in order to prevent on-site seed production and the enlargement or off-site spread of the infestation (Phase 1);

(2) effect containment and reduction of the population within a specified timeframe after the first year to prevent seed production, confine the infestation on-site, and begin to reduce infestation size to zero plants (Phase 2); and,

(3) effect eradication [that is, permanent elimination of the noxious weed from the site (Phase 3)]. Eradication is often an expensive and lengthy process. The time required for eradication is based on the date when the last reproducing plant is observed, plus the

number of years required to deplete viable propagules from the soil seed bank, plus a safety factor of two or more years. Eradication may not be possible if the new invader population is too large or widespread. The eradication concept is discussed by Dahlsten *et al.* (1989). A noxious plant eradication plan is presented by Zamora *et al.* (1989).

Early Treatment Strategy and Methods Selection

During Phase 1, the control and containment phase, treatments and methods are based on sustained prevention of propagule formation and containment of the noxious weed to the treatment site. Control efforts should first be directed against perimeter plants and then progress towards the infestation nucleus (Hoglund *et al.* 1991). All appropriate methods may be used but emphasis should be placed on using the least resource-impactive methods that will achieve the objectives.

During Phase 2, the containment and reduction phase, emphasis is directed toward continued prevention of seed production, containment, and reduction of the extant infestation. When diminution methods have resulted in no more individuals of the noxious weed being found within the treatment area, regular monitoring of the site will continue until the site can be declared noxious-weed-free or a new plant is found. Upon discovery of a new plant, the process immediately reverts to the containment and reduction phase (Phase 2).

The long-term goal of early treatment is the eradication of the noxious weed from the site. The application of IWM treatment methods to a new invader population during Phases 1 and 2 may reduce population density to the point where Phase 3 (eradication) becomes operationally feasible. Technically, eradication is not an IWM objective. True IWM program decision-making is based upon continuous evaluation of noxious plant population densities in relation to pre-determined damage and action thresholds. In an eradication program, thresholds are not used because no level of noxious weed occupancy at a site is tolerable.

The first priority in an eradication effort (Phase 3) is to eliminate satellite infestations within the treatment area because these contribute to the rapid and continued spread of the noxious weed species (Mack 1985). These outlier populations are peripheral to the main infestation front. Once the outliers or satellite infestations are eliminated, treatments should be directed against the perimeter of the primary infestation initially and then towards its core, thus effecting continual reductions in, and the eventual eradication of, the noxious species. Outlier, perimeter, and core treatments must prevent seasonal propagule production. A final priority should be the intensive suppression of populations of the target species in non-eradication areas proximal to the designated eradication site in order to decrease seed production and the threat of reinfestation from those sources.

4.2.4.3 Priority III: Established Invaders

Goal: Reduce the spread of established noxious emergent weeds by emphasizing control and containment within a site or geographic area.

Damage and Action Thresholds

Damage thresholds vary according to the noxious plant species, infestation intensity, site characteristics, and so forth. The damage threshold is quantified in terms of population density (number of plants per unit of land or water surface area), rate of spread, or some other measurable factor.

Action thresholds are established based upon a consideration of the noxious weed's damage potential. If the damage potential is high, the action threshold would be low. Conversely, if the damage potential is low, the action level would be higher. If the potential for resource damage is minimal, a high action threshold level would be adopted. When established action thresholds are exceeded, appropriate strategies (such as Correction or Maintenance strategies, as described below) must be implemented.

Treatment Strategy Selection and Objectives

Management objectives for established invaders are based upon which of three treatment strategies are selected: Correction, Maintenance, or No Action. These strategies are described below:

Prevention: specific preventive methods have been previously discussed in Section 4.2.4.1.

Correction: the correction strategy includes use of treatments and methods to effect control, containment, and reduction of noxious emergent plant species. Treatments and methods include the following:

(a) Mechanical/physical
  (1) Hand removal/cutting (mowing)
  (2) Covering (smothering)
  (3) Dewatering/drainage
  (4) Flooding/inundation
  (5) Trampling/crushing
  (6) Burning/flaming
  (7) Dredging
  (8) Rotovation

(b) Chemical (application of selective and/or nonselective herbicides)

(c) Biological
  (1) Microbial pathogens
  (2) Release of insect bioagents
  (3) Forced grazing by livestock
  (4) Plant competition/forced succession

Maintenance: maintenance supports the current conditions on the site. However, actions such as hand pulling, mowing, and/or bioagent use may be used to contain the noxious weed on-site.

No Action: no actions would be taken on the site that would interfere with natural processes. Site monitoring must be maintained to detect changes that may require the selection of a different strategy (Maintenance or Correction) and objective(s) (containment, control, reduction).

The Prevention strategy is always applicable and should be utilized in combination with the other strategies. Eradication is an inappropriate objective for an established noxious weed infestation.

For a Correction strategy, the Phase 1 objectives would be control and containment. Special efforts should be made to control "escapees" from the established infestation, and those populations occurring in sites subjected to heavy and/or repeated human disturbance. Selected treatment methods should prevent continued seed production and confine the noxious weed to the treatment site. All appropriate methods may be used. However, those methods that are self-sustaining and least harmful to the resource, such as biological controls, are given first consideration. Additional objectives would be defined based on site-specific conditions and management objectives for the area. Long-term, Phase 2 objectives would include the application of containment and reduction techniques to further lower the population density below damage and action thresholds.

Once the population has been contained and reduced to a point where the thresholds are no longer exceeded, the strategy for the site then becomes Maintenance. If post-treatment monitoring conducted during Phase 3 indicates a breech of the established action threshold, the process reverts to Phase 1, the control and containment phase. For a Maintenance strategy, the objective is containment during Phase 1. Regular monitoring is necessary during all Phases to detect population density increases. As long as the action threshold is not exceeded, the Maintenance strategy remains in effect. If the on-site noxious weed population exceeds the threshold, the Maintenance strategy would be re-evaluated and the Correction strategy would be implemented.

In a No Action strategy, the objective is to monitor noxious weed population levels through time to determine if or when the established action threshold is exceeded. If the threshold is surpassed, the site is re-evaluated and either a Maintenance or Correction strategy is then selected and implemented.

4.3 NOXIOUS EMERGENT PLANT SPECIES-SPECIFIC MANAGEMENT PLANS

Because development of a specific IWM plan is dependent upon plant invasive status and infestation density, the resource to be protected, budgetary, labor force, and other constraints, it is not possible or realistic to detail absolute procedures to be followed in every potential management situation. The decision to utilize a combination of treatments and methods must be based on an assessment of plant developmental status and density, a characterization of sites infested or susceptible to infestation within the resource habitat, treatment method utilization constraints, anticipated method-induced environmental impacts, available mitigation measures, and various other considerations. Flexibility in decision-making and management option selection is essential to the successful application of the integrated approach.

Generic integrated management scenarios are presented for purple loosestrife (Table 1), cordgrasses (Table 2), and giant hogweed (Table 3). These tables describe the broad suite of methods available to weed managers, the "best" timing of those methods, and the general efficacy of the methods for various infestation situations. Little is known about the efficacy of the management methods listed in each of these tables. Most available information is anecdotal or relates to limited studies, sometimes without adequate experimental design. Selection of management methods included in the table is based on best professional judgement of the authors. Potential efficacies are estimated for achieving management objectives in average infestations, using a moderate level-of-effort in implementing each management method. Actual efficacy is site- and project-specific and varies depending on type of infestation, specific site characteristics, exact application method, application timing, and number of treatments.

The following fictitious integrated management scenarios have been developed to illustrate possible management strategies. For purposes of constructing these examples, it is assumed that there are no monetary and labor force constraints, and all treatment methods (mechanical/physical, biological, chemical, and preventive) are available for use by resource management personnel. Method-related environmental impacts, use constraints, and mitigation measures are detailed elsewhere (Ebasco Environmental 1993d, 1993e, 1993f, 1993g).

4.3.1 Priority-Based, Management Plans for Purple Loosestrife (*Lythrum salicaria*)

4.3.1.1 Priority I: Potential New Invader Management

Scenario: A 400 ha (1,000 ac) wildlife refuge (illustrative of a natural environment) not yet infested by purple loosestrife is located 1.6 km (1 mi) downriver from a well-established population of the noxious weed. The river traverses the center of the refuge.

Table 1. Integrated management for generic monospecific infestation situations for purple loosestrife (*Lythrum salicaria*).

INFESTATION THREAT AND LOCATION WITHIN INFESTATION	OBJECTIVE	MANAGEMENT METHOD	POTENTIAL EFFICACY		ACTION OR PLANT GROWTH STAGE	TIMING
			SMALL INFESTATION	LARGE INFESTATION		
Established Invader: Core	Containment or Control	Biocontrol (insects)	Medium	High	Insect releases or redistributions	May-August
		Competitive Plantings (trees and other vegetation)	Medium to High	High	Planting/seeding	May-July
		Herbicides	High	Medium to High	Seedling to pre-flowering	May-July
		Burning	Medium	Medium	Seedling and old-growth	April-May
		Covering	Medium to High	Medium to High	All plant stages	April-October
		Cutting/mowing	Medium	Medium	Pre-flowering	June-August
		Grazing	Medium to High	Medium to High	Seedling to pre-flowering	May-June
	Prevention	Education/awareness	Medium to High	Medium to High		Continuous
		Surveys	Medium to High	Medium to High		March-November
Established Invader: Perimeter	Containment, Control, Reduction	Biocontrol (insects)	Low to Medium	Medium	Pre-flowering	May-August
		Herbicides	Medium to High	Medium	Pre-flowering	May-July
		Cutting/mowing	Medium	Medium	Pre-flowering	June-August
		Burning/flaming	High	High	Seedlings to pre-flowering	April-May
	Prevention	Education/awareness	Medium to High	Medium to High		Continuous
		Surveys	Medium to High	Medium to High		March-November

Table 1. Continued.

INFESTATION THREAT AND LOCATION WITHIN INFESTATION	OBJECTIVE	MANAGEMENT METHOD	POTENTIAL EFFICACY		ACTION OR PLANT GROWTH STAGE	TIMING
			SMALL INFESTATION	LARGE INFESTATION		
Established Invader: Outliers	Containment, Control, Reduction	Hand pulling/digging	High	High	Seedlings to flowering plants	April-August
		Herbicides	High	High	Seedlings to pre-flowering	April-July
		Flaming	High	High	Seedlings	April-May
	Prevention	Education/awareness	Medium to High	Medium to High		Continuous
		Surveys	Medium to High	Medium to High		March-November
New Invader	Eradication	Herbicides	High	Medium to High	Seedling, pre-flowering	May-July
		Hand pulling/digging	High	Medium	Seedling, pre-flowering	May-July
	Containment, Control, Reduction	Covering	High	Low	Seedling, pre-flowering	April-October
		Competitive plantings	Medium to High	Medium		April-May
	Prevention	Education/awareness	Medium to High	Medium to High		April-August
		Surveys	High	High		April-July
		Competitive plantings	Medium to High	Medium to High		April-May
Potential New Invader	Prevention	Education/awareness	Medium to High	Medium to High		Continuous
		Surveys	Medium to High	Medium to High		March-November

Table 2. Integrated management for generic infestation situations for *Spartina* species.

INFESTATION THREAT AND LOCATION WITHIN INFESTATION	OBJECTIVE	MANAGEMENT METHOD	POTENTIAL EFFICACY		PLANT GROWTH STAGE	TIMING
			SMALL AREA	LARGE AREA		
Established Invader: Core	Containment or Control	Herbicides	Medium to High	Medium to High	Actively growing, especially pre-flowering	April-September
		Cutting/mowing	Medium to High	Medium to High	Pre-flowering or early flowering	March-September
		Mechanical crushing	Medium to High	Medium to High	Brittle stem	June-November
		Covering	Medium to High	Medium to High	All stages during growing season	March-November (1-2 growing seasons)
		Burning	Medium to High	Medium	Pre-flowering	July-September
		Grazing	Medium to High	Medium	Seed/pre-flowering	March-September
	Prevention	Education/awareness	Medium to High	Medium to High		Continuous
		Surveys	Medium to High	Medium to High		March-November
Established Invader: Perimeter	Containment or Control	Herbicides	Medium to High	Medium to High	Pre-flowering	July-September
		Cutting/mowing	Medium to High	Medium to High	Pre-flowering to early flowering	March-September
		Mechanical crushing	Medium to High	Medium to High	Brittle stem	July-November
		Burning/flaming	Medium to High	Medium to High	Pre-flowering	July-September
	Prevention	Education/awareness	Medium to High	Medium to High		Continuous
		Surveys	Medium to High	Medium to High		March-November

Table 2. Continued.

INFESTATION THREAT AND LOCATION WITHIN INFESTATION	OBJECTIVE	MANAGEMENT METHOD	POTENTIAL EFFICACY		PLANT GROWTH STAGE	TIMING
			SMALL AREA	LARGE AREA		
Established Invader: Outliers	Containment or Control	Hand pulling	Medium to High	Medium to High	Seedlings to small plants	March-July
		Herbicides	Medium to High	Medium to High	Seedlings, pre-flowering	July-September
		Flaming	Medium to High	Medium to High	Pre-flowering	July-September
	Prevention	Education/awareness	Medium to High	Medium to High		Continuous
		Surveys	Medium to High	Medium to High		March-November
New Invader	Eradication, Reduction, Containment, Control	Herbicides	Medium to High	Medium to High	Seedling, pre-flowering	February-September
		Hand pulling/digging	Medium to High	Medium to High	Seedling to small plant	March-June
		Covering	Medium to High	Medium to High	All stages during growing season	March-November (1-2 growing seasons)
		Mechanical crushing	Medium to High	Medium to High	Brittle stem	June-November
	Prevention	Education/awareness	Medium to High	Medium to High		Continuous
		Surveys	Medium to High	Medium to High		March-November
Potential New Invader	Prevention	Education/awareness	Medium to High	Medium to High		Continuous
		Surveys	Medium to High	Medium to High		March-November

Table 3. Integrated management for generic infestation situations for giant hogweed (*Heracleum mantegazzianum*).

INFESTATION THREAT	OBJECTIVE	MANAGEMENT METHOD	POTENTIAL EFFICACY	PLANT GROWTH STAGE	TIMING
Established Invader (Outlier, Perimeter, Core)	Containment or Control	Cutting/mowing	Low-Medium	Pre-flowering	April-June
		Crushing	Medium	Pre-flowering	April-June
		Grazing (hogs or cattle)	Low-Medium	Pre-flowering	April-June
		Hand pulling/digging	High	All stages	March-November
		Covering	Unknown	Seedling to pre-flowering	April-June
		Burning	Unknown	Unknown	Unknown
		Herbicides	High	Seedling to flowering	April-June
	Prevention	Education/awareness	Medium-High		Continuous
		Surveys	High		May-September
		Competitive plantings (trees and other vegetation)	Medium-High?		Continuous
New Invader	Eradication, Reduction, Containment, Control	Herbicides	High	Seedling to flowering	April-June
		Hand pulling/digging	High	All stages	March-November
	Prevention	Education/awareness	Medium-High		Continuous
		Surveys	High		May-September
		Competitive plantings (trees and other vegetation)	Medium-High?		Continuous
Potential New Invader	Prevention	Education/awareness	Medium-High		Continuous
		Surveys	High		May-September
		Competitive plantings (trees and other vegetation)	Medium-High?		Continuous

Management Plan: Based upon a knowledge of the mechanisms that facilitate purple loosestrife spread, refuge managers determine that refuge invasion is imminent. A prevention strategy is adopted. Current and new refuge personnel are trained to identify non-flowering and flowering plants and become knowledgeable of the species's biology and management methods. Intensive surveys are conducted between March and November in those areas of the refuge considered to be most vulnerable to initial infestation (leading edge of the refuge property, the banks of the river, any sites subjected to repeated animal- or human-based disturbance, for example). The landowner upriver of the infested property and the jurisdictional county weed control board/district are contacted and urged to initiate management procedures. Signs are erected at public access points to the refuge to inform users of purple loosestrife recognition and detrimental characteristics, and to encourage them to promptly report any discovered plants to refuge personnel. Timely rehabilitation of all disturbed soil areas with site-appropriate, desirable vegetation is undertaken within the refuge to prevent purple loosestrife or other noxious emergent plant species from establishing on those sites.

4.3.1.2 Priority II: New Invader Management

Scenario: Wildlife refuge personnel have discovered infestations of purple loosestrife during their weed survey effort. Both small [less than 2 plants/m^2 (10.8 ft^2)] and large infestations (more than 10 plants/m^2) of the noxious weed are present.

Management Plan: Although infestations of purple loosestrife have been found, prevention continues to be an important strategy. Preventive activities continue to detect additional invading individuals, deter further invasion of refuge lands from outside sources, and create an educational awareness of the present situation among refuge personnel and the public. Refuge personnel solicit public participation during the formulation of an integrated management plan. Environmental impacts expected from the use of the management methods potentially included in the integrated approach and potential specific mitigation measures are discussed and evaluated relative to the particular infestation sites. Purple loosestrife damage and action thresholds are determined to be one plant/m^2 (10.8 ft^2), extremely low thresholds. For all infestations (small and large), an Early Treatment strategy is selected. Objectives of this multi-phased strategy are to effect control and containment during the initial management year, achieve containment and further population density reductions the following year, and to begin the eradication process during the third and ensuing years.

During Phase 1, combinations of physical, biological, and chemical treatments are used. All methods selected must prevent seed production. Pulling by hand, covering with black plastic, and applying glyphosate are all selected as being potentially highly effective against seedling and/or pre-flowering plants in both small and large infestations. The herbicide will be used if pulling/digging and smothering prove inadequate; backpack sprayer spot treatment and/or wiping applications are determined to be preferable as these minimize non-target plant injury. Planting of competitive species is also implemented once purple loosestrife

population density has been diminished through use of the selected treatment methods. Method efficacy is determined through an ongoing monitoring program.

During Phase 2, emphasis is directed toward continued use of preventive measures and the previously selected suite of management methods to achieve control, containment, and further reduction of purple loosestrife populations. Monitoring is continued.

Once population densities have declined to one or two plants/m^2 (10.8 ft^2) as a consequence of the successful application of the integrated approach, eradication becomes the next objective. Only hand pulling/digging and/or herbicide treatments are used against outlier, perimeter, and core components of the infestation during the eradication phase. Prevention and monitoring activities are continued for the duration of the eradication effort.

4.3.1.3 Priority III: Established Invader Management

Scenario: The 400 ha (1,000 ac) wildlife refuge has succumbed to widespread infestation by purple loosestrife. There is an isolated, small 6 ha (15 ac) infestation and a larger 40 ha (100 ac) infestation that have been targeted for management by refuge personnel.

Management Plans: Refuge personnel, with input from concerned citizens, have developed integrated management plans to deal with both infestations. The damage and action thresholds for the small infestation (perimeter and core areas) are initially set at 5 and 3 plants/m^2 (10.8 ft^2), respectively; damage and action thresholds for the large infestation (perimeter and core areas) are 10 and 8 plants/m^2, respectively. Prevention and Correction treatment strategies are selected for the small infestation, whereas Prevention and Maintenance strategies are chosen for the larger infestation. Based upon a knowledge of the noxious weed's present densities, rate of spread, and damage potential, the No Action strategy was eliminated from consideration.

SMALL INFESTATION

The same Preventive methods described in Section 4.3.1.1 are used. During the implementation of the Correction strategy, management objectives are control, containment, and reduction of purple loosestrife populations within the area of infestation. Application of these management objectives are prioritized based on plant location within the infestation. The first priority is management of outlier populations because these contribute to continued spread. Perimeter population management is second priority. The final priority is management of central or core populations.

Outlier populations:

During Phase 1 of the Correction strategy directed against outlier populations, specified objectives are control and containment. Physical and/or chemical treatments are recommended to curtail seed production and/or plant survival. Flaming seedlings during the

early spring is determined to be highly effective. Hand pulling or digging seedlings or older plants is also conducted from early spring through late summer. Individual plants are targeted for backpack sprayer applications of glyphosate or 2,4-D, or wicking applications of glyphosate prior to flowering. Monitoring is conducted to evaluate treatment method efficacy and to detect any untreated plants.

During Phase 2, emphasis is placed on control/containment and reduction of Phase 1 plant escapees. Phase 1 treatment method combinations are continued. When these methods result in no more plants being found within the outlier treatment zone, Phase 3 or monitoring is initiated and continued. If surveillance results in discovery of new outlier plants, the process will revert to Phase 1.

Perimeter populations:

Perimeter population management is as important as outlier plant elimination. The long-term goal of perimeter management is to diminish the size of the infestation front. The Correction strategy objectives of control, containment, and reduction are appropriate.

During Phase 1, efforts are made to control and contain populations of purple loosestrife within this zone. Mechanical/physical, chemical, and biological treatment methods are used. Flaming small patches or the controlled burning of larger populations of living plants, especially seedlings, prove worthwhile. These activities are conducted during the early spring, achieving good results. Burning removed accumulations of dead stems and thus permitted better herbicide coverage. The burns also stimulated seed germination and the resultant flush of seedlings was easily controlled with herbicides. Cutting/mowing large patches several times between June and August prevented seed production and effect containment. In some locations, mowing was used along with or in lieu of burning to remove old vegetative parts preparatory to herbicide treatments.

Glyphosate and/or 2,4-D was used to control or contain perimeter plants. Depending upon the size of the area to be treated, wicking, backpack sprayers, boat or vehicle-mounted sprayers, or helicopters were used to apply the chemicals to pre-flowering purple loosestrife plants. Leaf-, flower-, seed-, and root-feeding insect bioagents were also released to adversely impact perimeter populations, although their greatest value would be against infestation core plants. Monitoring is conducted to assess treatment method efficacies.

Control/containment and further reduction of perimeter populations using the same Phase 1 treatment methods is continued during Phase 2. Refuge managers readjust the initially established damage and action thresholds as populations decline during Phase 2. Depending upon the age structure and density of perimeter zone plants, several years of management may be required before Phase 3 is realized. However, monitoring is continued within the treatment zone. Upon detection of new plants, the management process will revert to Phase 1.

Core population:

Small infestation management emphasis must first be directed toward elimination of outlier and perimeter populations and then, time and budget permitting, the core. The Correction strategy is used, but the primary objective is containment. Once outlier and perimeter infestations have been successfully managed and containment of the core population has been effected by using various combinations of mechanical/physical, chemical, and biological treatment methods, control and reduction efforts are pursued by following the phase approach outlined for satellite and perimeter plant management. It is necessary to periodically revise pre-treatment damage and action thresholds as plant density within the core is negatively impacted by the management program.

Purple loosestrife seed production or plant survival are impacted by covering large, monospecific stands within the core area with black plastic. Burning during the spring results in substantial seedling mortality and is used to enhance subsequent herbicide or covering treatment efficacy. Repeated cutting/mowing of established plants prevents or reduces seed production and dissemination. Additionally, mowing is used to diminish plant biomass prior to plastic cover installation.

Glyphosate and 2,4-D treatments are made against pre-flowering plants using the application methods mentioned for perimeter population suppression.

Plantings of competitive, site-appropriate species are made within the core area to protect identified at-risk sites from future noxious weed infestation. Areas previously treated with the non-selective herbicide glyphosate or covered by plastic should also be revegetated with competitive species. Approved insect biological control agents are released and established, aiding significantly in plant containment. Forced grazing by livestock on pre-flowering purple loosestrife is of some value in limiting seed production in areas able to accommodate fenced grazing animals.

Monitoring of the core population is ongoing to determine if the methods used are effective in population containment.

LARGE INFESTATION

Prevention and Maintenance strategies are used against the large infestation of purple loosestrife. Specific preventive methods are described in Section 4.3.2.1. Management objectives of the Maintenance strategy are population containment and/or suppression (reduction without the expectation of preventing all seed production). The treatment methods used should maintain purple loosestrife density below the established damage threshold. Management activities are prioritized based on plant location within the infestation. The first priority is management of outlier populations to restrict continued spread, followed by plant suppression within the perimeter and core infestation zones, respectively.

Outlier Populations:

During Phase 1 of the Maintenance strategy directed against outlier populations, the immediate objective is to halt further forward expansion of the demarcated infestation. Physical (hand pulling/digging and flaming) and/or herbicide treatments are used. Where the infestation front is extensive and hand removal and/or flaming are selected as treatment methods of choice, it is necessary to recruit volunteer assistance to accomplish the objective. Spot treatments of glyphosate or 2,4-D applied by backpack or vehicle-mounted sprayers or glyphosate wicking of plants is used. Monitoring is conducted to evaluate the effectiveness of the containment method.

During Phase 2 and 3 (second year and beyond), monitoring efforts are continued within the outlier zone. If additional plants are found, the process will revert to Phase 1.

Perimeter Populations:

Whenever possible, management efforts are directed against plant populations comprising the perimeter of the infestation. Repeated use of containment and/or suppression methods in this zone gradually pushes the infestation front towards the core population.

Phase 1 management includes mechanical/physical (burning/flaming, cutting/mowing), chemical (herbicides), and biological (insects) methods. Bioagents are of the utmost importance in containing perimeter populations of purple loosestrife and should always be used.

Regular surveillance of the perimeter zone is necessary to determine if the containment objective is being or has been achieved during Phases 1, 2, and 3. Purple loosestrife population density must be maintained below the established damage threshold. If treatments are successful in suppressing plant growth, it may be necessary to redefine the damage and action thresholds over time.

Core Population:

The short-term objective for the core population is to effect as much containment as is possible during each management program year through integration of appropriate mechanical/physical, chemical, and biological treatments and methods. Bioagents, competitive plants, mowing, and herbicides may be particularly effective containment/suppression methods. Post-treatment monitoring enables refuge personnel to gauge the usefulness of such methods.

Several years are required before Phase 1 of the Maintenance strategy is completed (that time when the damage threshold is no longer exceeded). As monitoring during Phases 1, 2, and 3 indicates a reduced infestation density, existing damage and action thresholds are revised. Refuge managers hope continued compression of the core population will eventually result in

its reclassification as a small infestation. When this happens, the Maintenance strategy is replaced by a Correction strategy and all attendant objectives and treatment methods become applicable.

4.3.2 Priority-Based, Management Plans for Cordgrasses (*Spartina* spp.)

4.3.2.1 Priority I: Potential New Invader Management

Scenario: A wildlife refuge is located 1 km (0.6 mi) from an established population of *Spartina alterniflora*. The cordgrass colony is flowering and producing viable seed.

Management Plan: Refuge managers determine that refuge invasion is imminent; a Prevention strategy is adopted. Refuge employees are trained in *Spartina* identification and control methods. Surveys for cordgrass plants are conducted between March and November, when plants are more readily detected. Intensive surveys are concentrated in areas particularly susceptible to colonization, such as mudflats where currents are likely to deposit seeds and waterfowl use areas. A public awareness program is implemented and neighboring landowners are encouraged to initiate management procedures. Signs are posted in public access areas to inform users of *Spartina* recognition and detrimental characteristics, and to encourage them to promptly report any discovered plants. A mechanism is established to facilitate reporting of *Spartina* occurrences to refuge managers.

4.3.2.2 Priority II: New Invader Management

Scenario: A small, sparse infestation [100 plants/ha (2.5 ac)] of *Spartina* seedlings and young colonies [(less than 30 cm (12 in) in diameter] have been found in the wildlife refuge.

Management Plan: Prevention and Early Treatment strategies are selected. Prevention activities lead to an awareness of the situation among refuge personnel and the public. Public information and refuge monitoring activities are initiated. Refuge personnel solicit public participation during the formulation of an integrated management plan. Potential environmental impacts and specific mitigation measures are discussed and evaluated. Damage and action thresholds are initially determined to be 1 plant/ha (2.5 acre). Objectives of the Early Treatment strategy are to effect control and containment during the initial management year (Phase 1), effect containment and population density reduction the following year (Phase 2), and to begin the eradication process during the third and ensuing years (Phase 3).

During Phase 1, combinations of physical and chemical treatments are used to weaken or kill plants and to prevent seed production. Seedlings are removed by pulling and digging by hand. Colonies are controlled by crushing by foot, mowing with a gas-powered weed trimmer, and applying glyphosate. Backpack sprayer spot treatment applications are used to minimize non-target plant injury during glyphosate treatments. Covering is not used for this

infestation because colonies are small and widely distributed. An ongoing monitoring program to assess the efficacy of treatments is initiated.

During Phase 2, preventive measures and the previously selected suite of management methods are continued to achieve control, containment, and further reduction of cordgrass populations. Monitoring is continued.

During Phase 3, following decline in weed densities to 1 plant/ha (2.5 ac), eradication becomes the objective. Hand pulling/digging and herbicide treatments are used to kill plants. Prevention and monitoring activities are continued.

4.3.2.3 Priority III: Established Invader Management

Scenario: A widespread infestation of *Spartina* has developed in the wildlife refuge. One small, 1 ha (2.5 ac) infestation and a larger 40 ha (100 ac) infestation have been targeted for management by refuge personnel.

Management Plans: Integrated management plans have been previously formulated by refuge managers to deal with both infestations. Damage and action thresholds for the small infestation (perimeter and core areas) are initially set at 10 and 5 percent vegetative cover per hectare, respectively, or presence of flowering plants. Damage and action thresholds for the large infestation (perimeter and core areas) are set at 40 and 10 percent vegetative cover per hectare, respectively, or presence of flowering plants. Prevention and Correction treatment strategies are selected for the small infestation, whereas Prevention and Maintenance strategies are chosen for the larger infestation. The No Action strategy was eliminated from consideration because high levels of environmental damage are anticipated if the infestations are not treated.

The efficacy of glyphosate applications in killing *Spartina* is estimated during experimental treatments in different areas of the infestation. It is determined that only 80 percent of the plants in the lower intertidal zone are killed following treatment. Treatments are more effective in upper intertidal areas, perhaps because the plants are taller and are emersed for a greater amount of time after herbicide application. This information is used during the planning process to develop management plans for the two infestations.

SMALL INFESTATION

Preventive methods are enacted throughout the treatment period. Management objectives of the Correction strategy are control, containment, and reduction of cordgrass populations within the infestation area. Management objectives vary, depending on location within the infestation. The first priority is management of outlier populations because these contribute to continued spread. Perimeter population management is second priority. The final priority is management of central or core populations.

Outlier populations:

During Phase 1, objectives of the Correction strategy are control and containment. Physical and chemical treatments are used to curtail seed production and to slow colony growth. Hand pulling and digging seedlings and other small plants is conducted from early spring through midsummer. Pre-flowering plants are flamed with a flamer or mowed with a weed trimmer to prevent seed production. Glyphosate is applied in the pre-flowering stage. Plants are sprayed using a backpack sprayer or wicked, depending on presence or absence of surrounding non-target vegetation. Monitoring is conducted to help evaluate treatment method efficacy and to detect any untreated plants.

During Phase 2, control/containment and reduction of plants remaining after Phase 1 are emphasized. Treatment methods used in Phase 1 are continued, although greater emphasis is placed on digging and chemical control methods. When no more plants are found within the outlier treatment zone, Phase 3 is initiated. Monitoring leads to discovery of new outlier plants, resulting in a return to Phase 1 in a few outlying areas.

Perimeter populations:

The long-term goal of perimeter management is to diminish the size of the infestation front. The Correction strategy objectives of control, containment, and reduction are applicable.

During Phase 1, efforts are made to control and contain populations of *Spartina* around the perimeter of the population. Cutting/mowing is done several times at the edges of colonies between March and September. Crushing by foot is done in a few accessible areas. These treatments prevent seed production and contain plant spread.

Glyphosate is applied using backpack sprayers to pre-flowering plants only in the upper intertidal zone of the site. Monitoring is conducted to assess treatment method efficacies and treatments are repeated in selected areas.

Phase 2 objectives are control/containment and further reduction of perimeter populations. Phase 1 treatment methods are continued during Phase 2, resulting in a reduction in infestation extent. Refuge managers lower damage and action thresholds as populations decline. Monitoring is continued within the treatment zone. Upon the detection of new plants, the management process will revert to Phase 1.

Core population:

Initially, the primary objective is containment. Refuge managers determine crushing treatments are appropriate for the site because there is good shore access to the core population. In addition, colonies are monospecific, nearly continuous, and uninterrupted by deep channels. All-terrain vehicles are used yearly, once each in June and August. A weed

trimmer is used to mow areas at the edges of some colonies within the core area, where all-terrain vehicles can not be used because of soft sediments.

Once the core population has been effectively contained, control and reduction efforts are pursued. Damage and action thresholds are revised as plant density within the core is reduced.

Refuge personnel determine two readily accessible areas within the core population can effectively be treated by covering because they are subjected to mild tidal currents and limited wave energy. After mowing to reduce biomass, geotextile fabric is placed over these colonies and securely anchored in the sediments. Surrounding areas continue to be managed with a combination of crushing and mowing treatments. Frequency of mowing treatments is increased, with the intention of reducing the population. Glyphosate is applied using a backpack sprayer to isolated plants in the upper intertidal area. Herbicides are not more widely used because of neighboring citizen concerns. Monitoring of the core population is ongoing to determine if the methods used are effective in population containment.

LARGE INFESTATION

Prevention and Maintenance strategies are used against the large infestation of *Spartina*. The primary management objective of the Maintenance strategy is population containment. Suppression (reduction without the expectation of preventing all seed production) is not deemed appropriate because of the high potential for environmental damage following widespread dispersal of seeds in the area. Treatment methods are designed to maintain *Spartina* density below the established damage threshold. Management activities are prioritized based on plant location within the infestation. The first priority is management of outlier populations to restrict continued spread, followed by plant containment within the perimeter and core infestation zones, respectively.

Outlier Populations:

During Phase 1, the primary objective is to halt further expansion of the infestation and to prevent seed production. Volunteer labor is recruited to assist in physical control methods (hand pulling/digging and flaming) and herbicide treatments. Pre-flowering plants are flamed with a flamer or mowed with a weed trimmer to prevent seed production. Glyphosate is applied using backpack sprayers or by wicking plants to kill outlying plants.

During Phase 2, emphasis is placed on control/containment and reduction of plants remaining after Phase 1. This is followed by Phase 3, in which eradication of outlier populations is the primary goal. Monitoring is continued within the outlier zone during Phases 2 and 3.

Perimeter Populations:

Phase 1, 2, and 3 management includes the use of mechanical/physical and chemical methods. Crushing twice a year, in combination with mowing monthly during the growing season in areas that can not be accessed for mechanical crushing, is found to substantially impact perimeter populations. Glyphosate is sprayed in selected areas around the outer perimeter. Repeated use of containment methods in this zone gradually pushes the infestation front toward the core population.

The perimeter zone is monitored frequently to assess success of Phases 1, 2, and 3. *Spartina* population density is maintained below established damage thresholds during each phase. Damage and action thresholds are redefined as colonies at the perimeter of the infestation are killed.

Core Population:

Containment, especially prevention of seed production, is the first management priority in the core area of the infestation. Several control methods are used because of varying conditions in different parts of the infestation, and because volunteers are available for implementing some (but not all) possible control measures. It is discovered that controlled burns can be conducted during the pre-flowering stage in some parts of the core population, where plants are exposed to air for sufficient lengths of time to dry adequately. In other areas, a combination of crushing with all-terrain vehicles and tractors and mowing with weed trimmers is used to crush or cut plants in the pre-flowering stage. Herbicides are applied by aerial spraying in some areas not used by the public. Monitoring enables refuge personnel to assess the efficacy of each method, and treatments are repeated in areas where pre-flowering plants are found.

Phase 1 of the Maintenance strategy is completed when the damage threshold is no longer exceeded, which occurs after several years of treatment. Damage and action thresholds are revised as infestation density decreases. Eventually, the core population is reduced in size to the point where it is reclassified as a small infestation, at which time the Maintenance strategy is replaced by a Correction strategy. Objectives and treatment methods for control, containment, and reduction become applicable.

4.3.3 Priority-Based, Management Plans for Giant Hogweed, (*Heracleum mantegazzianum*)

4.3.3.1 Priority I: Potential New Invader Management

Scenario: A stream reach not yet infested by giant hogweed is located 1.6 km (1 mi) downstream from a recently identified established infestation of this species along the shorelines of a tributary.

Management Plan: Based upon existing knowledge of the mechanisms that facilitate giant hogweed spread, county weed managers determine that continued shoreline invasion is imminent, with eventual spread of the species to shorelines of the stream of concern and its associated wetlands. A prevention strategy is adopted. Current and new county weed management personnel are trained to identify non-flowering and flowering plants and become knowledgeable of the species's biology and management methods. Intensive surveys are conducted between May and September in those areas of the river and its tributary close to the confluence of the tributary considered to be most vulnerable to initial infestation (the banks of the river, associated wetlands, adjacent sites subjected to repeated animal- or human-based disturbance, for example). The landowners on whose property the infestations occur along the tributary are contacted and notified by the jurisdictional county weed control board/district that all seed production must be prevented (as mandated by state law for this Class A noxious weed), and that management procedures should be initiated immediately. Opportunities for restoration of disturbed soil areas in nearby riparian and wetland habitats with site-appropriate, desirable vegetation are investigated to prevent establishment of giant hogweed or other noxious emergent plant species from establishing on those sites.

4.3.1.2 Priority II: New Invader Management

Scenario: County weed management personnel discover infestations of giant hogweed along the stream reach of concern and its associated wetlands during their yearly weed survey efforts. A number of small [less than 20 plants/ha (2.5 ac)] infestations of the noxious weed are present.

Management Plan: Although infestations of giant hogweed have been found, prevention continues to be an important strategy. Preventive activities continue to detect additional invading individuals, deter further invasion of shorelines from outside sources, and create an educational awareness of the present situation among weed management personnel and the public. Weed management personnel solicit public participation during the formulation of an integrated management plan. Environmental impacts expected from the use of the management methods potentially included in the integrated approach and potential specific mitigation measures are discussed and evaluated relative to the particular infestation sites. Damage and action thresholds for infestation of giant hogweed in this area are determined to be one plant/ha. For all infestations, an Early Treatment strategy is selected. Objectives of this multi-phased strategy are to effect control and containment during the initial management year, achieve containment and further population density reductions the following year, and eradicate the species from the site of concern during the third and ensuing years.

During Phase 1, chemical treatment alone is determined to be most effective with the least amount of adverse impact to associated resources. All methods selected must prevent seed production. Pulling/digging by hand, covering with black plastic, and crushing for these infestations were determined to be of limited effectiveness and of relatively high environmental impact at this site. A non-selective herbicide is applied by backpack sprayer spot treatment and/or wiping applications, as these approaches minimize non-target plant

injury. Planting of competitive species is also implemented once giant hogweed population density has been diminished through use of the selected treatment methods. Method efficacy is determined through an ongoing monitoring program.

During Phase 2, emphasis is directed toward continued use of preventive measures and the previously selected herbicide management method to achieve control, containment, and further reduction of the giant hogweed infestations. Monitoring is continued.

Once population densities have declined to one plant/ha as a consequence of the successful application of the integrated approach, eradication becomes the next objective. Only herbicide treatments are employed against the remaining individuals of the infestations during the eradication process. Prevention and monitoring activities are continued for the duration of the eradication effort.

5.0 INTEGRATED WEED MANAGEMENT PLAN IMPLEMENTATION

5.1 AUTHORITIES AND DESIGNATED RESPONSIBILITIES

Various agencies have regulatory responsibilities or mandates related to the management of noxious emergent plants. Recognizing this, a discussion of authorities and designated responsibilities will be presented in the introduction to the EIS.

5.2 PERMIT PROCESS

Various agencies have regulatory responsibilities or mandates related to the management of noxious emergent plants. Recognizing this, a discussion of pertinent permit processes will be presented in the introduction to the EIS.

5.3 PUBLIC INVOLVEMENT

The importance of soliciting public input when developing an integrated weed management program was addressed in Section 4.2.2. The involvement of the public during the implementation phase of the program is equally important.

Certain integrated management programs are often heavily dependent upon the use of nonchemical methods to attain the specified treatment objective(s). The application of these methods is frequently time and labor intensive. Due to resource management entity workforce and/or budget constraints, complete control, containment, or reduction of noxious weed populations may not be possible. In such situations, volunteer laborers could be recruited by the impacted entity to provide assistance with management activities. For example, volunteers could be utilized for hand pulling and cutting cordgrass, purple loosestrife, and other identified noxious emergent species, for purple loosestrife biological control agent collection and redistribution purposes, and perhaps (if certified) even for applying herbicides.

A diverse assemblage of community action and other non-civic organizations may be tapped for volunteer assistance: youth organizations (Boy and Girl Scouts, Camp Fire Girls, Washington Conservation Corps, 4-H, church groups); fraternal service groups (Eagles, Elks, Lions, Moose, Kiwanis); garden clubs (Master Gardeners); sportsman's groups (rod and gun clubs, Ducks Unlimited); and environment protection-oriented associations (Audubon Society, The Nature Conservancy, Washington Native Plant Society). An excellent manual for individuals interested in organizing volunteer weed management efforts has been prepared by Klaus *et al.* (1991).

Other sources of inexpensive labor could include inmate work crews provided by the Washington Department of Corrections (Beckstead *et al.* 1991) and persons sentenced by municipal courts to engage in community service work. County noxious weed control boards/districts and federal land/water management agencies could employ high school and college students or other individuals during the summer to assist with labor-intensive, noxious emergent plant control activities and monitoring/evaluation tasks.

In the case of the cordgrasses, private landowners may find an economic incentive to mechanically control this noxious plant. For example, the shoots of these species can be used to make a specialty paper. If commercial demand for cordgrass-based paper products increases, landowners or their designated contractors could periodically mow/cut the shoots and sell the harvested material. Control (annual prevention of seed production) of *Spartina alterniflora*, as required by state law, would be achieved as long as cutting operations are conducted prior to flowering.

In addition to involvement with control activities, interested public could also be recruited to assist in noxious emergent weed inventory and survey activities (Reinhartz and Cutright 1985), educational awareness endeavors, and to promote legislation and resource agency actions that support integrated weed management. The WSNWCB, in cooperation with the WSDA, WSU Cooperative Extension, and county weed control boards/districts, should assume leadership roles in organizing and directing these public participation efforts.

6.0 INFORMATION AND RESEARCH NEEDS

Development and implementation of IWM programs for noxious emergent plants should be the highest priority for all entities whose charge includes aquatic resource protection. Failure to adopt the IWM approach or take action against invasive noxious weeds will result in continued degradation of the quality of natural, agricultural, and built environments (Ebasco Environmental 1993d). IWM program development is facilitated by an adequate knowledge of target species biology and autecology, and of management methodologies. However, it is not necessary that everything be known about a noxious species prior to implementing a management program for that species. A rudimentary IWM program is better than no program. IWM is an inherently dynamic framework designed to address problematic plant species. Sufficient opportunity always exists for incorporating additional ideas and

technologies that will improve the operational efficacy of ongoing management. Every IWM program benefits from continual refinement.

Our present knowledge base is probably adequate to begin the development of site-specific integrated management programs for cordgrasses and purple loosestrife in Washington. However, further research is still necessary to generate more information about the bioecology and population dynamics of these species and the efficacies and impacts of various preventive, mechanical/physical, biological, and chemical management methods directed against them (ACOE 1993, Ebasco Environmental 1993a, 1993b, 1993e, 1993f, 1993g). Specific ongoing or future research activities designed to provide such information are described elsewhere (Ebasco Environmental 1993a, 1993b, 1993c, 1993g). The development of effective IWM programs for *Amorpha fruticosa*, *Heracleum mantegazzianum*, *Lysimachia punctata*, *Lysimachia vulgaris*, *Lythrum virgatum*, and other species will depend upon the acquisition of further bioecological and management method information (Ebasco Environmental 1993a,1993c, 1993d, 1993e, 1993f, 1993g). Data gaps identified for these and other noxious emergent species include the formulation of realistic damage and action thresholds for established invaders and the development of reliable, site-specific survey, monitoring, and program evaluation methods.

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