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Vegetated Buffer Strip Designation Method Guidance Manual

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Narragansett Bay Estuary Program

VEGETATED BUFFER STRIP DESIGNATION METHOD GUIDANCE MANUAL

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FOREWORD

In 1985 the United States Congress directed the U.S. Environmental Protection Agency (US EPA) to conduct programs in four estuaries including Narragansett Bay, citing its concern for the "health and ecological integrity" of the nations's estuaries and estuarine resources. The Narragansett Bay Project (NBP) was established in 1985 under the joint sponsorship of the US EPA and the Rhode Island Department of Environmental Management with the mandate to direct a program of research and planning focussed on managing Narragansett Bay and its resources for future generations. The National Estuary Program was created by the amendments to the Clean Water Act in 1987; and Narragansett Bay was designated an "estuary of national significance" in 1988.

The NBP developed a draft Comprehensive Conservation and Management Plan (CCMP) in December 1991, which recommended actions to improve and protect the Bay and its natural resources.

The NBP has established the following seven issues of concern for Narragansett Bay:

- management of fisheries
- nutrients and potential for eutrophication
- impacts of toxic contaminants
- health and abundance of living resources
- land-based impacts on water quality
- recreational uses

The NBP is taking a watershed-based ecosystem approach to address these problems and has funded research that will help to improve our understanding of various aspects of these priority problems. The Project is also working to expand and coordinate existing programs among federal, state and local agencies, as well as academic researchers, in order to apply research findings to the practical needs of managing the Bay and improving the environmental quality of its watershed.

This report represents the technical results of an investigation performed for the Narragansett Bay Project. The information in this document has been funded wholly or in part by the United States Environmental Protection Agency through Cooperative Agreement #CX812768 to the Rhode Island Department of Environmental Management. It has been subject to the Agency's and the Narragansett Bay Project's peer and administrative review and has been accepted for publication as a technical report by the Management Committee of the Narragansett Bay Project. The results and conclusions contained herein are those of the author(s), and do not necessarily represent the views or recommendations of the NBP. Final recommendations for management actions will be based upon the results of this and other investigations.

ABSTRACT

Vegetated buffer strips are an important component in an overall strategy to protect wetland and water resources within Rhode Island. In particular, the appropriate designation of vegetated buffer strips may be used to protect water quality as well as wetland habitat. There is a need for a consistent method to determine the buffer distance necessary to provide adequate protection of these resources.

The objective of this manual is to provide guidelines for the determination of vegetative buffer strip widths for pollutant attenuation on a case-by-case (site-specific) basis. The proposed buffer designation (or sizing) method is aimed at mitigating stormwater quality impacts from urban and suburban developments. The method was developed from multiple simulations of pollutant (total suspended solids) generation, transport and removal for buffer strips under various site conditions using the P8 Urban Catchment Model. The method also includes a special conditions component to address certain issues (i.e., threatened and endangered species habitat, in-fill development, poor buffer condition, and hazardous materials). Buffers may range from 25-feet to 300-feet for water quality mitigation. Buffer widths greater than 300-feet are possible for the protection of threatened or endangered species.

This buffer designation method is intended to provide planners with an alternative to structural or "engineered" solutions to stormwater management. The method has applications to both existing and future development. Retro-fitting buffers for existing development areas would benefit from this method. In addition, this method may be used for site design as implemented through state or local environmental review processes.

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 BACKGROUND

Narragansett Bay was selected for participation in the United States Environmental Protection Agency's (EPA) National Estuary Program in 1985. The Narragansett Bay Project (NBP), established to administer the five year program on the Bay, has funded extensive research on various aspects of the Bay. The primary goal of the five year program is to develop a Comprehensive Conservation and Management Plan (CCMP) to protect and improve water quality and living resources in the Bay.

The Bays' 450 miles of coastline and 120 square mile area provide essential habitat to wildlife, waterfowl, and marine life. In addition, Narragansett Bay is a vital socio/economic resource, supporting commercial fisheries of 17 million dollars in 1986, and a 1 million dollar tourism industry (Narragansett Bay Project, Informational factsheet). However, the deterioration in water quality within the Bay, and subsequent loss of habitat has in some cases severely impaired living resources in the upper bay, and threatens those in the lower bay. Presently, about one-third of the Bay is closed permanently or conditionally to shellfishing, as a result of degraded water quality. Inland wetlands and waterways also represent valuable recreational and wildlife habitat resources. In addition to providing habitat for wildlife, the inland wetlands and waterways also serve to improve the quality of water reaching Narragansett Bay via its 8 principal tributaries.

Over 150 industrial and municipal point sources discharge contaminants directly or indirectly to the bay (Narragansett Bay Project, Informational factsheet). The control of pollutants from these sources has received much attention over the last decade. However, these sources alone, do not account for the level of degradation observed in Narragansett Bay. Nonpoint sources (NPS) of contaminants, such as stormwater runoff from urban and suburban land uses, also represent a significant contribution of contaminants to the Bay and its tributaries.

The Hunt-Potowomut River watershed has been the focus of several projects under the Narragansett Bay and the Land Management Projects, which focus on land use planning and nonpoint source pollution control. This watershed, like most watersheds within Rhode Island, has experienced an increase in residential and commercial development in recent years. For example, between 1985 and 1988, approximately 140 acres of forested and agricultural land have been developed into residential, commercial or other urban land uses within the Hunt-Potowomut watershed (IEP, 1989). This transition from agricultural, open, and forested lands into developed land has serious implications relative to the long-term protection of wetland and water resources, and ultimately on the Bay.

In general, the change from undeveloped to developed land produces a number of pronounced changes in the landscape and environment. These changes include an increase in surface runoff (decrease in infiltration) caused by an increase in impervious surfaces (i.e., roadways, parking areas, rooftops, etc.). With an increase in the volume and rates of surface runoff, the pollutants are carried into the receiving resource areas.

1.2 THE NEED FOR RESOURCE PROTECTION

Wetlands provide critical habitat for wetland-dependent wildlife, including a disproportionately high number of rare and endangered species (Mitch and Gosselink, 1986). In addition, wetlands serve an important function in influencing water quality and quantity in adjacent and downstream water systems (i.e., rivers, streams, lakes, ponds, reservoirs, estuaries, etc.) and wetlands (Hemond and Benoit, 1988; Lee and Gosselink, 1988; Mitch and Gosselink, 1986). Numerous investigators have demonstrated that the quality and quantity of surface and ground water entering a wetland influences the structure and function of that wetland (Preston and Bedford, 1988; Lee and Gosselink, 1988; Hemond and Benoit, 1988, Shuldiner, et al., 1979).

The pollutant attenuation (removal) capabilities of wetlands is well documented (Hemond and Benoit, 1988; Novitzki, 1981; Richardson and Nichols, 1985; Nichols, 1983; and others). However, excessive pollutant inputs (loading) to a wetland may lead to changes in vegetational composition, wetland class primary and secondary productivity, as well as cause mortality of aquatic species or restrict faunal movements (Hemond and Benoit, 1988; Shuldiner, et al., 1979; Bedford and Preston, 1988). These changes can be attributed to one of several processes or factors; 1) eutrophication (the excessive addition of nutrients), 2) sedimentation (the deposition of suspended material in the wetland); 3) thermal (a change in ambient temperature), and 4) toxicity (the loss of flora/fauna associated with toxic levels of contaminants). Such changes in wetland structure and/or function may reduce habitat value and diminish pollutant attenuation capabilities. Wetland habitat value may also be lost or damaged through the actual loss of habitat (i.e., through fill or permanent alteration), as well as from passive disturbances, such as noise (Brown et al., 1987).

The protection of valuable wetland resources from development impacts can be accomplished through the effective implementation of land use planning, wetlands protection, stormwater runoff management, and land use regulation/policy. Within Rhode Island, such regulatory and planning efforts such as town-wide comprehensive planning, wetlands protection, RI Department of Environmental Management (RIDEM) ISDS setback regulations, local site plan review, all play a critical role in the protection of wetland resources. Specifically, wetlands protection is regulated by the RIDEM Freshwater Wetlands Division and the Coastal Resources Management Council.

1.3 RELATED STATE AND LOCAL REGULATION AND POLICY

In many cases, vegetated buffer strips (VBS) are presently required under existing state and local regulations, although their name and definition varies from agency to agency (e.g., setback, buffer zone, vegetated setback, undisturbed setback, perimeter wetland, and riverbank wetland). However, all of these buffer requirements define some regulated distance between the limits of work (disturbance by human activity) and the limits of a protectable wetland, waterbody, and watercourse. In general, a buffer zone or vegetated setback designation requires that natural vegetation within this zone (distance) be maintained in an undisturbed condition, whereas a setback, in its strictest sense, does not.

A review of the existing state regulations as well as local regulations for communities within the Hunt-Potowomut River watershed revealed that setbacks or buffer zones are frequently imposed relative to the placement of septic systems, but may not address other construction and development activities. Details of this review are provided in Appendix A. Under the recently amended RIDEM setback requirements, septic system setback distances may range from 50 - 200 feet from the resource boundary, and up to 400 feet from the edge of water for water supplies (i.e., 200 feet from drinking water supply reservoirs and their tributaries and 400 feet from public drinking water supply wells) (Pers. Comm., Andrew DiRiso, RIDEM/ISDS Section). In addition, the RIDEM Freshwater Wetlands program may require that the 50 to 200 jurisdictional area be maintained as an undisturbed setback, if warranted by existing site conditions. In most cases, local communities follow applicable state regulations. However, North Kingstown requires a 150-foot setback, and Warwick a 50-foot undisturbed zone from inland or coastal wetland boundaries. The zoning ordinance for West Greenwich requires a 200-foot setback from the edge of water bodies. Based upon this review of local ordinances, only the Warwick zoning ordinance which requires a 50-foot undisturbed setback prohibits any alteration, and is not limited to the placement of the septic system.

Although existing regulations governing setback distances provide some resource protection, these regulations, in many cases, do not consider site specific conditions which may affect the level of protection afforded by the required setback distance. Site specific variables, such as slope, soil type, and contributing land area/usage, affect the pollutant removal capabilities of a vegetated buffer strip. Ideally, these factors should be considered in determining the buffer distance required to achieve a desired level of protection. Therefore, a variable buffer width for pollutant attenuation, based upon site-specific characteristics, may provide a more consistent level of protection for wetland and water resources.

1.4 OBJECTIVES AND GUIDANCE MANUAL FORMAT

Vegetated buffer strips are a critical component in an overall strategy to protect wetland and water resources within Rhode Island. In particular, the appropriate designation of vegetated buffer strips may be used to protect water quality as well as wetland habitat. There is a need for a consistent method to determine the buffer distance necessary to provide adequate protection of these resources.

The objective of this manual is to provide guidelines for the determination of vegetative buffer strip widths for pollutant attenuation on a case-by-case (site-specific) basis. The proposed buffer designation method is aimed at mitigating stormwater quality impacts from urban and suburban developments. However, it is not intended that the proposed method should over-ride or replace wetlands protection as mandated under the Wetlands Protection Act, but rather to serve as a complementary instrument to protect valuable resource areas.

This buffer designation method may provide planners with an alternative to structural or "engineered" solutions to stormwater management. The method has applications to both existing and future development. Retrofitting buffers for existing development areas would benefit from this method. In addition, this method may be used for site design as implemented through state or local environmental review processes.

An overview of vegetated buffer strips for the control of nonpoint source runoff is provided in Section 2.0 of this manual, and an annotated bibliography of pertinent literature is provided in Appendix B. Section 3.0 of the manual describes the proposed buffer designation method, the basis for its development, and step-by-step application procedures. Guidance regarding appropriate maintenance and use practices for vegetated buffer strips is provided in Section 4.0, and a glossary of terms is provided in Section 5.0.

2.0 VEGETATIVE BUFFER STRIPS FOR THE CONTROL OF NONPOINT RUNOFF

2.1 WHAT ARE THEY AND HOW DO THEY WORK?

Vegetated buffer strips (VBS) are one of many Best Management Practice (BMP) alternatives used in the control of stormwater runoff. In this guidance manual a vegetated buffer strip refers to an undisturbed vegetated area located between areas of human activity and water or wetland resources, although "engineered" buffer strips are also used in stormwater management (Schueler, 1987). As the name implies, vegetated buffer strips are intended to provide a neutral area to lessen (or buffer) the impact of man's activities (i.e., fertilizer use, on-site septic systems, construction, urban runoff) on sensitive resources. Nearstream vegetation may influence instream water quality, temperature, and stream channelization by moderating the quality, quantity and timing of runoff inputs from the upland landscape (Karr and Schlosser, 1978).

Vegetated buffer strips serve not only to reduce water quality impacts on receiving water bodies by removing pollutants from surface runoff, but also to protect wetland habitat and associated wildlife. While much of the research regarding vegetated buffer strips (Appendix B) has focused on water quality mitigation, greenway and stream corridor planning has commonly focused on wetland wildlife habitat protection. Both stream corridors and site-specific vegetated buffer strips approaches have merit. That is, while most models for the designation of vegetated buffer strips account for site-specific characteristics, stream corridor programs aim to preserve a contiguous (often non-variable width) corridor along sensitive habitat areas.

The level of protection of wildlife habitat provided by a given buffer strip is largely dictated by the adequacy of the buffer distance relative to wildlife habitat requirements. On the other hand, a number of physical, chemical, and biological processes are involved in the mitigation of water quality. The primary modes of pollutant removal from surface runoff include filtration and sedimentation. On the other hand, subsurface pollutant attenuation is largely related to vegetative uptake, microbial degradation, and soil adsorption (Groffman et al., 1990). However, vegetative uptake is only effective where pollutants remain in or during the time in which they pass through the root zone (i.e., within about 2-feet of the surface for a wooded buffer zone).

2.2 FACTORS CONTROLLING POLLUTANT ATTENUATION

The effectiveness of vegetated buffer strips with respect to pollutant removal is controlled by a number of factors which may vary from site-to-site. In general, the factors controlling surface runoff pollutant removal are well documented. However, information regarding the specific factors controlling subsurface pollutant removal are less well documented.

Slope, soil hydrologic class (infiltration rate), and vegetative cover are generally considered the principal factors which control pollutant attenuation in surface runoff (Dennis et al., 1989; Wong and McCuen, 1982; Dillaha et al., 1986a). The infiltration of runoff is generally considered to be the most important factor controlling surface runoff pollutant removal. In general, as the infiltration rate increases, the pollutant removal from surface runoff increases. Several investigators suggest that as percent slope increases the buffer width required to achieve the desired pollutant removal should increase (Dennis et al., 1989; Dillaha et al., 1986a). In addition, the effectiveness of vegetated buffers in surface runoff pollutant removal is greatly reduced if short-circuiting or channelization occurs within the buffer (Dillaha et al., 1986a). That is, the maximal effectiveness of the buffer is depended upon a uniform shallow overland flow.

Subsurface pollutant removal is largely controlled by the characteristics of the soils within the buffer strip. In particular, the removal of heavy metals is related to the Cation Exchange Capacity (CEC) of the soil (Groffman et al., 1990). CEC is determined largely by the content of organic matter and clay in the soil, which act to bind cations such as heavy metals. On the other hand, removal of nitrate is controlled by microbial denitrification and plant uptake. Research conducted by Groffman et al., (1990) suggests that vegetative uptake is the primary mode of nitrate removal in upland soils. However, where the depth to ground water is below the root zone (> 2-feet), vegetative uptake is negligible. Therefore, since depth to ground water in uplands is usually greater than 2-feet, nitrate uptake is minimal in upland buffers.

2.3 MULTIPLE USE BENEFITS

In addition to providing benefits for water quality and quantity control and habitat protection, vegetative buffer strips may provide a number of additional benefits. For example, the buffer strips may provide valuable transitional habitat area for both wetland dependent and upland wildlife species (Brown et al., 1987; Groffman et al., 1990; Chesapeake Bay Critical Area Commission, 1988). According to the Chesapeake Bay Critical Area Commission (1988), natural vegetated buffers provide habitat and corridors for wildlife moving from one resource area to another. In the Hunt-Potowomut watershed, Groffman et al. (1990) documented the use of buffer areas by a number of different avian, amphibian, and other wildlife species. In addition, these area serve as an important landscape component, providing a natural transition between uplands and wetlands. While some uses must be restricted within these buffer zones to maintain the integrity of the buffer, such passive activities as hiking, picnicking and aesthetic enjoyment are additional benefits provided by vegetated buffer zones.

3.0 BUFFER DESIGNATION METHOD

3.1 METHOD OVERVIEW

This buffer designation method has been developed based upon existing information, including similar models developed in other states, scientific research regarding the pollutant removal capabilities of vegetated buffer strips, and research conducted by the University of Rhode Island under a separate contract to investigate the multiple uses of vegetated buffer strips with the Narragansett Bay Project. Figure 1 illustrates the basic model structure. A detailed description of the technical basis for the buffer designation is provided in Section 3.2 of this manual.

The first component of the model is a data gathering and site assessment phase. The information will provide the basis for the Special Conditions Evaluation and the determination of the appropriate buffer width for stormwater runoff mitigation. The model incorporates the the stormwater treatment objectives recommended by RIDEM (RIDEM, 1988). That is, a high level of protection required for sensitive areas (i.e., water supply reservoirs and their tributaries, coastal ponds, etc.), and the opportunity to adjust the level of protection for non-sensitive resources. A more detailed discussion of the treatment objectives is provided in Section 3.2.

Buffer widths for pollutant attenuation in surface runoff are determined based upon the site characteristics. The treatment objective of the model targets the removal efficiency of total suspended solids (TSS) as the key urban runoff pollutant. In cases where more than 300 feet would be required to provided the necessary pollutant attenuation, it may be desirable to employ other mitigation measures. In addition, a minimum 25-foot buffer width is recommended for subsurface pollutant attenuation.

A brief summary of the primary assumptions and limitations of this method are provided below.

<u>Assumptions</u>

The proposed buffer designation method is based upon the following assumptions and conditions:

1) All stormwater runoff from the site passes through the vegetated buffer strip as diffuse, shallow, overland flow, without channelization.

2) Other stormwater mitigation measures (e.g., detention ponds, infiltrations basins, etc.) are not proposed on the development site.

3) In cases where the site runoff is collected via catch basins and conveyed to the buffer area, the discharge from the conveyance system is spread evenly across the upper edge of the buffer strip (i.e., using a level spreading device).

4) Total suspended solids is an appropriate indicator pollutant for evaluating the removal of other pollutants in urban runoff.

Limitations

The buffer width assignment method relies upon TSS removal efficiencies predicted by the P8 Urban Catchment Model (Walker, 1990). The P8 Model estimates (or predicts) pollutant removal based upon detailed simulation of runoff and pollutant build-up and washoff. The actual pollutant removal efficiencies predicted by the P8 Model have not been verified against field measurements. Further, because this method utilizes an equation which approximates removals predicted by P8 based on a single variable (impervious area), the percent removal may vary slightly (2 - 5 %) from the more detailed simulations provided by P8.

The model does not specifically address such issues as upland wildlife habitat protection or attenuation of nutrients from septic system (ISDS). Additional research is needed to provide the scientific basis for assigning buffer widths to address these issues. However, by maintaining an undisturbed upland vegetated buffer strip for pollutant attenuation, valuable upland and transitional habitat may be preserved. While it may be desirable to protect upland wildlife habitat, this may be more effectively accomplished through sound open-space planning and protection. Further, although septic systems (ISDS) are recognized as a significant contributor of nutrients (particularly nitrogen) from upland areas, sufficient scientific documentation is not yet available to prescribe vegetated buffer strips widths necessary for adequate subsurface pollutant attenuation, based upon site-specific characteristics. Hence, at this time septic system impacts may be better addressed via setback requirements to provide adequate distance for dilution, maintenance and inspection programs, land use planning (density limitations), and the use of alternative (innovative) system design. Further, because not all wildlife species are adversely affected by noise, it is not considered appropriate to require buffer widths sufficient for noise attenuation in all situations as is recommended by Brown et al. (1987).

The proposed method does provide an opportunity to adjust the level of treatment required for proposed developments adjacent to non-sensitive resource areas. However, to provide a consistent method for the determination of resource sensitivity and the appropriate level of protection, a resource sensitivity evaluation component should be considered in the future. While a number of sound resource characterization methods are available (Golet, 1973; Hollands and McGee, 1985, and others), most require extensive field assessments. Hence, the major constraint is balancing the needs for detailed site investigation to determine sensitivity with a level consistent with the practical application of this procedure.

3.2 TECHNICAL BASIS

The following provides a detailed discussion of the technical basis for each primary component of the buffer designation method.

3.2.1. Special Conditions Evaluation

When assigning protective buffers, situations where either the proposed activity is known to have a high potential for impact, or the wetland is or (is associated with) an extremely sensitive resource area, warrant special consideration. Therefore, as with several other buffer assignment models (Roman and Good, 1985; Rogers, Golden and Halpern, 1988), a "special conditions" evaluation has been included in this designation model. If one or more special cases do apply, the guidelines are provided for additional considerations (Figure 2). The clarifying conditions, rationale, and recommended buffer are provided below for each special condition:

A. Commercial or Industrial Facility That May Release Hazardous Materials

Recommendation: A minimum 300-foot undisturbed vegetated buffer should be maintained between the wetland boundary and any commercial or industrial facility engaged in operations, which include the generation, manufacture, refining, transportation, treatment, storage, handling, or disposal of hazardous substances or hazardous waste.

Clarifying Conditions: Hazardous substances are those elements or compounds, defined as such by RIDEM, or otherwise provided by law. Hazardous wastes are those required to be reported on a waste manifest form, or otherwise provided by law.

Rationale: The potential exists for severe and possibly irreversible environmental impacts on wetland resources associated with the accidental or intentional release of hazardous materials. Despite the use of extreme caution in the handling of these materials, accidental release is possible. Although, no data exists to prescribe a minimum buffer for hazardous materials, a buffer of 300 feet is recommended. Similar minimum buffers have been recommended by Rogers, Golden and Halpern (1988). In the event of a release of hazardous materials, this buffer may allow for the implementation of appropriate spill response and containment activities before materials reach the wetland resources.

B. Development in a Residential Infill Area

Recommendation: Maintain a buffer consistent with existing buffers in the infill development area.

Clarifying Conditions: The following guidelines were suggested by Roman and Good (1985) to determine if a particular development project qualifies as an infill-type development.

FIGURE 2

SPECIAL CONDITIONS EVALUATION

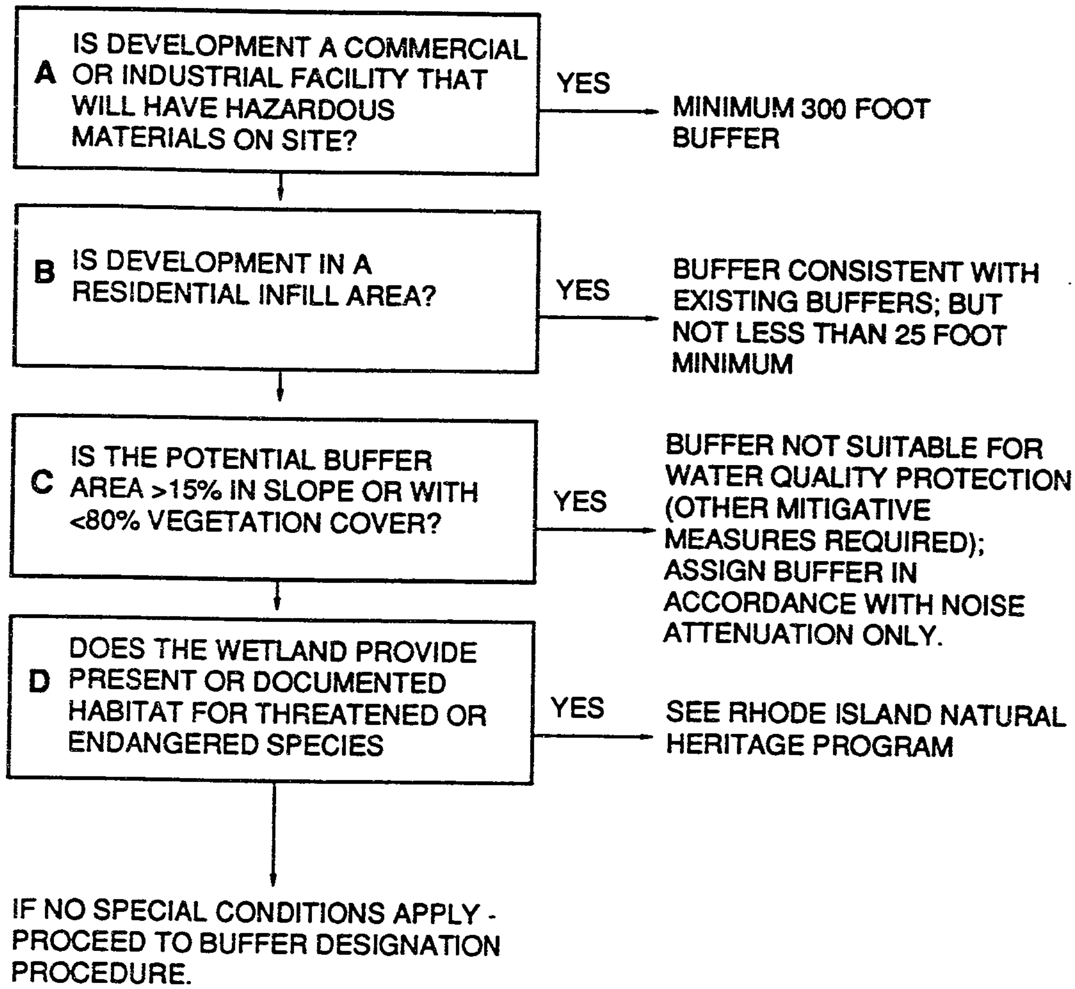

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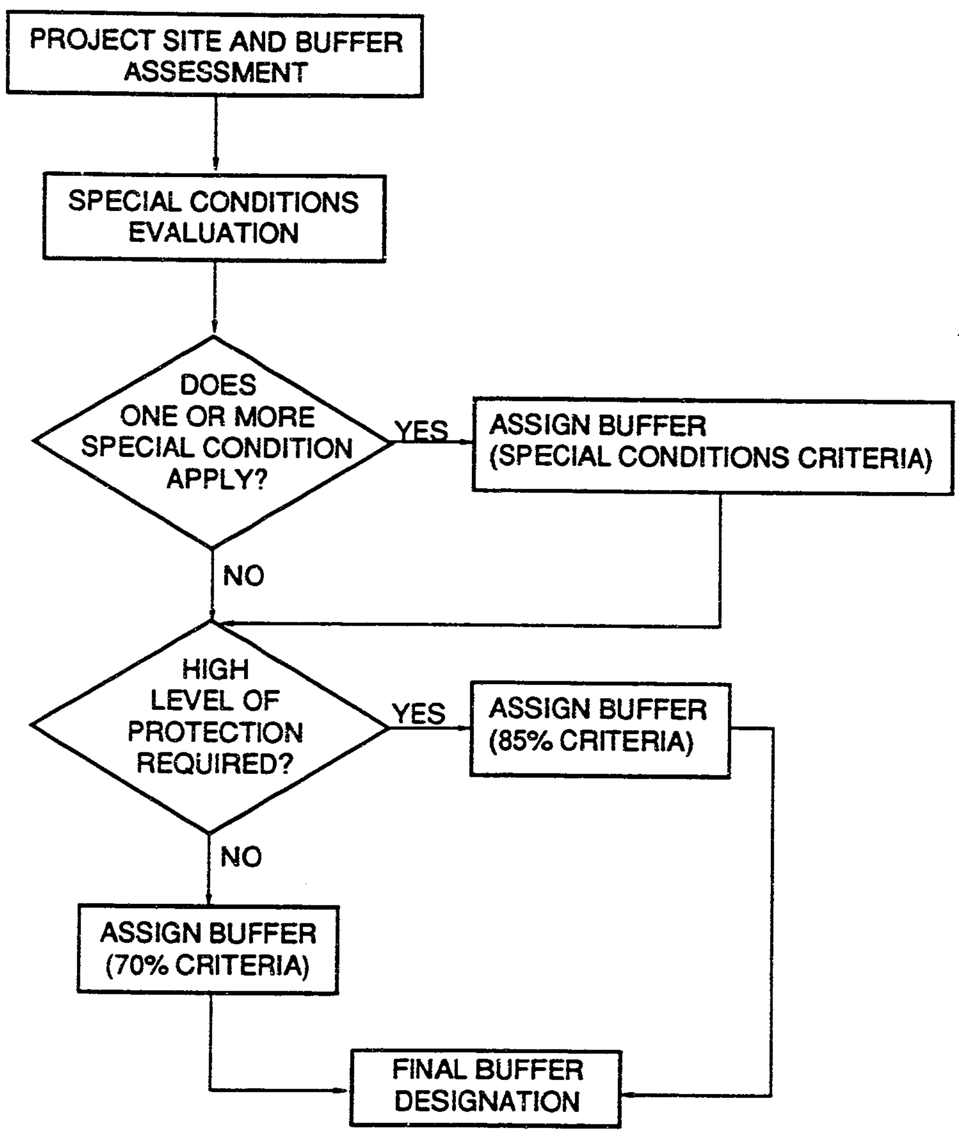
FIGURE 1

BUFFER DESIGNATION MODEL OVERVIEW



- Occurs in a residential area which is presently developed.
- Maximum lot size of 1.0 acre.
- Has direct access to a paved public road.
- Area serviced by a municipal wastewater treatment system.

Rationale: According to Roman and Good (1985), allowing similar types of development within existing developed areas are consistent with regional planning objectives. So as not to constrain such development activities, while providing a minimum level of protection, buffers consistent with existing buffers or a minimum of 25-feet, whichever is greater, should be provided. Roman and Good (1985) make similar recommendations for the treatment of infill developments, with the exception that a minimum 50-foot buffer is required.

C. Buffer Area With Slope >15% or <80% Vegetation Cover

Recommendation: Buffer is not considered suitable for pollutant attenuation, and other mitigation measured should be utilized for water quality protection.

Clarifying Conditions: Assess vegetative cover based upon a visual inspection of the potential buffer area. Slope should be determined based upon SCS soils information or site plan.

Rationale: As vegetation cover decreases the pollutant removal capabilities of vegetated buffers also decline (Wong and McCuen, 1982). In addition, these conditions may promote erosion, and actually result in increased pollutant loads. It may be possible, through seeding and planting of indigenous grasses and ground covers, to restore vegetative cover in disturbed and degrade buffers. However, the existing absence of complete vegetative cover (>80%) may be indicative of erosional tendencies, and it may be difficult to establish vegetation in these areas. Routing increased runoff from the site into these buffer areas after development may compound erosion problems. Therefore, revegetation of disturbed or degraded buffers is not recommended. Similarly, where slope exceeds 15%, the pollutant attenuation capabilities of a buffer decrease substantially (Dillaha et al., 1986a).

D. Wetland Provides Habitat for Threatened or Endangered Species

Recommendations: A minimum buffer, determined in consultation with the Rhode Island Natural Heritage Program, but not less than required for a high level (85% removal criteria) of stormwater pollutant attenuation should be maintained.

Clarifying Conditions: Rhode Island Natural Heritage Program should be contacted to determine if the wetland area presently provides or had documented habitat for threatened or endangered species. Threatened and endangered species include those species on either state or federal lists of threatened and endangered species including both plants and animals.

Rationale: Because the future existence of threatened and endangered species is questionable, special measures are necessary to ensure the protection of critical habitat. In addition to the effects of post-development on the vegetational composition, species associated with wetland area are often reliant on upland "transitional" habitat (Rogers, Golden and Halpern, 1988).

3.2.2 Pollutant Attenuation

A key aspect of this buffer designation method is the water quality component. This model component is used to determine the buffer width required to provide the desired level of pollutant attenuation. While there is a suite of parameters of concern relative to urban runoff (e.g., heavy metals, nutrients, suspended solids, petroleum hydrocarbons, etc.) it is generally considered impractical to monitor and/or regulate all chemical constituents which may be present in urban runoff. Therefore, it is necessary to select an "indicator" or target parameter which is predictive of other typical urban runoff pollutants. Many pollutants found in urban runoff are bound to particulate matter, and are often expressed on the basis of pollutant mass per total suspended solids mass (Huber, 1986; Novotny and Chesters, 1981; Hoffman et al., 1982). Further, RIDEM has recommended a pollutant removal criteria based upon the percent removal of total suspended solids (TSS) for the design of stormwater management treatment systems (RIDEM, 1988). Therefore, total suspended solids will serve as the "keystone" pollutant for surface runoff pollutant attenuation.

Level of Protection

As mentioned previously, RIDEM recommends an 85 removal of TSS in sensitive areas (i.e., water supply reservoirs and their tributaries, coastal ponds, etc.) and 70 percent removal for non-sensitive areas. These treatment objectives appear to provide an adequate level of protection for wetland resources. For example, copper, identified as a key urban runoff pollutant in the NURP studies, exceeded the freshwater chronic exposure criteria for aquatic life 82 percent of the time (Athayede et al., 1983). In addition, copper concentrations are found to be related to TSS concentrations in urban runoff (Athayede et al., 1983), such that, in treated stormwater, the exceedance of the copper criterion declines as TSS removal increases, falling below 5 percent exceedance with an 85 percent removal of TSS (Walker, 1990). Therefore, the 85 percent treatment objective is expected to provide an adequate level of attenuation of other urban runoff pollutants of concern.

As discussed in Section 3.1, the buffer designation method, as proposed, does not include a detailed procedure to assess the sensitivity of adjacent and downstream resources. While some resource areas have been designated as sensitive (i.e., water supply watersheds, vernal ponds, cedar swamps, scenic rivers, conservation lands and coastal ponds), other wetland areas may also be sensitive to direct and/or cumulative impacts from urban runoff. Therefore, for the purposes of the designation model, all wetland resources will be afforded a high level of protection (85% TSS removal), unless it is demonstrated by the applicant to the satisfaction of the regulatory agency that a high level of protection is not necessary to protect the wetland resource value. If a high level of protection is not warranted based upon the findings of a detailed wetland evaluation, the 70% TSS removal treatment objective should be used to determine the minimum buffer width.

Surface Runoff Pollutant Attenuation

A number of models or methods for determining the buffer distance necessary to provide a given level of pollutant attenuation in surface runoff have been developed (Wong and McCuen, 1982; Brown et al., 1987; Dennis et al., 1989). In most cases these models utilize a minimum of site-specific information (i.e., slope, soil erodability, infiltration rate, etc.). However, these models do not, in some cases, directly account for the hydraulic loading from a given site to a potential buffer area. Several investigators have identified that the pollutant removal efficiency is directly related to the hydraulic and/or pollutant load (Dillaha et al., 1986a; Dennis et al., 1989). More simply, the buffer required to treat runoff from a 100-acre site with 25 percent impervious area should be greater than that for a 10-acre site with the same percent impervious area assuming all other site characteristics are the same.

The approach used in this buffer designation method is one that assigns a buffer area (BA) based upon the impervious area (IA) of the project site and other site characteristics (i.e., infiltration rate). The P8 Urban Catchment Model (Walker, 1990; IEP, 1990), developed for the Narragansett Bay Project, was used to determine the percent removal of suspended solids from sites of varying impervious area and site characteristics. This model simulates the build-up and wash-off of pollutants from urban catchments, and the removal of pollutants in a variety of stormwater BMP's (e.g., buffer strips, wet ponds). The model considers only physical removal processes (i.e., sedimentation and infiltration), and does not account for biological or chemical processes such as plant uptake or chemical binding, which may also act to remove pollutants. Therefore, the buffer sizes determined by this approach are conservative.

Although the P8 model may be used to determine the buffer distance required to treat a given site's runoff to the treatment objective, this level of effort may not be warranted for many smaller projects. Therefore, multiple simulations were completed for various possible site characteristics. The analysis of the simulation results revealed that the buffer area to impervious area ratio is a reliable predictor of percent TSS removal (Figure 3). Walker (1990) states that the predicted removal efficiencies for buffer strips are relatively insensitive to Mannings-n (roughness coefficient) and slope. Further, removal efficiencies were more sensitive to changes in infiltration rate. Therefore, percent removal rating curves were developed for various infiltration rates.

To determine the buffer area required to treat a given project site to the desired treatment objective (e.g., 85% or 70% TSS removal), the following equations are given:

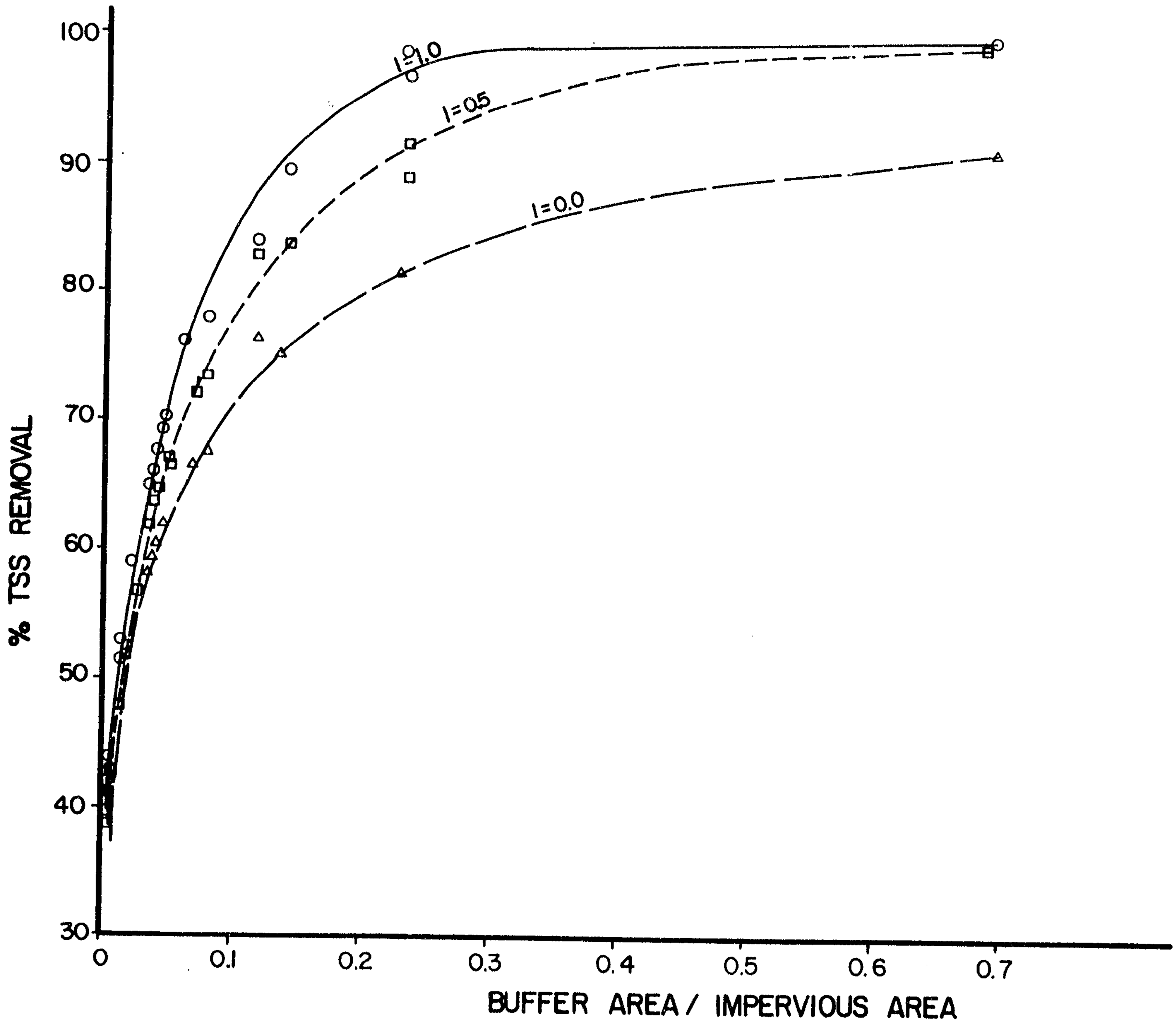
For I > 0.5 (in/hr):

$$BA_{85\%} = 0.12(IA)$$
$$BA_{70\%} = 0.05(IA)$$

For I = 0.25 - 0.50 (in/hr):

$$BA_{85\%} = 0.17(IA)$$
$$BA_{70\%} = 0.06(IA)$$

FIGURE 3 - PERCENT TOTAL SUSPENDED SOLIDS REMOVAL AS A FUNCTION OF BUFFER AREA / IMPERVIOUS AREA RATIO



iEP inc.

For I < 0.25 (in/hr):

$BA_{85\%} = 0.31(IA)$

$BA_{70\%} = 0.09(IA)$

Where: BA = buffer area required for 70 or 85% TSS removal (acres)
IA = impervious are of project site (acres)
I = infiltration rate (inch/hr)

The minimum buffer width required for water quality mitigation is determined by the following equation:

$$BW = (BA*43,560)/SBL$$

Where: BW = baseline buffer width
SBL = site boundary length (feet)
43,560 = conversion factor for acre to square feet

The site boundary length (SBL) is the boundary distance parallel to the upland resource edge, where no substantial changes in site characteristics occur.

Subsurface Pollutant Attenuation

The buffer width designation described above addresses the removal of pollutants from surface runoff. However, soluble pollutant fractions may enter ground water via infiltration within the buffer strip, as well as from subsurface sources (i.e., septic systems). These soluble pollutant fractions may ultimately reach and affect wetlands and valuable water resources. Therefore, it is necessary to address pollutant removal in shallow ground water. In general, mechanisms which may account for pollutant attenuation in shallow ground water include vegetative uptake, microbial degradation, adsorption, and complexation. Research has documented the attenuation of pollutants in wetlands (Gilliam and Skaggs, 1987; Lawrence et al., 1984). However, research regarding the use of upland vegetated buffer strips for the removal of pollutants in shallow ground water is limited. Additional research is needed to more clearly define the factors controlling ground water pollutant attenuation, and to refine our ability to predict pollutant removal based upon limited site-specific information.

The ability of a soil to adsorb cations, such as heavy metals is characterized by the soil's cation exchange capacity (CEC). The cation exchange capacity of a soil is related to the amount of clay and organic matter in the soil (Rogers, Golden & Halpern, 1988). Rogers, Golden, & Halpern (1988) suggested that buffer widths should be increased by as much as thirty feet to account for differences in subsurface pollutant attenuation associated with different soil types. For soils of low organic content, an increase of 20 to 30 feet is recommended for upland soils. Despite low clay and organic content in upland soils, University of Rhode Island researchers observed complete attenuation of copper in upland soils (Groffman et al., 1990). Based upon estimated cation exchange capacities, they state that complete attenuation of 45 grams of copper applied would be achieved in 1.7 feet (0.52 meters) of horizontal movement (Groffman et al., 1990). However, the typical annual copper load from a residential development is much lower (3-5 gm/yr). Although, the CEC may become saturated with continued inputs, the CEC of a 50-foot buffer would probably not be exceeded in over 100 years of continued application. Therefore, a modification to the buffer width for subsurface attenuation of metals does not appear to be warranted.

Soluble nitrogen fractions, particularly nitrate, are however of concern. In a concurrent investigation, Groffman et al., (1990) compared observed nitrate attenuation in upland buffers to several site variables (mean water table elevation, soil, pH, organic content, travel distances from pollutant source, and microbial parameters). Of the variables compared, only mean water table elevation demonstrated a statistically significant relationship to nitrate attenuation (Groffman et al., 1990). In addition, they suggest that the primary mechanism affecting nitrogen attenuation in upland buffers is vegetative uptake, while microbial denitrification may be more important in wetland soils. Based upon these findings, the buffer width may need to be increased to account for soil characteristics which may facilitate the removal of particulates from surface runoff (infiltration), but provide inadequate removal of subsurface nitrate. In general, where the depth to ground water was less than 60 cm (approximately two feet) or within the root zone, greater than 70 percent attenuation of nitrate was observed within 25 to 50 feet from the pollutant source (Groffman et al., 1990). Therefore, a minimum 25-foot buffer width is recommended for moderately well and somewhat poorly drained soils where the depth to ground water falls within the root zone. However, as nutrient removal is, in part, associated with contact time in the root zone, some additional width (distance) may be necessary for well drained to excessively well drained soils. Data are not available to accurately determine the appropriate additional widths required for well drained soils and/or in cases where the depth to water table is greater than two feet. In the interim, it is suggested that a minimum 25-foot buffer width be considered for subsurface pollutant attenuation. Additional research is needed to verify the appropriateness of these distance under varying site conditions.

3.3 USING THE MODEL (STEP-BY-STEP)

The following section illustrates the step-by-step use of the buffer designation model. The reader is referred to Section 3.2 for a more detailed discussion of the technical basis and documentation, and Appendix C for example applications. A buffer assignment worksheet is provided at the end of this section to facilitate data collection.

Step 1: Site Assessment

This step involves gathering information regarding the proposed development site and adjacent resource area for evaluation. Part A of the form should be completed based upon a visual inspection of the site, USGS topographic maps, soil survey maps, and information which may be available from the site plan.

Where a given buffer area is underlain by several soil types, all soil types should be listed in addition to the area they occupy. Hydrologic soil group and infiltration rates should be representative of average conditions in the potential buffer strip area. Table 1 provides guidelines for the selection of infiltration rates based upon hydrologic soil group.

Table 1. Infiltration Rates (inch/hr) for Hydrologic Soil Groups (Musgrave, 1955).

Soil Group	Infiltration Rate
A	.30 - .45
B	.15 - .30
C	.05 - .15
D	.00 - .05

Vegetation type, condition, and percent cover should be determined based upon visual inspection.

Upon completion of the site assessment step, proceed to Step 2.

Step 2: Special Conditions Evaluation

If one or more special cases do apply, the most restrictive minimum undisturbed vegetated buffer width is applied (Figure 2). The recommended buffer and clarifying conditions are provided below for each special condition:

A. Commercial or Industrial Facility That May Release Hazardous Materials

Recommendation: A minimum undisturbed vegetated buffer should be maintained between the wetland boundary and any commercial or industrial facility engaged in operations, which include the generation, manufacture, refining, transportation, treatment, storage, handling, or disposal of hazardous substances or hazardous waste.

Clarifying Conditions: Hazardous substances are those elements or compounds, defined as such by RIDEM, or otherwise provided by law. Hazardous wastes are those required to be reported on a waste manifest form, or otherwise provided by law.

B. Development in a Residential Infill Area

Recommendation: Maintain a buffer consistent with existing buffers in the infill development area.

Clarifying Conditions: The following guidelines were suggested by Roman and Good (1985) to determine if a particular development project qualifies as an infill-type development.

- Occurs in a residential area which is presently developed.
- Maximum lot size of 1.0 acre.
- Has direct access to a paved public road.
- Area serviced by a municipal wastewater treatment system.

C. Buffer Area With Slope >15% or <80% Vegetation Cover

Recommendation: Buffer is not considered suitable for pollutant attenuation, and other mitigation measured should be utilized for water quality protection.

Clarifying Conditions: Assess vegetative cover based upon a visual inspection of the potential buffer area. Slope should be determined based upon SCS soils information or site plan.

D. Wetland Provides Habitat for Threatened or Endangered Species

Recommendations: A minimum buffer, determined in consultation with the Rhode Island Natural Heritage Program, but not less than required for a moderate level of stormwater pollutant attenuation.

Clarifying Conditions: Rhode Island Natural Heritage Program should be contacted to determine if the wetland area presently provides or had documented habitat for threatened or endangered species. Threatened and endangered species include those species on either state or federal lists of threatened and endangered species including both plants and wildlife.

If no special conditions apply, proceed to Step 3.

Step 3: Buffer Assignment

Use the following equations to determine the required buffer area for surface runoff treatment (85% TSS removal):

$$BA85\% = k(IA) \qquad (1)$$

Where: BA85% = buffer area required for 85% TSS removal (acres)
IA = impervious area of project site (acres)
I = infiltration rate (inch/hr)
k = buffer sizing factor (see Table 2)

If a high level of protection is not deemed necessary (as demonstrated by the applicant to the satisfaction of the regulatory agency), use the following equations to determine the required buffer area for surface runoff treatment (70% TSS removal):

$$BA70\% = k(IA) \qquad (2)$$

Where: BA70% = buffer area required for 70% TSS removal (acres)
IA = impervious area of project site (acres)
I = infiltration rate (inch/hr)
K = buffer sizing factor (see Table 2)

Table 2. Buffer sizing factor (K) for various infiltration rates (I; in/hr):

TREATMENT LEVEL	I > 0.5	I = 0.25-0.5	I < 0.25
High (85% Removal Criteria	0.12	0.17	0.31
Moderate (70% Removal Criteria)	0.05	0.06	0.09

To translate this buffer area into a minimum buffer width, use the following equation:

$$BW = (BA*43,560)/SBL \qquad (3)$$

Where: BW = minimum buffer width
BA = buffer area determined in equations 1 or 2)
SBL = site boundary length (feet)
43,560 = conversion factor for acre to square feet

The site boundary length (SBL) is the boundary distance parallel to the upland resource edge, where no substantial changes in site characteristics occur.

As described in Section 3.2.2 a 25-foot minimum buffer width is suggested for subsurface pollutant attenuation. If the buffer width prescribed according to equation 3 is less than 25 feet, the 25-foot minimum buffer requirement is applied. The buffer width determined should extend in an upland direction from the resource boundary for the required distance. Guidelines for use and maintenance within the buffer zones are provided in the following section.

BUFFER ASSIGNMENT WORKSHEET

Date:_______________ Investigator(s):_______________
Site Location:_______________
USGS Topographic Sheet:_______________
Soil Survey (county):_______________
Drainage basin:_______________

PART A - SITE INVENTORY

Project Description:

1) Is Proposed Land Use a Commerical/Industrial Facility with Hazardous Materials On-site *(yes/no)?_______◆
2) Impervious Area (acres):_________(IA)
3) Site Boundary Length (feet):_______(SBL)
4) Is this an In-fill Development (yes/no)?__________◆

*Includes any facility engaged in the generation, manufacture, refining, transportation, treatment, storage, handling or disposal of hazardous materials

Potential Buffer Strip Characterization:

5) Soil type:_______________
6) Hydrologic Class:________
7) Infiltration Rate (in/hr):____________(I)
8) Is Slope > 15% (yes/no):___________◆
9) Depth to Ground Water (feet):_______________

10) Vegetation Type (check one)
- ❐ Grassed
- ❐ Forested w/ground cover
- ❐ Forested w/o ground cover
- ❐ Other

11) Buffer Condition (check one)
- ❐ Good Condition
- ❐ Evidence of Human Disturbance
- ❐ Evidence of Channelization

12) Is Vegetation Cover <80% (yes/no): ______◆

Receiving Resource:

13) Documented Habitat of Threatened or Endangered Species (yes/no)?______◆
14) Resource Area Documented as Non-Sensitive (yes/no)?________

PART B - SPECIAL CONDITIONS

Those items denoted with an diamond "◆", provide information necessary for the special conditions evaluation. If the answers to any of these items are "yes", special conditions below apply.

Commercial or Industrial Facility - Hazardous Materials (Item 1): Minimum 300-foot buffer.
Infill-Development (Item 4): Buffer consistent with surrounding buffer widths or 25-foot minimum which ever is greater
Slope/Vegetation Cover (Items 8 or 12): Site conditions are not suitable for buffer strips, and other mitigations measures should be considered.
Threatened or Endangered Species (Item 14): Contact RI Natural Heritage Program for guidance in buffer requirements for habitat protection, with buffer requirement not less than required for stormwater mitigation using 85% Removal Criteria.

PART C - BUFFER ASSIGNMENT

If response to Item 14 is "yes", use 70% removal criteria (Equation 2). In all other cases, use 85% removal criteria (Equation 1). Buffer sizing factor (k) based on Infiltration Rate (I) from Item 7 above.

Equation 1 (85% Removal Criteria)

$$BA85\% = k(IA)$$

Where: BA85% = buffer area required for 85% TSS removal (acres)
IA = impervious area of project site (acres)
k = buffer sizing factor (See look-up table below)

BA= ___________

Equation 2 (70% Removal Criteria)

$$BA70\% = k(IA)$$

Where: BA70% = buffer area required for 70% TSS removal (acres)
IA = impervious area of project site (acres)
k = buffer sizing factor (see look-up table below)

BA= ___________

LOOK-UP TABLE - BUFFER SIZING FACTOR (k)

	Infiltration Rate (I; in/hr)		
Treatment Level	I≤.25	I=.25-.5	I≥.5
High: 85% Removal Criteria	0.31	0.17	0.12
Moderate: 70% Removal Criteria	0.09	0.06	0.05

Equation 3

$$BW = (BA*43{,}560)/SBL$$

Where: BW = minimum buffer width
BA = buffer area (determined in equations 1 or 2)
SBL = site boundary length (feet)
43,560 = conversion factor for acre to square feet

BW= ___________

Notes: If BW <25 feet, the minimum buffer requirement of 25-feet is applied.

If Special Conditions apply, the buffer requirement is equal to the Special Conditions buffer requirement or BW, which ever is greater.

4.0 GUIDELINES FOR BUFFER MAINTENANCE AND USE

Vegetated buffer strips are an effective means of controlling nonpoint sources of pollution. However, maintenance of these buffer strips is necessary to ensure long-term pollutant removal and habitat protection. The following use and maintenance recommendations are adapted from Dennis et al. (1989), Schueler et al. (1987) and Dillaha et al. (1986b). Some general maintenance practices that may be applied to all types of vegetated buffer strips include:

- Buffers must be inspected annually for evidence of erosion or concentrated flows through or around the buffer. Any eroded areas should be seeded and mulched. A shallow stone trench installed as a level spreader to distribute flows evenly may be necessary in areas showing repeated channelization. If the use level spreader is necessary, quarterly inspections should be completed.

- Uses which should be avoided within undisturbed vegetated buffer strips include, 1) the use of fertilizers, herbicides, or other chemicals; 2) vehicular traffic; 3) excessive pedestrian traffic; 4) building or construction; and 5) burning, cutting or removal of vegetation which is inconsistent with maintenance practices described below.

- The buffer strip should remain undisturbed, however, a winding path may be established within the buffer no wider than 6 feet. A straight line path would allow water to channelize.

- Lawn areas are not, in the context of this manual considered appropriate non-forested buffers. Low maintenance, naturalistics buffers are appropriate.

The following maintenance practices are recommended for non-forested vegetated buffer strips:

- Should be mowed and the clippings harvested a maximum of 2 to 3 times per year to promote a thick vegetation with optimum pollutant-removal capabilities. The latest mowing of each year occur prior to September 1 to allow sufficient growth to provide filtration during the non-growing season.

- Should be inspected for stand establishment after planting and if stand is inadequate, the area should be overseeded.

- Periodic spot repairs and watering may be required to maintain a dense, vigorous growth of vegetation.

- Any accumulated sediments deposited over time near the top of the strip will need to be manually removed to keep the original grade.

The following maintenance practices are recommended for forested buffer strips:

- All existing undergrowth, forest floor duff layer, and leaf litter should remain undisturbed and intact.

- Pruning of live tree branches that do not exceed 12 feet above the ground can be initiated provided that at least the top two-thirds of the tree canopy is maintained.

- Removal of storm damaged, diseased, unsafe, or dead trees results in a cleared opening, those openings should be replanted with native trees at least 3 feet in height unless existing new tree growth is present.

Maintenance practices and use restriction of the buffer strips is the responsibility of the land owner, and should be enforced through deed restriction or other regulatory alternatives. To this end, it may be necessary for the regulatory authority(ies) to inspect buffer strips every 1 to 2 years.

5.0 GLOSSARY

Best Management Practices (BMPs): Nonstructural and low-structural measures that are determined to be the most effective, practical means of preventing or reducing pollution inputs from nonpoint sources in order to achieve water quality goals.

Endangered Species: Native species in imminent danger of extirpation from Rhode Island which are included on either the state or federally endangered species list.

Erosion: The wearing away of the land surface by running water, wind, ice, or other geological events.

Eutrophication: The process of physical, chemical, and biological changes associated with nutrient, organic matter, and silt enrichment and sedimentation of a lake or reservoir. If the process is accelerated by man-made influences, it is termed cultural eutrophication.

Forested Buffer: Buffer dominated (>50%) by trees with an average height of greater than 20 feet.

Heavy Metals: Metals present in industrial, municipal, and urban runoff, including lead, copper, cadmium, zinc, mercury, nickel, and chromium.

Hydrologic Soil Group (Class): Classification of soils into groups based on their runoff potential. Groups range from A soils, which have high infiltrative capacity and generate little runoff, to D soils, which have little infiltrative capacity and generate substantial runoff.

Impervious Area: Surface that is impermeable to water, such as pavement and rooftops, and prevents infiltration of water into the soil.

Infiltration: The gradual downward movement of water from the surface into the subsoil.

Level Spreader: Device used to spread stormwater runoff uniformly over the ground surface as sheet flow. The purpose of level spreaders is to prevent concentrated, erosive flows and to enhance infiltration.

Nonforested Buffer: Land dominated (>50%) by herbaceous species with an average height of less than 12 inches.

Nonpoint Source Pollution (NPS): Pollution caused by sediment, nutrients, and organic and toxic substances originating from land-use activities and/or from the atmosphere, which are carried to lakes and streams by runoff. Nonpoint source pollution occurs when the rate at which these materials entering water bodies exceeds natural levels.

Sedimentation: Removal, transport, and deposition of detached sediment particles by flowing water or wind.

Sheet Flow: Runoff that flows over the ground surface as a thin, even layer, and is not concentrated in discernible channels.

Short-circuiting (channelization): The passage of runoff through a buffer strip in less than the design treatment time, thereby preventing treatment from occurring. With buffer strips, short-circuiting refers to channelized flow.

Slope: The inclination of the land surface from the horizontal. Percentage slope is the vertical distance divided by the horizontal distance.

Threatened Species: Native species which are likely to become state endangered in the future if current trends in habitat loss or other detrimental factors remain unchanged which may occur on state or federally threatened species list.

Urban Runoff: Surface runoff from an urban drainage area that reaches a stream or other body of water or a sewer.

Vegetated Buffer Strip: Strips of vegetated land downslope of cleared or impervious areas or along stream and lake shorelines.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Water Table: The upper limit of the soils underlying rock material that is wholly saturated with water.

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7.0 APPENDICES

APPENDIX A. Review of Pertinent State and Local Regulations
APPENDIX B. Annotated Bibliography
APPENDIX C. Example Application

APPENDIX A

Review of Pertinent State and Local Regulations

SUMMARY OF SETBACK AND BUFFER REGULATIONS FOR SEPTIC SYSTEMS IN THE HUNT-POTOWOMUT WATERSHED, RHODE ISLAND

State agencies:

1) Department of Environmental Management, Division of Land Resources/ISDS Section (Individual Septic Disposal System)

2) Department of Environmental Management, Division of Water Resources/Freshwater Wetlands Section (DEM/FWS)

3) Coastal Resources Management Council (CRMC)

Local authorities in the following Towns: East Greenwich, West Greenwich, Warwick, West Warwick, Exeter, North Kingstown, and Coventry.

Setbacks and buffer zones may vary from site to site depending on site conditions and applicable local and state regulations. Definitions of these parameters also vary from agency to agency: setback, buffer zone, undisturbed setback, vegetated setback, perimeter wetland, and riverbank wetland all define some regulated distance between the limits of work and the limits of a protectable wetland, waterbody or watercourse. Generally, a buffer zone or vegetated setback require that natural vegetation within this distance be maintained in an undisturbed condition, whereas a setback, in the strictest sense, does not.

CRMC requires that applicants obtain all other local and state permits prior to processing a state coastal permit. Pre-applications with applicable agencies can provide applicants with setback and buffer zone requirements early in the permitting process in order to confirm locations of wetland and other protected resource boundaries and plan for the strictest requirements on a proposed septic system. Confirmation of freshwater and coastal wetland boundaries is ultimately the authority of the DEM/Freshwater Wetlands Section and the Coastal Resources Management Council, respectively.

Variances and special exceptions may be obtained for placement of septic systems at problem sites. Current setbacks and buffers may not be applicable to repairs of failing septic systems which were installed prior to regulatory adoption or amendments.

The following summarizes current setback and buffer requirements at both state and local levels for placement of individual septic systems.
Requirements listed for the DEM/ISDS Section are as amended January 3, 1990.

STATE REQUIREMENTS

DEM/ISDS Section - Setback requirements have been amended, effective January 3, 1990. For inland areas, a 50-foot setback is required from the boundary of any bog, swamp, marsh pond or lake unless designated Critical Areas; a 100-foot setback is required from watercourses less than 10 feet wide, and a 200-foot setback from watercourses greater than 10 feet wide; designated Critical Areas (Scituate Reservoir and its tributaries, and other drinking water reservoirs and tributaries) require a 200-foot setback from the edge of water. Public drinking water supply wells require a 400 foot setback.

For coastal areas, designated Critical Areas (the Narrow River estuary and the Salt Ponds) require a 150-foot setback from the inland edge of the shoreline feature; all other coastal wetlands and tidal waters require minimum setback of 50 feet from the inland edge of the shoreline feature, but this may be greater than 50 feet as mandated by CRMC. That these setbacks be required to remain in an undisturbed natural state is at the authority of DEM/Freshwater Wetlands and/or CRMC, as applicable.

DEM/Freshwater Wetlands Section -
A 50-foot "perimeter wetland" is regulated as part of all wetlands subject to the Wetlands Protection Act (swamps, bogs, marshes, ponds and lakes) and this "perimeter wetland" is defined from the edge of the "biological wetland."
A 100-foot "riverbank wetland" is regulated from the banks of watercourses less than 10 feet wide, and a 200-foot "riverbank wetland" is regulated from the banks of watercourses which are greater than 10 feet wide.

Activities and alterations within any of these protected areas is determined on a case-by-case basis.

CRMC:

CRMC jurisdiction extends 200 feet landward from the edge of the furthest inland coastal feature (top of dune, top of coastal bank, coastal and contiguous wetland boundaries, top of seawall, etc.).

A minimum Setback of 50 feet is required from the most inland edge of coastal feature and greater setback distances are mandated in Critical Erosion Areas. On a case by case basis, vegetated setbacks may be required in areas of especially high erosion potential.

A Buffer Zone of undisturbed, natural vegetation is required on a case by case basis, ranging from no buffer required (for example, manmade shorelines) and up to 200 feet for significant potential impacts to sensitive coastal resources. Buffer Zones are measured from the further inland edge of coastal features. Where no buffer is required, a minimum 50 foot setback from the inland edge of coastal feature is still mandated. Buffer Zones are intended to function in erosion control, abating pollution of water bodies, protection of flora and fauna and preservation and enhancement of scenic quality.

MUNICIPAL REQUIREMENTS

Town of East Greenwich: Coastal areas (Greenwich Cove) are entirely sewered; for inland wetlands and waters, the Town follows State regulations.

Town of North Kingstown: For both inland and coastal wetlands, a 150-foot setback is required for septic systems in new subdivisions, not applicable to frontage lots.

City of Warwick: Zoning ordinance requires a 50-foot undisturbed setback from inland and coastal wetlands and other coastal features (as defined by CRMC); this undisturbed setback provision prohibits any alteration and is not limited to placement of septic systems.

Town of Coventry: Local ordinances follow applicable State regulations (inland only).

City of West Warwick: The City is 95% sewered; no ordinances for septic systems are in place for remaining 5% undeveloped land.

Town of West Greenwich: Zoning ordinance requires a 200-foot setback from the edge of water bodies for placement of a septic system; in other cases, the Town follows State requirements (inland only).

Town of Exeter: In all cases, placement of septic systems must meet State requirements (inland only).

APPENDIX B

Annotated Bibliography

Brinson, M. M. 1988. Strategies for Assessing the Cumulative Effects of Wetland Alteration on Water Quality. Environmental Management 12(5): 655-662.

Assessment of cumulative impacts on wetlands can benefit by recognizing 3 fundamental wetland categories; basin, riverine, and fringe. The relative proportion of these wetland types within a watershed, and their status relative to past impacts can be used to develop strategies for wetland protection. Past impacts on wetlands, however, are not likely to be clearly revealed in water quality records from monitoring studies, either because records are too short or because too many variables other than wetland impacts affect water quality. It is suggested that hydrologic records be used to reconstruct historical hydroperiods in wetlands for comparison with current, altered conditions. Changes in hydroperiod imply changes in wetland function, especially for biogeochemical processes in sediments. Hydroperiod is potentially a more sensitive index of wetland function than surface areas obtained from aerial photographs. The depositional environment of wetlands is a landscape characteristic that has not been carefully evaluated nor fully appreciated. Impacts that reverse depositional processes also may accelerate rates of change, causing wetlands to be larger net exporters rather than modest net importers. Increases in rates as well as direction can cause stocks of materials, accumulated over centuries in wetland sediments to be lost in decades, resulting in nutrient loading to down stream aquatic ecosystems.

Brown, Mark T. and Joseph M. Schaefer. 1987. Buffer Zones for Water, Wetlands, and Wildlife. Unpublished. Prepared for St. Johns River Management District.

Provides a detailed review of the existing scientific understanding of upland buffer zones, their importance to adjacent wetland and waters, and the effects of alterations of those transitional areas on downstream water quality and quantity, and wetland wildlife habitat values. The following equation allows for the determination of the width of a buffer strip for water quality maintenance:

$$B_w = \frac{S1/2}{E}$$

Where: B_w = width of buffer in feet
S = average slope of land in ft/100ft
E = Erodibility factor

Erodibility factor; use four for soils with SCS erosion factor (K) = 0.1, use for three soils with (K) = 0.15, use two for soils with (K) = 0.17, and one for soils with (K) > 0.17.

Also provides equations to determine width of buffer for water quantity maintenance, and calculating buffers for noise impacts.

Cain, D., D. R. Helsel, and S. E. Ragone. 1989. Preliminary Evaluations of Regional Ground Water Quality in Relation to Land Use. Groundwater, Vol. 27, No.2, pp. 230-244.

Describes preliminary results from six studies being made in New York, New Jersey, Connecticut, Florida, Nebraska, and Colorado as part of the Toxic Waste Groundwater Contamination Program to evaluate the degradation of regional ground water quality as a result of human activities, expressed as land use, to the quality of ground water at a regional scale.

A 5 step approach was developed to test the hypothesis that human activities, as defined by a variety of land uses, have predictable effect on regional ground-water quality. Steps are; reconnaissance, experimental design, data collection, data analysis, and verification of results. The results presented in this study are based on the reconnaissance step, which entailed existing hydrogeologic, land use, and water quality information were obtained. Conclude regional ground water quality has been affected by human activities on the land surface as characterized by land use. Ground water where overlying land use is urban or industrial, had increased frequencies of detection of volatile organic compounds such as trichloroethylene and chloroform and some trace elements in comparison to less developed areas. Waters underlying agricultural areas in Nebraska and the recharge zone of the Potomoc-Raritan-Magothy Aquifer system in New Jersey had increased nitrate and an increased frequency of detection of pesticides. For both urban and agricultural areas, effects on water quality appear with increased intensity of urbanization or irrigation.

Dillaha, T.A., J.H. Sherrard, D. Lee, S. Mostaghim, and V.O. Shanholtz. 1988. Evaluation of Vegetative Filter Strips As a Best Management Practice for Feedlots. Journal Water Pollution Control Federation 60: 1231-1238.

The use of vegetative filter strips (VFS) as an effective best management practice for the control of some nonpoint source pollutants were studied. Field experiments were designed to investigate the transport of sediment, nitrogen, and phosphorus from areas confined livestock activity, as influenced by flow characteristics and filter strip length were conducted.

Simulated rainfall was applied to a series of 5.5 by 18.3 meter bare soil plots with vegetative filter strips 4.6 and 9.1 meters long located at the lower end of the plots to simulate feedlot conditions. Results indicate that VFS are effective for the removal of sediment and other suspended solids contained in surface runoff from feedlots if runoff is shallow and uniform. Effectiveness of VFS for sediment removal decreases with time as sediment accumulated within the filters; total nitrogen and phosphorus are not removed as effectively.

Hemond, H. F. and J. Benoit. 1988. Cumulative Impacts On Water Quality Functions of Wetlands. Environmental Management Vol. 12, No. 5; pp 639-653.

Defines cumulative impacts as multiple impacts whose effects on the wetland cannot be simply adding the effects of all the individual impacts. Discusses wetland water quality functions such as they may function as short or long-term storage reservoirs. Nitrogen and phosphorus exogenously supplied to wetlands can be removed from wetland waters in the short term by plant uptake, in the long-term by peat and sediment accumulation, and permanently by denitrification. States that the percent nutrient removal by wetlands is generally high at low loading rates, low at greater loading rates and wetlands that receive effluent over several years, retentive capacity tends to decrease over time. Removal of BOD and COD is suggested best accomplished by wetlands with long residence times. Removal of suspended solids by wetlands is achieved by slowing water velocities. Reported values as high as 97 percent total suspended solids removal by wetlands. However, they may also serve as a source for suspended solids depending on conditions. Authors also discuss removal of bacteria and viruses, metals, neutralization of acid deposition, removal of xenobiotic organic pollutants, humic substance production, organic carbon contributions to the food web, trace gas production, typical cumulative and non-cumulative impacts on wetlands, and measures in assessing cumulative impacts on wetlands.

Makeig, K.S. 1982. Natural Buffers For Sludge Leachate Stabilization. Ground Water 20(4): 420-429.

Describes a study designed to quantify the amount of buffer area necessary for natural soils to stabilize sludge leachate around a trenching operation to protect ground water quality. Includes description of vertical as well as horizontal buffer distances. Common soil properties and various chemical processes are used to estimate the effectiveness of a given setting for stabilizing the leachate from buried sludge. The effectiveness is used to calculate appropriate buffer zones by simple analytical techniques and site characteristics. Groups sludge leachate components into five categories into five categories based on similar chemical nature: heavy metals (Hg, Zn, Cu, Se, Fe, Ni, Ag, Cr, Cd, and Pb), exchangeable bases are salts (K, Na, Ca, Cl, and Mg), pathogens (parasites, bacteria, and viruses), nitrogen products (nitrate etc.), and phosphorus. Classification does not account for the reactive natures of various parameters. Basis for buffer calculations are adsorption to clay particles, microbial transformations of nitrates, and dilution by ground water. Purpose of buffer zone to provide sufficient soil contact vertically between sludge and water table and horizontally between trench operation and the site boundary. Vertical buffer designed to stabilize heavy metals and salts, while horizontal buffer designed to provide stabilization of more mobile leachate components. Vertical buffer calculation assumes that 1) 100% of cations in sludge are leached; 2) all leachate will move vertically downward to water table of a confining layer; and 3) once a cation is adsorbed, it will not desorb.

Preston, E. M. and B. L. Bedford. 1988. Evaluating Cumulative Effects On Wetland Functions: A Conceptual Overview and Generic Framework. Environmental Management 12(5): 565-583.

This article outlines conceptual and methodological issues that must be confronted in developing a sound scientific basis for investigating cumulative effects on freshwater wetlands. The authors are particularly concerned with: (1) effects expressed at temporal and spatial scales beyond those of the individual disturbance, specific project, or single wetland, that is, effects occurring at the watershed or regional landscape level; and (2) the scientific component of the overall assessment process. The aim is to lay the foundation for a research program to develop methods to quantify cumulative effects of wetland loss or degradation on the functioning of interacting systems of wetlands. Toward this goal the authors: (1) defines the concept of cumulative effects in terms that permit scientific investigation; 2) distinguishes the scientific component of cumulative impact analysis from other aspects of the assessment process; (3) defines critical scientific issues in assessing cumulative effects on wetlands; and (4) sets up a hypothetical and generic structure for measuring cumulative effects on the functioning of wetlands as landscape systems.

The authors provide a generic framework for evaluating cumulative effects on three basic wetland landscape functions: flood storage, water quality, and life support. Critical scientific issues include appropriate delineations of scales, identification of threshold responses, and the influence on different functions of wetland size, shape, and position in the landscape.

Roman, C.T. and R.E. Good, 1986. Delineating wetland buffer protection areas: The New Jersey Pinelands Model. Proceedings of the National Wetland Assessment Symposium, Portland, Maine. June 17-20, 1985. ASWM Technical Report 1: 224-230.

Provides an overview of the buffer delineation model for the New Jersey Pinelands described in Roman and Good (1985). Model was developed to aid the Pinelands Commission in the implementation of site-specific decisions regarding buffer requirements. The model provides a systematic and consistent decision-making approach. The maximum buffer (300 ft.) is based primarily on assumption that this distance is sufficient to ensure that a high impact development activity does not result in irreversible effects. States that a carefully controlled long-term monitoring program is necessary to increase scientific testing of assumptions, and to determine the effectiveness of the model in assigning buffer protection areas. Suggests that the maximum buffer widths utilized for the Pineland area may not be suitable for other areas, and should be based on such factors as, wetland type, regional geology and land use. Maximum buffers should be reasonable and practical. Buffer regulation should establish a maximum buffer distance which can be reduced based on demonstration that no significant impacts on wetlands will occur.

Roman, C.T. and R.E. Good, 1985. Buffer delineation model for New Jersey Pineland wetlands. Center for Coastal and Environmental Studies, Rutgers - the State University of New Jersey, New Brunswick, NJ 73 pp.

This Buffer delineation model was developed to aid in the implementation of buffer requirements established under the Wetlands Management Program of the Pinelands Comprehensive Management Plan. Under this plan development is not permitted within 300 feet of any wetland, unless the applicant can demonstrate that the proposed development will not have a significant adverse impact on wetlands.

The buffer delineation model is designed to determine the minimum site-specific buffer width needed to protect wetlands from impacts associated with upland development. The model begins with preliminary data/information collection (i.e., site plan, topographic maps, Pinelands Commission vegetation maps, U.S. Fish and Wildlife Service National Wetlands Inventory maps, and US SCS maps and/or County Soil Surveys) relative to the proposed development. Provisions made to account for special case buffer delineation (5 guidelines relating to specific situations or special cases). In sensitive resource areas, buffer guidelines require a minimum 300 ft. buffer, or if, development is a residential infill area, then the minimum is set at compatible with existing buffers but not less than 50 ft. The document provides a discussion clarifying conditions and the rationale for each special case guideline. If no special case guidelines apply, then buffer delineation is based on a land capability areas procedure.

This procedure requires the evaluation of relative water quality (under wetland or lake/pond scheme) and the relative potential impacts associated with proposed development. A relative numbered index is determined for each, the average of which provides the buffer delineation index. The buffer delineation index is converted to actual distance (50-300 feet) using a conversation table. Actual buffer distance associated with a given delineation number varies depending upon the land capability area (forested, rural development areas, regional growth areas.

Schueler, T.R., 1987. Controlling Urban Runoff: A practical manual for planning and designing urban BMP's. Washington Metropolitan Water Resources Planning Board, Washington, D.C.

Manual includes a chapter on vegetative BMP's, including filter strips. Schueler suggests filter strips are similar to grassed swales except are designed only to accept overland sheet flow. Focuses on designed ("engineered") rather than natural "undisturbed" buffers. Channelization is common in VBS which short-circuits VBS. States that to work properly VBS must be equipped with level spreading device, dense vegetation with effective soil binding capacity, graded to a uniform, even low slope, and be at least as long as the contributing runoff area. VBS can provide landscape value, wildlife habitat, screening, and stream protection. Grass VBS can be used to protect surface infiltration trenches from sediment clogging. Value of VBS lies in reduced cost/size for downstream control facilities, and for preserving riparian zone and stabilizing streambeds. Rate of removal largely depended on length, slope, soil permeability, size of contributing area, and runoff velocity.

Cites that buffers of 100-300 feet are probably necessary for removing smaller size particles in urban runoff. Suggests that because of low infiltration volumes, the efficiency of soluble pollutants is not great (Wong and McCuen, 1982). Primary soluble pollutant removal is accomplished after infiltration via plant uptake. Cites that forested VBS have greater pollutant removal, but need to be about twice as long because of lower vegetation cover. Makes recommendations for design, optimal conditions, and maintenance. VBS serve as habitat for "edge" species of songbirds and mammals. Cites that buffer width of 600 feet may be necessary to support a full diversity of songbirds.

Wigham, D. F., C. Chitterling, and B. Palmer. 1988. Impacts of Freshwater Wetlands on Water Quality: A Landscape Perspective. Environmental Management, Vol. 12, No. 5, pp. 663-671.

Article provides a framework that might be used to evaluate how cumulative impacts to wetlands might affect or alter water quality and that this framework may lead to suggestions about the types of research that should be conducted. A landscape approach to wetland function can be used instead to make reasonable decisions about how any particular wetland might affect water quality parameters, and can even be used for whole landscapes.

The percentage of total river flow that contacts wetland environments decreases as stream order increases. Authors suggest that this relationship can be used to determine the potential impact of wetlands on water quality. Hypothesize that the amount of nutrient processing that occurs at any point along a hydrologic gradient is positively related to the total flow through wetlands. Maximum contact occurs in areas associated with smaller streams, and in areas where stream flow is constricted and water flows through wetlands. Strong evidence exists that riparian areas are important for nitrogen processing and retention of larger sediment particles. Phosphorus removal appears to occur farther downstream in watersheds; the most important areas are those in which water flows through vegetation/litter zone. Most wetland types in this category are Palustrine. These systems are probably most important as sites for processing surface waters while riparian areas are important for nitrogen processing in phreatic water. Riverine systems are also efficient processors of nutrients, but they are primarily important during flooding events. Lacustrine wetlands have less impact on water quality compared to other types, because the ratio of vegetated surface to open water is comparatively small.

Wilson, L.G. 1967. Sediment Removal From Flood Water by Grass Filtration. Transactions of the ASAE. pp.35-37.

Objectives of the research were: to determine filtration efficiency of various grasses, to determine the reactive effect of the following factors on grass filtration, including length and slope of plots, initial turbidity of flood water, application rate, degree of submergence, and stage of grass development. Seven plots were planted with the following grasses; goars Fescue, Coastal Bermudagrass, Common Bermudagrass, Sudan Grass, and Lahontan Alfalfa. Turbid river water was used in all experiments. Results display the two Bermudagrasses were the most efficient than the other varieties for sediment removal, which was 95 percent at a flow rate of 0.011 cfs per foot of width of check and a length of 200 feet. Growth of the grasses were not inhibited by the deposition of sediments. Conclude that grass filtration is an effective, economical, first stage procedure for reducing sediment in flood water. Length, initial turbidity, application rate, slope, grass height, and degree of ramification and degree of submergence are interrelated. Suggest that action of grass filters may be enhanced if flood water, when highly turbid, is passed through settling basins prior to flooding the grass filter areas.

Wong, S.L. and R.H. McCuen. 1982. The Design of Vegetative Buffer Strips for Runoff and Sediment Control. Stormwater Management in Coastal Areas. Coastal Resources Division Tidewater Administration. Maryland Department of Natural Resources. 23 pp.

Provides general discussion and literature review regarding vegetative buffer strips (VBS). Cites the following benefits: economical, low design effort, multipurpose (aesthetic and recreational). Also suggests that buffers may reduce total volume of detention storage for runoff mitigation when properly designed and located buffers are used to reduce runoff volume and sediment loads to the detention pond. Objective of study to develop a method for sizing buffers and computing volume reduction. States that buffer design (sizing) is a function of stormwater management policy considerations as well as physical characteristics of the site. Provides equations for runoff velocity (using Manning's roughness coefficient, spacing hydraulic radius, and buffer strip slope), spacing hydraulic radius (using grass media spacing and depth of flow) particle settling velocity (using specific gravity of sediment particle, acceleration of gravity, kinematic viscosity of water, and particle size). Provides curves for determining buffer length needed for various % removal (75-95%), for a given slope and mannings-n for coarse silt. Also provides settling velocity ratios for coarse silt to fine silt, medium silt, fine sands, medium sands, which can be used to adjust predicted buffer lengths for various particle sizes (settling velocities). Similarly, equations are provided for the control of runoff quantity. Rate of infiltration is dependent on condition of vegetative cover, soil properties, rainfall intensity, and ante ceder soil conditions. Provides narrative example (scenario) for model application.

Yates, M. V. and S.R. Yates. 1989. Septic Tank Setback Distances: A Way To Minimize Virus Contamination of Drinking Water. Groundwater 27: 202-208.

Objective was to produce a wide range of septic tank setback distances. Setback distances were established using the travel time necessary to achieve a seven-order magnitude reduction in virus number as a criterion. Setback distances between septic tanks and drinking water wells were calculated using a modified form of Darcy's Law:

$D = (tki)/n_e$ Where: D = Setback distance in meters
t = travel time (d)
k = hydraulic conductivity (md^{-1})
i = hydraulic gradient ($m\ m^{-1}$)

Virus inactivation rates were determined experimentally. Techniques used to estimate setback distances utilizes geostatistical analysis. Specifically, disjunctive kriging, which is a non-linear statistical technique. Calculated setback distances ranged from 15m to 75m with the higher setback distances corresponding to an area of high transmissivity where the wells were adjacent to an intermittent stream.

Yates, P. and J.M. Sheridan. 1983. Estimating The Effectiveness of Vegetated Floodplains/Wetlands as Nitrate-nitrite and Orthophosphate Filters. Chemistry, Agriculture, Ecosystems and Environment, pp. 303-314.

The objective was to estimate the effectiveness of vegetated wetlands/floodplains in reducing losses of nitrate plus nitrite and orthophosphate phosphorus moving in runoff from cultivated areas in the coastal floodplain of southeastern United States. Water-borne nitrate plus nitrite nitrogen budgets and orthophosphate phosphorus budgets from a cropped agricultural area were compared to those of a watershed with alluvial forest below the cropped areas. Analyses were made to determine if observed differences in nutrient concentrations and loads were the result of dilution of cropped area runoff by flows from non-cropped areas. Reductions in the observed levels of nitrate plus nitrite and orthophosphate phosphorus between upland cropped areas and watershed outlets exceed reductions that would be caused by dilution effects. Significant portions of the observed nutrients leaving cropped areas were retained, utilized and/or transformed in the vegetated floodplains/wetlands characteristic of these coastal plain watersheds.

Procedure entailed 2 sampling stations in which rainfall and runoff samples were collected and analyzed for nitrate plus nitrite and orthophosphate phosphorus over a 2 year period. Concentrations were integrated with rainfall and flow volumes to determine rainfall input and runoff output loads. Computations of nutrient mass discharge were made by linear interpolation of concentration values between samplings and then summing the product of interpolated daily concentration and mean daily discharge.

Young, R.A., T. Huntrods, and W. Anderson. 1980. Effectiveness of Vegetated Buffer Strips In Controlling Pollution from Feedlot Runoff. J. Environ. Quality, 9: 483-487.

Evaluates the ability of land and cropping practices to absorb and retain pollutants in runoff from livestock feedlots. Rainfall simulator tests were conducted for 2 consecutive years on six plots. Located at the lower edge of an active feedlot. Cropped buffer strips below the feedlot, on a 4 percent slope, reduced runoff and total solids transported from a feedlot by 67 and 79 percent, respectively. Total nitrogen and phosphorus were reduced, by an average of 84 and 83 percent, respectively. Ammonia-nitrogen and PO_4^--phosphorus were similarly reduced, but average nitrate-nitrogen in the runoff increased because nitrate-nitrogen was gained from sorghum, sudan grass, and the oat buffer strips. During both years, the number of coliform organisms in the runoff water was reduced after runoff passed through the vegetated buffer strips. The results of the study indicate that non-structural feedlot discharge control practices are a promising alternative method for controlling pollution from feedlot runoff.

Zirschky, J., D. Crawford, L. Norton, and D. Deemer. 1989. Metals Removal in Overland Flow. Journal Water Pollution Control Federation. pp. 470-475.

Describes a pilot study on the effectiveness of overland flow to remove primarily ammonia-nitrogen and secondly heavy metals from advanced secondary quality wastewater over a period of 1 year. Five overland flow terraces were constructed with dimensions of 140m x 91m and 70m x 10m with a 2 percent slope grade. The terraces were seeded with equal percentages of Bermuda grass, Dallis Grass, Reed Canary Grass, and with annual Rye Grass. Three different methods of wastewater distribution were tested including; high pressure sprinklers, Fan Nozzles, and Gated pipe. Monitoring of terraces were conducted with samoles collected at beginning, middle, and end of each terrace. Parameters measured include Ca, Cu, K, N, Zn, B, Cd, Cr, Fe, Pb, Mn, Na, S, N, and reactive P. Soil samples were collected and tested prior to pilot for background levels. Results concluded that overland flow did not appear to effect metals removal. Only Cu and Zn were consistently removed. An exchange of wastewater K and soil Ca occurred resulting in higher calcium concentrations in effluent. Recommends a conservative approach is either to assume that no metals removal will occur in overland flow and design for metals removal in pre-application treatment; or to conduct further pilot testing.

APPENDIX C

Example Applications

Scenario 1: <u>Residential Development Adjacent to a Water Supply Reservoir</u>

A moderate density residential development is proposed on a 37 acre parcel adjacent to Clean Water Reservoir, a drinking water supply. Approximately 9.25 acres of the site will be occupied by impervious surfaces (rooftop, roads, driveway). The site is also located in the documented habitat of a threatened species of salamander. A visual inspection of the site indicates that the potential shrub/grassed buffer area appears to be in good condition, with about 85% vegetative cover. Documentation provided with the site plan indicates that the soils fall into Hydrologic Class B, with a 0-3 percent slope.

The Natural Heritage Program recommends a 300 foot buffer zone in critical habitat areas for the protection of the salamander.

BUFFER ASSIGNMENT WORKSHEET

Date: 2/6/89 Investigator(s): G. Smith
Site Location: Newtown Road
USGS Topographic Sheet: Compton, RI
Soil Survey (county): Rhode Island
Drainage basin: Still River

PART A - SITE INVENTORY

Project Description:

1) Is Proposed Land Use a Commerical/Industrial Facility with Hazardous Materials On-site *(yes/no)? No ◆
2) Impervious Area (acres): 9.25 (IA)
3) Site Boundary Length (feet): 950' (SBL)
4) Is this an In-fill Development (yes/no)? No ◆

*Includes any facility engaged in the generation, manufacture, refining, transportation, treatment, storage, handling or disposal of hazardous materials

Potential Buffer Strip Characterization:

5) Soil type: RhB
6) Hydrologic Class: B
7) Infiltration Rate (in/hr): 0.3 (I)
8) Is Slope > 15% (yes/no): No ◆
9) Depth to Ground Water (feet): 3'

10) Vegetation Type (check one)
- ☒ Grassed
- ☐ Forested w/ground cover
- ☐ Forested w/o ground cover
- ☐ Other

11) Buffer Condition (check one)
- ☒ Good Condition
- ☐ Evidence of Human Disturbance
- ☐ Evidence of Channelization

12) Is Vegetation Cover <80% (yes/no): No ◆

Receiving Resource:

13) Documented Habitat of Threatened or Endangered Species (yes/no)? Yes ◆
14) Resource Area Documented as Non-Sensitive (yes/no)? No

PART B - SPECIAL CONDITIONS

Those items denoted with an diamond "◆", provide information necessary for the special conditions evaluation. If the answers to any of these items are "yes", special conditions below apply.

Commercial or Industrial Facility - Hazardous Materials (Item 1): Minimum 300-foot buffer.
Infill-Development (Item 4): Buffer consistent with surrounding buffer widths or 25-foot minimum which ever is greater
Slope/Vegetation Cover (Items 8 or 12): Site conditions are not suitable for buffer strips, and other mitigations measures should be considered.
→ **Threatened or Endangered Species (Item 14):** Contact RI Natural Heritage Program for guidance in buffer requirements for habitat protection, with buffer requirement not less than required for stormwater mitigation using 85% Removal Criteria.

PART C - BUFFER ASSIGNMENT

If response to Item 14 is "yes", use 70% removal criteria (Equation 2). In all other cases, use 85% removal criteria (Equation 1). Buffer sizing factor (k) based on Infiltration Rate (I) from Item 7 above.

Equation 1 (85% Removal Criteria)

BA85% = k(IA)

Where: BA85% = buffer area required for 85% TSS removal (acres)
IA = impervious area of project site (acres)
k = buffer sizing factor (See look-up table below)

BA = 1.57 acres

Equation 2 (70% Removal Criteria)

BA70% =k(IA)

Where: BA70% = buffer area required for 70% TSS removal (acres)
IA = impervious area of project site (acres)
k = buffer sizing factor (see look-up table below)

BA = ____________

LOOK-UP TABLE - BUFFER SIZING FACTOR (k)

	Infiltration Rate (I; in/hr)		
Treatment Level	I≤.25	I=.25-.5	I≥.5
High: 85% Removal Criteria	0.31	0.17	0.12
Moderate: 70% Removal Criteria	0.09	0.06	0.05

Equation 3

BW= (BA*43,560)/SBL

Where: BW = minimum buffer width
BA = buffer area (determined in equations 1 or 2)
SBL = site boundary length (feet)
43,560 = conversion factor for acre to square feet

BW = 72 feet

Notes: If BW <25 feet, the minimum buffer requirement of 25-feet is applied.

If Special Conditions apply, the buffer requirement is equal to the Special Conditions buffer requirement or BW, which ever is greater.

Required buffer = 300' per Natural Heritage recommendation

Scenario 2: <u>Commercial Development Adjacent to a Non-Sensitive Resource Area</u>

A commercial development is proposed on a 25 acre parcel adjacent to Noname Brook. A detailed wetland evaluation has been completed by the applicant and has demonstrated that the resource area is considered non-sensitive to water quality and wildlife impacts. The site boundary, as shown on the site plan is 1044 feet. The proposed development with a total impervious area (driveways, parking areas, rooftops, etc.) of 16.25 acres (or 65 percent). The resource area is not documented habitat for threatened or endangered species. A visual inspection of the site reveals that the potential buffer area is densely wooded, without significant evidence of human disturbance or channelization. The percent vegetation cover within the potential buffer is nearly 100 percent. The parcel is not located in a high density in-fill development area.

The soils on the parcel are as follows:

Bridgehampton-Charleton Complex (BnB) - 15 acres
Wapping Extremely Stony Silt Loam (WcB) - 10 acres

Both soil types fall into hydrologic class B, with slopes of 0-8 percent.

BUFFER ASSIGNMENT WORKSHEET

Date: 2/6/90 · Investigator(s): N. Palmstrom
Site Location: Bridge Road
USGS Topographic Sheet: Warwick, RI
Soil Survey (county): Rhode Island
Drainage basin: Hunt - Potowomut River

PART A - SITE INVENTORY

Project Description:

1) Is Proposed Land Use a Commerical/Industrial Facility with Hazardous Materials On-site *(yes/no)? No ◆
2) Impervious Area (acres): 16.25 (IA)
3) Site Boundary Length (feet): 1044´ (SBL)
4) Is this an In-fill Development (yes/no)? No ◆

*Includes any facility engaged in the generation, manufacture, refining, transportation, treatment, storage, handling or disposal of hazardous materials

Potential Buffer Strip Characterization:

5) Soil type: BnB (15 acres) WcB (10 acres)
6) Hydrologic Class: B
7) Infiltration Rate (in/hr): 0.15 (I)
8) Is Slope > 15% (yes/no): No ◆
9) Depth to Ground Water (feet): 2 feet

10) Vegetation Type (check one)
- ☐ Grassed
- ☒ Forested w/ground cover
- ☐ Forested w/o ground cover
- ☐ Other

11) Buffer Condition (check one)
- ☒ Good Condition
- ☐ Evidence of Human Disturbance
- ☐ Evidence of Channelization

12) Is Vegetation Cover <80% (yes/no): No ◆

Receiving Resource:

13) Documented Habitat of Threatened or Endangered Species (yes/no)? No ◆
14) Resource Area Documented as Non-Sensitive (yes/no)? Yes

PART B - SPECIAL CONDITIONS

Those items denoted with an diamond "◆", provide information necessary for the special conditions evaluation. If the answers to any of these items are "yes", special conditions below apply.

Commercial or Industrial Facility - Hazardous Materials (Item 1): Minimum 300-foot buffer.
Infill-Development (Item 4): Buffer consistent with surrounding buffer widths or 25-foot minimum which ever is greater
Slope/Vegetation Cover (Items 8 or 12): Site conditions are not suitable for buffer strips, and other mitigations measures should be considered.
Threatened or Endangered Species (Item 14): Contact RI Natural Heritage Program for guidance in buffer requirements for habitat protection, with buffer requirement not less than required for stormwater mitigation using 85% Removal Criteria.

PART C - BUFFER ASSIGNMENT

If response to Item 14 is "yes", use 70% removal criteria (Equation 2). In all other cases, use 85% removal criteria (Equation 1). Buffer sizing factor (k) based on Infiltration Rate (I) from Item 7 above.

Equation 1 (85% Removal Criteria)

BA85% = k(IA)

Where: BA85% = buffer area required for 85% TSS removal (acres)
IA = impervious area of project site (acres)
k = buffer sizing factor (See look-up table below)

BA= ____________

Equation 2 (70% Removal Criteria)

BA70% =k(IA)

Where: BA70% = buffer area required for 70% TSS removal (acres)
IA = impervious area of project site (acres)
k = buffer sizing factor (see look-up table below)

BA= 1.46 acres

LOOK-UP TABLE - BUFFER SIZING FACTOR (k)

	Infiltration Rate (I; in/hr)		
Treatment Level	**I<.25**	**I=.25-.5**	**I>.5**
High: 85% Removal Criteria	0.31	0.17	0.12
Moderate: 70% Removal Criteria	0.09	0.06	0.05

Equation 3

BW= (BA*43,560)/SBL

Where: BW = minimum buffer width
BA = buffer area (determined in equations 1 or 2)
SBL = site boundary length (feet)
43,560 = conversion factor for acre to square feet

BW= 61 feet

Notes: If BW <25 feet, the minimum buffer requirement of 25-feet is applied.

If Special Conditions apply, the buffer requirement is equal to the Special Conditions buffer requirement or BW, which ever is greater.

Required buffer = 61 feet

Scenario 3: **Residential Development In an In-Fill Development Area**

A low density residential development is proposed on a 10 acre parcel adjacent to Clearwater Brook. The site is located within a in-fill development area. The average width of buffer zones on the adjacent properties is 15 feet. No detailed wetland assessment has been completed by the project proponent. Therefore, it is assumed that the wetland area is sensitive. The site boundary length (SBL) measured on the site plan is 660 feet. The proposed development includes 4 single family homes, with a total impervious area of 1.4 acres. The resource areas is not documented habitat for threatened or endangered species. A visual inspection of the site reveals that the buffer areas is densely wooded, without significant evidence of human disturbance or channelization. The percent vegetative cover is nearly 100%. The soil types on the site fall into hydrologic class A, with slopes of 0 - 8 percent.

BUFFER ASSIGNMENT WORKSHEET

Date: 7/3/90 Investigator(s): N. Palmstrom
Site Location: Frenchtown Road
USGS Topographic Sheet: E. Greenwich
Soil Survey (county): Rhode Island
Drainage basin: Frenchtown Brook

PART A - SITE INVENTORY

Project Description:

1) Is Proposed Land Use a Commerical/Industrial Facility with Hazardous Materials On-site *(yes/no)? No ◆
2) Impervious Area (acres): 1.4 (IA)
3) Site Boundary Length (feet): 660' (SBL)
4) Is this an In-fill Development (yes/no)? Yes ◆ (Adjacent buffer width = 15')

*Includes any facility engaged in the generation, manufacture, refining, transportation, treatment, storage, handling or disposal of hazardous materials

Potential Buffer Strip Characterization:

5) Soil type: MmB
6) Hydrologic Class: A
7) Infiltration Rate (in/hr): > 0.5 (I)
8) Is Slope > 15% (yes/no): No ◆
9) Depth to Ground Water (feet): 5'

10) Vegetation Type (check one)
- ☐ Grassed
- ☒ Forested w/ground cover
- ☐ Forested w/o ground cover
- ☐ Other

11) Buffer Condition (check one)
- ☒ Good Condition
- ☐ Evidence of Human Disturbance
- ☐ Evidence of Channelization

12) Is Vegetation Cover <80% (yes/no): No ◆

Receiving Resource:

13) Documented Habitat of Threatened or Endangered Species (yes/no)? No ◆
14) Resource Area Documented as Non-Sensitive (yes/no)? No

PART B - SPECIAL CONDITIONS

Those items denoted with an diamond "◆", provide information necessary for the special conditions evaluation. If the answers to any of these items are "yes", special conditions below apply.

Commercial or Industrial Facility - Hazardous Materials (Item 1): Minimum 300-foot buffer.
→ **Infill-Development (Item 4):** Buffer consistent with surrounding buffer widths or 25-foot minimum which ever is greater
Slope/Vegetation Cover (Items 8 or 12): Site conditions are not suitable for buffer strips, and other mitigations measures should be considered.
Threatened or Endangered Species (Item 14): Contact RI Natural Heritage Program for guidance in buffer requirements for habitat protection, with buffer requirement not less than required for stormwater mitigation using 85% Removal Criteria.