THE SCIENTIFIC BASIS
FOR WETLAND & WATERCOURSE BUFFER ZONES

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1.0 INTRODUCTION

Buffer zones are natural or enhanced vegetated areas located upslope of a wetland (i.e., tidal or inland) or surface water (i.e., ponds, lakes, streams, rivers). They function as a ***land-use management tool*** that can effectively protect regulated resources from multiple "indirect" *physical* impacts associated with development proposals, including hydrologic alterations; sedimentation; degradation from excess nutrients, such as those originating from septic systems and maintained lawns; toxins; and increases in light, temperature, and/or ambient sound levels.

Numerous scientific studies have examined vegetated buffer performance, although many focus primarily on a single, narrowly defined function, such as nitrate attenuation, sediment retention, or the removal of specific pesticides. While such studies are informative, this report also considers the broader ecological and hydrologic functions performed by buffer systems at the landscape scale.

Buffer areas contribute directly to the hydrologic integrity of adjacent wetlands and watercourses. They help maintain infiltration, shallow groundwater recharge, hydroperiod (duration/depth of inundation), and the moderation of runoff entering these systems. These functions are particularly important in semi-permanently saturated seepage wetlands, and in seasonally saturated and seasonally flooded wetlands, including vernal pool habitats, where relatively small alterations in groundwater inputs, runoff timing, or local water storage may affect inundation patterns, soil saturation, vegetation communities, and use by associated wildlife.

Buffers also help preserve water quality, wetland vegetation structure, soil development processes, and other physical and biological characteristics recognized as integral wetland functions. Forested buffers, in particular, provide important ecosystem inputs including leaf litter, woody debris, shallow groundwater enriched with dissolved minerals (e.g., calcium and magnesium), and dissolved organic matter (DOM). These are allochthonous inputs[1] and support nutrient cycling, microbial processes, aquatic food webs, and the long-term ecological function of wetland and stream systems.

Wetland and watercourse buffers also provide essential, complementary terrestrial habitat for many wildlife species that forage and/or breed in wetlands and watercourses—that is, wetland-dependent and wetland-associated species. Among the most widely recognized are

[1] They originate at another locatin, e.g. further up the hillside, within the buffer zone.

vernal pool obligate amphibians. Wood frogs (*Lithobates sylvaticus*) and spotted salamanders (*Ambystoma maculatum*), two keystone species, play critical roles in the vernal pool and forest food web, which is based on leaf litter, algae, and the diverse invertebrate communities inhabiting forest soils and vernal pools. Through trophic interactions and the "production export" wetland function, wildlife contributes to the physical cycling of carbon, nitrogen, phosphorus, and other elements within wetlands. However, where a buffer is severely degraded by invasive species and/or other disturbances, certain buffer functions and/or values—such as wildlife support, suitability for rare and uncommon plant species, and aesthetics—may be substantially diminished, while others may remain largely intact (e.g., hydrologic and filtration functions). In such cases, less-than-optimal buffer widths can be mitigated through buffer restoration and/or enhancement, with the goal of achieving a net gain in wetland functions and values.

2.0 BUFFER FUNCTIONS

The functions of riparian and wetland buffer zones are succinctly described in the 1991 *Policy Statement: Riparian Corridor Protection,* issued by the Inland Fisheries Division of the Connecticut Department of Environmental Protection (CT DEP 1991). This document recommends a 100-foot buffer to perennial streams, and a 50-foot buffer to intermittent watercourses. These functions are also elucidated in the *Guidelines: Upland Review Area Regulations; Connecticut's Inland Wetlands & Watercourses Act*, by the CT DEP's Wetlands Management Section (CT DEP 1997). A 100-foot upland review area (URA) is recommended in this document and has been implemented in the wetland & watercourse regulations in most Connecticut municipalities. Avoiding degradation of water resources is also spelled out as a guiding *principle* for environmental planning in Connecticut's official Water Resources Policy in Section 22a-380 of the Connecticut General Statutes.[2] The CT DEEP OLISP (Office of Long Island Sound Programs) Tidal Wetlands Buffer Guidance document (2003) also describes buffer functions and calls for a 100-foot setback. It references the first version of this present REMA document (i.e., 2003).

Buffer zones offer a variety of ecological and social functions.[3] Widely recognized functions include:

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[2] Sec. 22a-380. Water resources policy: The following are declared to be the goals and policies of the state: (1) To preserve and protect water supply watershed lands and prevent degradation of surface water and groundwaters;…

[3] The following section, and portions of other sections draws heavily on prior riparian and wetland buffer zone publications and research by George Logan of *Rema Ecological Services, LLC*, Vernon, CT. Roy Schiff, working for the Quinnipiac River Watershed Partnership and Quinnipiac River Watershed Association also assembled many of the references.

2.1 Hydrologic Functions

Surface runoff, shallow subsurface flow, and groundwater discharge from buffer areas contribute water to adjacent wetlands, streams, ponds, and associated vegetation communities. Buffer zones help maintain infiltration, shallow groundwater recharge, hydroperiod, and sustained seepage to downgradient aquatic systems. These functions are particularly important in seasonally saturated and seasonally flooded habitats, including vernal pools and headwater wetlands, where relatively small changes in water storage, runoff timing, or groundwater elevation may alter inundation patterns, vegetation composition and structure, and wildlife habitat conditions.

In developed landscapes, buffer soils may infiltrate runoff originating from impervious surfaces, lawns, and other disturbed areas. Following significant precipitation events, shallow groundwater movement through buffer soils may continue discharging to streams, ponds, and wetlands for days or weeks, thereby moderating seasonal low-flow conditions and helping maintain more stable hydrologic regimes.

Hydrologic behavior within a buffer is strongly influenced by soil depth, permeability, topography, and the presence of confining layers such as shallow bedrock or dense subsoils. In shallow hillside soils overlying confining layers, a relatively large proportion of infiltrated precipitation will move laterally through the upper soil horizons toward riparian vegetation and downgradient watercourses. In deeper, more permeable soils, a greater proportion of water will percolate vertically to the groundwater table, while riparian vegetation continues to rely heavily on moisture retained within finer-textured upper soil horizons.

Buffer vegetation and soils also influence flood attenuation and soil moisture regulation. Forest canopy interception, evapotranspiration, litter accumulation, root uptake, and maintenance of soil structure collectively enhance infiltration and temporary water storage within upper soil horizons. These processes help maintain aerated surface soils and increase the capacity of riparian soils to absorb and store stormwater and overbank floodwaters, and then slowly release them. Although many riparian and wetland tree species tolerate periodic flooding or short-term soil saturation, prolonged waterlogging and reduced soil oxygen may impair root function, reduce seedling establishment, and contribute to tree stress or mortality.

Removal of riparian vegetation through clearing, disease, or other disturbance may substantially reduce transpiration and interception losses, resulting in localized water table rise and prolonged saturation of near-surface soils. This phenomenon, commonly referred to as “watering up,” has been documented in riparian and wetland systems and may inhibit regeneration of certain tree species while favoring more water-tolerant or invasive vegetation communities. Ridolfi et al. (2006) describe these vegetation–groundwater feedback mechanisms and their influence on ecosystem stability and resilience.

2.2 Support for the Wetland Ecological Community

Buffer zones provide important complementary habitat for a variety of upland, aquatic, and wetland species, including vernal pool amphibians, reptiles, mammals, migratory songbirds, and larger predators such as barred owls and red-shouldered hawks. They provide foraging habitat, nesting areas, cover, dispersal corridors, and seasonal refuge for wildlife species associated with wetlands and watercourses. In many cases, the ecological integrity of a wetland system depends not only on the wetland itself, but also on the quality and continuity of adjacent upland buffer habitat.

Well-vegetated buffer zones also help maintain wetland plant diversity and ecological structure. Inundation regimes continue to support submerged, rooted aquatic plants sometimes including uncommon species of bladderwort (*Utricularia*) and *Potamogeton* or state-listed rare plants like featherfoil (*Hottonia inflata*) and lizard's-tail (*Saururus cernuus*). Minerotrophic plant species[4] are supported by shallow groundwater enriched with dissolved minerals (e.g., calcium and magnesium) as it flows through upland soils toward a wetland[5]. Buffer vegetation moderates light levels, wind exposure, humidity, soil moisture, and temperature within wetlands and adjacent riparian areas. Forested buffers help maintain cool stream temperatures and the moist microclimatic conditions needed by mosses, liverworts, amphibians, and other hydrophytic organisms sensitive to desiccation and thermal stress. These buffers moderate the ground-layer microclimate through canopy shading and evapotranspiration by foliage[6].

Leaf litter and woody debris derived from nearby forests are also important ecological inputs to wetland and stream ecosystems. These materials contribute to organic soil development, nutrient cycling, microbial activity, and detrital food webs. Leaf litter protects soils from

[4] Herbaceous species of the mineral-rich, slope-base landscape position include many of the spring ephemeral wildflowers, such as red trillium, blue cohosh, dolls' eyes (*Actaea* spp.) and the laxiflorae sedges. They are especially prevalent in traprock and shale areas and include uncommon species such as leatherwood (*Dirca palustris*). Distributions of this group of species typically include the outer portion of the wetland and the lower portion of the adjacent upland buffer. As a group, minerotrophic herbaceous plant species are important to wetland vegetation structure and nutrient cycling because of their their phenology (active growth in spring) and the fact that most are perennials with underground storage organs, a winter food source for herbivores. They also have high aesthetic value.

[5] The extent to which soil minerals are released into groundwater and infiltrating precipitation depends on the type of parent soil material (Gradey and Mullaney, USGS,1998) and the duration of contact time. Higher mineral content (reflected in specific conductivity) was found to be associated with higher plant diversity in a study of wetlands in St. Lawrence County, New York (1994). This is consistent with the widely accepted pattern of diverse, slope-base plant communities in mineral-rich soils on wetland margins. A substantial buffer with intact soils is needed to enrich seepage groundwater.

[6] Tree transpiration acts like a natural air conditioner by releasing water vapor through leaf pores (stomata), a process that absorbs heat from the surrounding air to convert water from liquid to gas. A large tree can transpire 100 gallons (378.5 L) of water every day, EPA. Climate Change Division. 1992.

erosion, helps retain moisture, and provides habitat and food resources for invertebrates and amphibians. In forested wetlands and headwater streams, these allochthonous organic inputs are often major drivers of ecosystem productivity and biological function. Forest canopy cover and shade also help limit colonization by certain shade-intolerant invasive plant species by maintaining lower light levels and more stable microclimatic and hydrologic conditions.

Buffers can also serve as travel corridors for migratory, nomadic, and resident wildlife species, particularly in fragmented landscapes. In Connecticut and throughout the Northeast, river and stream corridors are important pathways for migratory birds during spring and fall migration. Large-diameter trees, cavity trees, snags, and mature canopy structure within riparian buffers provide important habitat features for raptors, bats, and other wildlife species associated with older forest conditions.

2.3 Protection from harmful runoff and leachate constituents

Naturally vegetated buffer zones help reduce the movement of sediment, phosphorus, nitrogen, herbicides, insecticides, hydrocarbons, and other contaminants into adjacent wetlands and watercourses. Through a combination of biological, chemical, and physical processes, riparian and wetland buffers can filter, transform, adsorb, store, and biologically assimilate significant quantities of pollutants transported by surface runoff and shallow subsurface flow.

These treatment processes function most effectively when runoff enters the buffer as dispersed sheet flow rather than concentrated or channelized flow. As runoff infiltrates through organically enriched topsoil and vegetative root zones, sediment is filtered, nutrients are taken up by vegetation and microorganisms, and certain pollutants undergo biodegradation, adsorption, volatilization, denitrification, or other chemical transformations. Naturally vegetated and biologically active topsoil with relatively high organic matter content, generally maintains a porous structure, even where soils contain substantial silt or clay fractions, thereby enhancing infiltration and pollutant attenuation capacity.

Pollutant removal efficiency is influenced by numerous site-specific factors, including pollutant type and loading rate, runoff volume and velocity, slope, vegetation density, soil permeability, travel time, and the extent of groundwater dilution. Pollutant attenuation may be especially effective where shallow lateral groundwater flow is directed through the biologically active upper soil horizons due to the presence of a confining layer such as shallow bedrock or hardpan within the subsoil. Under such conditions, runoff and shallow groundwater remain in prolonged contact with organic-rich and oxygenated soil layers, increasing opportunities for filtration, adsorption, nutrient uptake, and microbial transformation processes. Hill et al. (1996) and other investigators have emphasized the importance of shallow lateral flow paths in nutrient attenuation within riparian buffer systems.

Forested buffers may also contribute to partial neutralization of acid precipitation through ion exchange and interception processes occurring within the forest canopy and upper soil horizons. Klapproth and Johnson (2000) provide a comprehensive review of the scientific literature addressing the water quality renovation functions of vegetated buffers.

2.4 Ecological Integrity

A well-buffered wetland with a range of different predators (e.g. insectivorous songbirds, amphibians, bats, hawks, owls, otters, mink) has a more complex and stable food web, and a more complex nitrogen and carbon cycle than a wetland with minimal adjacent upland habitat[7, 8]. Predators control population levels of mosquitoes and also control herbivores such as voles, rabbits, and foliage insects.[9] Buffers protect wildlife and aquatic organisms from adverse physical changes to their environment (altered noise and light levels) by screening excess illumination and noise. Dense plantings can enhance the screening function of buffers, a form of mitigation, compensating for sub-optimal buffer width.

The resilience and genetic health of plant populations are enhanced by generous wetland buffer zones. When some species decline or disappear due to disease or intolerance of climate changes, other plants can be used as food sources. The presence of wetland buffers results in larger population sizes of facultative wetland plant species and associated fauna. Larger gene pools are less vulnerable to inbreeding and better able to adapt to ecological changes. (Frankham, Ballou, and Briscoe 2004.)

Scientific research has shown that buffer zones are an *integral component of the landscape* and can protect significant wetland and watercourse functions (Chase et al. 1995, Castelle et al. 1992, Welch 1991, Brown et al. 1987).

3.0 DETERMINATION OF BUFFER WIDTH:

POLLUTANT REMOVAL MECHANISMS AND STUDY RESULTS

The width of wetland/watercourse buffer zone needed to prevent significant adverse impacts to the wetland and/or watercourse is generally related to three factors: (1) the intrinsic ***properties*** of the buffer zone and setbacks (e.g. habitat quality, steepness, soil permeability, depth to water table, and vegetation density (Brinson 1993); (2) the ***intensity***

[7] It is a widely accepted ecological principal that with more and different predators, more prey species can coexist, applicable in ecosystems as different as coral reefs and vernal pools.

[8] A shortage of predators may have undesirable public health ramifications, e.g., excessive densities of mosquitoes, tick-carrying white-footed mice, or an outbreak of a foliage insect.

[9] Because herbivory significantly impacts vegetation structure and composition (Howe and Lane 2004), wetland function improves, if the wetland supports predator populations.

of the proposed development, which often relates to the type of development (e.g., commercial, residential), and (3) the ***sensitivity*** of the receiving wetland or watercourses.

As runoff moves across a naturally vegetated buffer as sheet flow or as shallow groundwater, it gradually infiltrates into the soil, ***sediment is filtered***[10], and ***nutrients are utilized by vegetation*** or converted into nitrogen gas through ***denitrification***. Processes such as ***volatilization, photodegradation, biodegradation, bio-uptake, and adsorption*** act to reduce pollutant concentrations and toxicity in runoff and shallow groundwater (Hemmond and Fechner, 1994; Klapproth et al., 2000). These processes generally function more effectively in undisturbed soils with relatively high organic matter content, intact soil structure, and active microbial communities.

Several meta-analyses have evaluated pollutant removal efficiencies across multiple buffer studies conducted under varying climatic conditions, buffer widths, vegetation cover types, and hydrologic flow regimes. These studies consistently demonstrate that wider, well-vegetated buffers generally provide greater pollutant attenuation, particularly where runoff remains diffuse and infiltration opportunities are maintained. In a widely cited synthesis, Mayer et al. (2007) reported average nitrate removal efficiencies of approximately 79.5% for forested buffers and 54% for herbaceous buffers, with buffers wider than 150 feet exhibiting average removal rates exceeding 85%.

Dilution by groundwater is also an important component of buffer function. Hemmond and Fechner (1994) emphasize the importance of ***travel time*** in determining the degree to which pollutants are attenuated before reaching a sensitive wetland or receiving water body. Longer residence times also increase opportunities for infiltration, adsorption, microbial transformation, plant uptake, and other pollutant reduction processes.

A review by Hill et al. (1996) concluded that nitrate removal within riparian zones occurs most effectively where shallow groundwater is forced into lateral flow paths by relatively impermeable subsurface layers near the ground surface. Under these conditions, ***groundwater remains in prolonged contact with organic-rich and biologically active riparian soils***, thereby increasing opportunities for denitrification and nutrient uptake. Research has also demonstrated the ***importance of deep-rooted woody vegetation*** in extracting nitrate and other dissolved constituents from shallow groundwater within subsoil horizons (Hefting and Klein, 1998; Correll, 1997). These nutrients are subsequently incorporated into woody biomass and

[10] Stormwater runoff that has passed through and treated by a treatment train of a stormwater management system still contains suspended fine sediment that is effectively polished by sheet flow over permeable buffer soils.

leaf litter and eventually cycled into upper soil horizons, where microbial activity, de-nitrification, and other decomposition processes are generally far more active than in deeper mineral subsoils.

Travel time is a function of ***setback distance*** moderated by factors such as ***slope, soil infiltration capability andstorage capacity*** and ***vegetative cover.*** A number of independent investigators have reviewed the technical literature [e.g., Diamond & Nilson (RGH, Inc), 1988; Schueler, 1995, Welch, 1991] and have concluded that a ***minimum*** **of 75 feet to 100 feet** to the sensitive receiving wetland and/or watercourse is needed for water quality renovation; ***larger distances are needed if soils are very pervious (sandy) or shallow, or if slopes are steep.*** A guidance document produced by the NRCS-USDA (March 2000) also recommends buffer widths of at least **100 feet** for removal of soluble pollutants such as soluble triazine herbicides. This document points out that:

> *"It takes more surface area and longer flow paths to adsorb and infiltrate soluble material than to entrap solid material. Climate conditions and storm events… influence the effectiveness of the buffer to retard flow and remove pollutants."*

A guidance document produced by the USDA Forest Service, *Riparian Forest Buffers, Function and Design for Protection and Enhancement of Water Resources (NA PR 0791)* recommends streamside buffers ranging from **75 feet to 150 feet** in width depending on ***soil capability classes.*** This document emphasizes that certain uses such as trails and selective logging may be compatible with buffer effectiveness, with stricter restriction needed in the zone closest to a stream.

Diamond (1988) and Tom Schueler (1995) (among others) recommend adjusting wetland buffer width based on ***slope steepness***. Various formulas have been devised. One frequent element is to subtract the sections with slopes steeper than a certain threshold (e.g. 15%), when calculating buffer widths for regulatory purposes. Steep slopes exacerbate the natural tendency of flows to concentrate, converging into larger and larger channels, which erode rills and gullies, becoming a sediment source rather than a sediment filter.

A buffer review paper by Barling and Moore (1994) also emphasizes that the pollutant removal capacity of a given buffer width varies with site conditions. Barling and Moore cite a study by Philips (1989) of the distances needed to remove nitrate in agricultural runoff, finding that fifty meters (150 feet) was not wide enough in some cases, but 15 meters (45 feet) was sufficient under other site conditions. Hefting and Klein (1998) found greater nitrate removal by forested than non-forested buffer zones. In the absence of detailed investigations of buffer characteristics, a conservative buffer width – at least 100 feet - is desirable. Of course, the types and concentrations of nutrients and toxicants to be treated or diluted also influence the setback width needed.

Note that nitrogen and phosphorus concentrations in groundwater discharging from forested buffers — and in streams and wetlands draining largely undeveloped watersheds — are typically very low. USEPA data sets used in development of the Agency's nutrient ecoregion criteria[11] generally reported concentrations below approximately 0.2 mg/L for total phosphorus and below 1.0 mg/L for nitrate-nitrogen and total nitrogen in relatively unimpaired systems. These data formed part of the scientific basis for USEPA's 2000 recommended nutrient criteria framework for streams, rivers, lakes, and reservoirs within individual ecoregions of the United States.

Subsequent research has provided additional support for the ecological significance of these low nutrient thresholds. A large-scale 2012 study by Chambers et al. found that degradation of stream-bottom macroinvertebrate communities was associated with nutrient concentrations exceeding USEPA-recommended thresholds. Sensitive aquatic invertebrate taxa — including mayflies, stoneflies, and certain caddisflies — showed measurable declines as nutrient enrichment increased. Although USEPA nutrient criteria remain "draft" recommendations unless formally adopted by an individual state, they continue to serve as an important scientific benchmark for evaluating nutrient enrichment and potential biological impairment in aquatic systems.

4.0 RESOURCE SENSITIVITY AND BUFFER NEEDS

Several characteristics of waterbodies and wetlands make them more sensitive to human disturbance and increase the need for generous setbacks. This is especially so, if these are high-functioning wetlands or support valuable and/or unique ecological communities.

4.1 Sensitivity of Aquatic Fauna and Flora to Toxins

Numerous studies have shown close correlation between stream health as measured by biotic indices (measuring the diversity and composition of aquatic invertebrate communities) and the percent of developed land in its watershed. A more recent major study by Morley et al (2002) is set in the Portland, Oregon area. Healthy, diverse, aquatic

[11] Nutrient Criteria Technical Guidance Manual: Rivers and Streams (pdf) (2.72 MB, July 2000, EPA 822-B-00-002)

communities with ***pollution-intolerant macroinvertebrate organisms*** such as stoneflies, mayflies, and case-bearing caddisflies are an important food source for trout and are very sensitive even to relatively low concentrations of stormwater pollutants, especially PAHs (Polyaromatic hydrocarbons), heavy metals, and soluble neonicotinoid insecticides. The classic study by Plafkin (1989) classified stream organisms based on sensitivity to stream pollution and is still the basis for the USEPA Stream Bioassessment methodology. The CT DEEP Pesticide Division has studied the effects of toxic organophosphate insecticides on stream insects. ***Vernal pool breeding amphibians***, such as the mole salamanders and wood frogs are also known to be intolerant of water pollution, more so than amphibians of permanent ponds, such as green frogs and bullfrogs.

Toxicity screening has shown that widely used landscaping and agricultural pesticides and partially degraded toxic compounds will adversely impact ***wetland plants[12], fungi, pollinators[13], soil invertebrates, and frogs[14],*** *both individually and via food web alterations.* One hundred (100) foot setbacks between wetlands and areas of pesticide application are recommended in several federal guidance documents, and on the labels of many individual pesticide products, used for landscaping as well as farming.[15] Note that pesticide labels calling for wide setbacks to wetlands and prohibiting use during rainy, wet conditions are often ignored, especially if thickets visually obscure the nearby wetland. This is less of a problem if an ecologically conservative Integrated Pest Management (IPM) program is in place. This can often be requested for residential communities to be managed under a Homeowners Association (HOA), or for commercial and industrial development.

Toxins may reach wetlands and streams via shallow groundwater flows, via drift, or via surface runoff. Indirect adverse impacts occur through consumption of contaminated worms and other soil invertebrates, or a diminished prey supply. *Headwaters streams and wetlands* with little throughflow are most vulnerable to toxins. Flushing and dilution of pollutants is minimal in still pools and slow-moving channels, and low water volumes. Roadway pollutants such as polycyclic aromatic hydrocarbons (PAHs) tend to build up in

[12] Seed germination and seedling development in many plant species is inhibited by hydrocarbon breakdown products. Runoff containing glyphosate, the widely used and highly souble herbicide in RoundUp, may cause marsh vegetation kills. The authors have observed this personally in a wetland downgradient of an Ellington utility corridor.
[13] Neonicotinoid insecticides (widespread lawn and farm pesticides) are neurotoxins that disorient honeybees and other insects, at low concentrations (less than 30 ppb) - sublethal adverse impacts.
[14] Atrazine, a widely used farm herbicide, is an endocrine disrupter of frogs, at very low concentrations (less than 20 ppb based on studies with leopard frog and other frog species.
[15] 100-foot buffers are recommended in Conservation Buffers to Reduce Pesticide Losses and the USDA March 2000 and the US District Court (Coughgenour) pesticide buffer ruling 1/27/2004.

these areas. Periods of low dissolved oxygen (DO) may heighten the biological impact of toxic pollutants such as heavy metals by bringing them into solution, thus increasing pollutant concentrations.

Generous setbacks between wetlands and stormwater outfalls, lawns or farm fields protect sensitive wetland organisms. They also prevent incidental harm because pollinators, birds, and other larger wetland creatures often wander into treated upland areas near wetlands. A wetland buffer of **at least 100 feet** is especially important where the resource has been designated a critical habitat or is known to have exceptional functional value.

4.2 Variable Vulnerability to Sediment &Nutrients, for Different Wetland Types

Wetland and stream sensitivities to sediment and nutrients vary widely. Nutrient and sediment sources include partly treated stormwater runoff, excess fertilizers from farm fields and lawns, and partially treated septic leachate[16] in shallow groundwater flow.

Less vulnerable wetland types include *emergent marshes* and *wet meadows*, and also *floodplains of larger streams and rivers*, which already have a relatively high nutrient status, and are subject to natural sediment deposition. However, the majority of wetland types are somewhat vulnerable to nutrient and sediment inputs.

Some types of wetlands are highly sensitive. The unusual plant communities and wetland soils in oligotrophic (low nutrient) wetlands such as *bogs, fens, and headwaters seeps*[17] will be irreversibly degraded by nutrients in sediment and in partially treated stormwater runoff, especially phosphorus. These wetland types are often ***valuable***, with high functions and/or values. Some headwaters ecological communities, like bogs, are uncommon in the Connecticut landscape.

In mesotrophic (moderate nutrient status) *ponds and lakes,* excessive nutrient inputs typically cause algal blooms and accelerated growth of aquatic vegetation, which may precipitate eutrophication, a wetland degradation process whereby microbial breakdown of excess dead biomass severely depletes the water of oxygen.) Competition with overly tall, dense stands of *Phragmites* (i.e. common reed) and purple loosestrife eliminate rare and uncommon species.

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[16] See further discussion in Sections 4.3 and 5.2 of this report, explaining how a fully compliant, per CT Heath Code, septic system can still pose a singificant threat to the water quality of certain streams and wetlands.

[17] Headwater seeps can be seasonal or semi-permanent. The latter are often inhabited by uncommon wildlife such dusky salamanders and invertebrates such as spring mayflies.

If buffers are inadequate, excessive nutrient loading also causes adverse changes to *mesotrophic wooded swamps*; the cinnamon fern - high bush blueberry- red maple community; organic and mossy substrates in wetlands; and populations of perennial wildflowers or ferns are all significantly altered by deposition of sediment, and by changing hydrology and nutrient status. Sediment deposits in wetlands form a seedbed for weedy, annual, nutrient-demanding colonizers like jewelweed. A wetland's *physical structure* is altered when non-persistent, nutrient-loving annuals like false nettle and jewelweed become dominant rather than ferns and sedge tussocks, which provide year-round cover.

Benthic (stream-bottom) macroinvertebrate communities are highly sensitive. Sediment deposits coat gravelly or cobbly substrate or woody debris. This smothers gravelly fish-spawning habitat and habitat used by stream-bottom invertebrates: crevices, stones, twigs, and leaf litter. It may degrade habitat needed by rare state-listed species such as wood turtles and certain freshwater mussels (e.g., eastern pearly shell). *Suspended* sediment abrades the gills of fish, being most harmful to juveniles, and clogs the gills of certain sensitive macroinvertebrates (e.g. case bearing caddisflies, stoneflies, and mayflies). Sediment and algal proliferation (triggered by excess nutrients) also smother key aquatic food sources: decomposing leaves and microscopic plants (diatoms). Nutrient-stimulated green algae proliferate at the expense of diatoms.[18] Large, slow-flowing streams or rivers with naturally sandy bottoms are less vulnerable than smaller, rocky streams. Larger watercourses are better able to dilute turbid water (or other pollutants) that may reach them.

4.3 Comparing Nutrient Removal Efficiencies

A supplemental buffer is usually needed to protect wetlands from nutrients and sediment because other best management practices BMP's) are not sufficient. This generalization applies to septic systems, stormwater basins/treatment trains, perimeter silt fence, and perimeter silt socks.

Properly functioning septic systems typically remove only 40-50% of the nitrogen[19] that enters the system, though they do filter most of the phosphorus. With a 100-foot buffer,

[18] The multiple adverse impacts of sediment on aquatic habitat are thoroughly covered in *Impacts of Suspended and Deposited Sediment* by Wood amd Armitage (1997) and Crowe (2004). Periphyton is the scientific term for the thin film of microscopic plants that coats the substrate of a healthy stream, and is a major food supply.

[19] Proprietary technologies, such as the Soil Air (Geomatrix) system can enhance nitrogen removal to 60%. Passive Nitrogen Reduction (PNR) systems are still in the testing phase, potentially pushing nitrogen removal efficiencies to 74% to 95% (pers. comm. Nathan L. Jacobson & Associates, Inc.).

the roots of trees and shrubs, and dilution by groundwater will substantially reduce nitrate concentrations reaching the wetland.[20] Similarly, a correctly designed stormwater management system will still discharge a substantial percentage of the nutrients that enter the system. Large data sets on performance of water quality basins (e.g. USEPA NURP data, UNH-SC 2010[21]) show that average phosphorus and nitrogen removal rates in excess of 80% are rare, and expensive to achieve, and 40-60% removal is common.

None of the alternative, sophisticated erosion and sediment or stormwater management control practices match natural wetland buffers as a sediment filtering tool. Tom Schueler, principal scientist at the Center for Watershed Protection (1995) focused on sediment removal, in formulating his recommendation of an ***80-foot minimum buffer*****.**

Regardless of how well sediment barriers are installed, fine sediment (very fine sand or finer) passes through the mesh of silt fence or between hay strands in hay bales; these perimeter controls are *not complete sediment barriers*. In fact, they depend on through-flow to function. Pressure from a stream of flowing runoff stretches the openings in silt fence mesh to maximum size.[22] The 2024 CT DEEP Erosion and Sedimentation Guidelines specify only 75% removal efficiency for geotextile silt fencing. This is less of an issue for a large construction site that depends primarily on earthen berms, rather than barrier fencing. Where berms prevent sediment-laden through-flow, runoff must be retained within sediment traps (correctly sized basins or trenches at low points on the site). They may overflow due to back-to-back rain events or during very large storms, especially if soil permeability is limited by freezing conditions or a high seasonal water table.

However, sheet flow through a forested wetland buffer, over forest leaf litter or through meadow vegetation, will achieve nearly complete filtration of the residual sediment in turbid overflow from sediment traps and in through-flow from perimeter barriers. It will also achieve *nearly complete nutrient uptake*, if the buffer is over 80 feet wide with a gentle to moderate slope, and flow volumes are low and dispersed. Groundwater discharge into the wetland will contain minerals and dissolved organic matter. Especially where proposed grading is extensive, with steep cut slopes, buffers are an important supplementary best management practice (BMP). If the project includes on-site sewage disposal, excess nitrogen in septic effluent will also be removed. Dissolved phosphorus in

[20] To accurately model the setback needed from the septic leachfield to the wetland, use the latest CTDEP Dilution model (2003), which takes soil type and watershed area into consideration. It is usually used for community septic systems but is applicable to any setting, per CTDEP staff. Also consider resource senstivity.
[21] UNH-SC, 2010. University of New Hampshire Stormwater Center. 2009 Biannual Report.
[22] The mesh size in AMOCO silt fence (when stretched by water under pressure) according to specifications provided by the vendor is between 850 and 710 microns, the size of a medium to coarse sand grain particle.

lawn runoff will be removed by a buffer with a minimum width of roughly 50 feet[23] (Woodard and Rock, 1995[24]), provided the wetland or watercourse is not oligotrophic (i.e. low nutrient) and, therefore, more sensitive than most other resources.

Note that Compost berms (silt socks) can remove a higher percentage of sediment than silt fence mesh or haybales. However, they release dissolved phosphorus unless specialized additives are inserted into the medium, at additional cost (rarely done). Long-term, a narrow setback behind a compost tube will also be unable to perform multiple other buffer functions post-construction (see Section 3.0).

4.4 Ecological Integrity and Productivity

Leaving a naturally vegetated buffer increases the likelihood that disturbance-sensitive and area-sensitive wildlife species will continue to utilize a wetland or stream corridor as part of a functioning ecological community and food web. Many wildlife species associated with wetlands and riparian systems — including wood duck, green heron, barred owl, veery, certain amphibians, and numerous small mammals — are sensitive to human disturbance, habitat fragmentation, elevated noise levels, increased lighting, and reductions in effective habitat area.

Buffer vegetation also helps absorb and diffuse sound, thereby enhancing habitat quality for birds and other wildlife while improving the aesthetic and recreational value of wetlands for human users. Reijnen and Foppen (1997) documented substantially reduced bird density and diversity in areas exposed to major highway noise, with measurable ecological effects extending outward as far as approximately 300 feet from the roadway.

Artificial lighting may similarly alter ecological function within wetlands and riparian habitats. Longcore and Rich (2004), in a review of available literature regarding ecological light pollution, identified numerous studies demonstrating disruption of predator-prey relationships, altered foraging behavior, and depletion of nocturnal insect prey populations associated with elevated nighttime light levels. These effects may be particularly important in wetlands and riparian corridors that support amphibians, bats, nocturnal birds, and invertebrate-dependent food webs[25].

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[23] In this study a 15 meter buffer strip was adequate to return total phosphorus levels to background levels (i.e., <1.5 mg/l).

[24] Woodward, S.E., and C.A. Rock. 1995. Control of Residential Stormwater by Natural Buffer Strips. Lake and Reservoir Management. 11(1):37-35.

[25] Light inhibited foraging by smaller nocturnal wildlife species (e.g. small mammals, amphibians, and slow-flying bats). Similarly, one study showed that fewer zooplankton migrated to the water surface at night to feed on algae

Studies evaluating wildlife habitat use have also demonstrated that required buffer widths vary considerably depending on species ecology and habitat sensitivity. Buffers approximately 100 feet in width have been found sufficient for general avian use in some settings, whereas substantially wider setbacks — at least 300 feet — may be required to maintain suitable habitat conditions for forest interior bird species (Milligan, 1985), including wetland-associated species such as veery. The Conservation Plan for the Wood Turtle in the NE US calls for a 90 meter (295-foot) unfragmented buffer for watercourse segments still supporting this species of high conservation need.(Jones et al 2018).

DeGraaf et al. (1987) reported that wetland and watercourse buffers approximately 96 to 117 feet wide encompassed the home ranges of numerous New England mammal species. These findings illustrate that wildlife habitat functions of buffers extend well beyond simple pollutant filtration and frequently require maintenance of relatively large, contiguous, and undisturbed vegetated areas.

The wildlife habitat value of a buffer, in terms of ecosystem productivity[26], is affected by the width of the zone adjacent to the wetland with high humidy and dense vegetation. The high insect densities and thick vegetation in wetlands and in moist upland buffers make them less desirable for human residential use, but very valuable for wildife, more so than typical well-drained upland oak forest. A large scale study in Massachusetts of bird distribution in relation to habitat components (Swift et al. 1983) demonstrated signficantly higher bird densities within and adjacent to forested wetlands, than in well-drained upland forest, even for faculative birds that use both uplands and wetlands. Densities of treefrog, woodfrog, bats, shrews, and predaceous invertebrates are also assumed to be higher, than in well-drained upland habitat. The larger combined area of a wetland and its adjacent moist upland buffer can support more wetland-associated wildlife, than a wetland closely flanked by development.

Because mosquitoes are intolerant of dry air, they are active in humid, low-lying upland buffer habitat, in the vicinity of wetlands with standing water, but *not* in drier upland buffer areas. Because high mosquito densities may be associated with health concerns, pesticide application is more likely, with potential adverse impacts on aquatic habitat,

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under well-lit conditions, a behavior presumably related to avoidance of fish predation. Night lighting inhibited reproductive behavior in frogs.

[26] The carrying capacity of the habitat unit (wetland and adjacent moist buffer) is the total number of songbirds, insectivorous amphibians and bats and other small mammals that it supports. A wide body of research has shown that larger populations of plants and animals are genetically healthier (more genetic diversity and less prone to inbreeding depression, infertility, and loss of alleles from genetic drift). If buffer habitat is moist enough to support wetland-associated species, the wetland ecosystem benefits from the larger population sizes, and greater production export.

when homes are built in moist, low-elevation, upland areas, near wetlands. In a nutshell, generous wetland and watercourse buffers also provide a margin of safety for public health – and protect the wetlands from pesticides. Note that if the wetland or stream is bordered by well-drained uplands, these particular concerns regarding health and quality-of-life are reduced, for a setback less than 100 feet wide.

4.5 Headwaters Wetlands

Generous protective buffers are especially important for *low order streams and headwater wetlands*. Mark Brinson emphasized the vulnerability of headwater wetlands in his 1993 landmark paper. He pointed out that a given area of adjacent soil disturbance would affect lower order, headwaters streams *proportionately more* than large, higher order streams. Biodiversity, including rare species, is especially high in headwaters seeps and streams (Meyer et al 2003). Because significant *denitrification* takes place in the microbe-rich substrate of healthy streams and stream banks, maintaining the integrity of lower order streams has a significant role in protecting downgradient waterbodies, including Long Island Sound from excess nitrogen inputs (Meyer et al. 1997).

Buffer areas and level spreaders between stormwater outfalls and streams help reduce concentrations of roadway pollutants, but headwaters open space preserves and "soft" drainage systems (without catch basins and storm drains) provide the best protection for headwater streams. Note that headwaters streams in an urbanized watershed may already be so degraded that their value and functional level is low, reducing the impact of activities within buffers, although downstream impacts remain an issue.

5.0 POLLUTANT MOVEMENT AND DEGRADATION IN WETLAND BUFFERS

5.1 Pesticides

The NRCS-USDA document, *Conservation Buffers to Reduce Pesticide Losses* (March 2000), recommends a 100-foot setback from farm fields to streams, as noted in Section 3.1 (Footnote 15)[27]. The stated rationale is to allow sufficient dilution and degradation, on average, to protect aquatic resources. This paper also emphasizes the need to protect intermittent streams, pointing out that smaller streams combine to provide the water source for perennial streams with fish populations – the watershed perspective. The impacts to wetland biota of toxins such

[27] available on the internet from the USDA web site

as pesticides and PAHs have already been discussed in Section 4.1. This section provides more detail in support of the buffer needs to protect wetland resources.

Because ***soluble pollutants pass readily through saturated soil***, it is important that setback distances be measured from the wetland boundary, not the bank of the watercourse. In evaluating a proposed setback to regulated activities, the perennial question is as follows: Will fertilizers and pesticides from the lawn or farm field reach the downgradient aquatic resources in sufficient concentrations to harm aquatic organisms or plants? Will they harm plants and invertebrates in wetland soils? Certain plant taxa are sensitive to very low herbicide concentrations. Sub-lethal effects of neurotoxins should also be considered.

Although highly persistent organochlorine pesticides such as DDT are no longer registered for general use in the United States, numerous pesticides and herbicides currently in widespread use continue to exhibit characteristics associated with potential aquatic impacts, including high aquatic toxicity, substantial solubility in water, mobility in soil, and/or environmental persistence. These include, for example, certain **neonicotinoid** insecticides commonly used for lawn grub control, ornamental plantings, and seed treatments. The labels for two widely used, non-restricted herbicides, **Round-up and Brush-B-gone**[28] prohibit use in wet weather because they are water-soluble. In dry weather, infiltration and adsorption to soil particles prevent their migration in runoff. However, an unexpected downpour sometimes causes heavy mortality of non-target wetland vegetation.

Even pesticides classified as having relatively “rapid” environmental breakdown rates may persist in soils or shallow groundwater for days to weeks after application. Depending on chemical properties, site hydrology, soil permeability, travel time and runoff conditions, some compounds may move through narrow vegetated setbacks too rapidly for substantial degradation or adsorption before reaching downgradient wetlands or watercourses.

Dilution by shallow groundwater is very important for dilution of concentrations of herbicide concentrations that are still high enough to kill or injure adjacent non-target plants. For example, the herbicide **2,4-D** may require several weeks for substantial degradation under field conditions, while the widely used, soluble neonicotinoid insecticide **Imidacloprid** (Merit®) has reported environmental half-lives ranging from approximately 48 to 190 days, depending on soil and climatic conditions. Imidacloprid and

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[28] Glyphosate is the active ingreadient inr Round-up; and trichlopyr-amine is the active ingredient inr Brush-B-Gon, These herbicides are available over-the-counter to homeowners and land trust stewards, though their use, for pay, by unlicensed professionals is illegal.

related neonicotinoids have also been associated in the scientific literature with adverse effects on pollinators and +aquatic invertebrates at relatively low concentrations.

Research evaluating pesticide attenuation within vegetated buffers has demonstrated variable and sometimes limited removal efficiencies, particularly for soluble compounds transported during storm events. Arora et al. (1993), studying herbicide removal within a 20-meter (approximately 66-foot) grassed buffer under natural rainfall conditions, reported Atrazine reductions of only 9% to 12%, Metolachlor reductions of 15% to 27%, and Cyanazine reductions of 7% to 21%. These findings illustrate that relatively narrow buffers may provide only limited attenuation for certain highly mobile agricultural and turf chemicals, particularly where runoff becomes concentrated or infiltration opportunities are limited.

In addition, breakdown products of pesticides and herbicides may themselves remain biologically active or toxic if key functional chemical groups remain intact following partial degradation. As a result, reductions in parent compound concentrations do not necessarily eliminate ecological risk to sensitive wetland, stream, or aquatic communities.

In assessing the need for buffers to attenuate pesticides, consider the intensity of the threat: total upgradient areas of lawn, fairway, or farm field; anticipated rates of application; whether an Integrated Pest Management Plan will be in place; soil permeability, and the details of that plan. A highly conservative IPM plan might make substantial use of cultural practices and choose pest control products with minimal impacts to non-target organisms (Carlisle 2006).

With a small project, land use commissions simply ***cannot enforce permit stipulations that restrict fertilizer or pesticide use,*** for example, allowing only products with low aquatic toxicity or low mobility in soil. Product-based regulation is not practical, due to the number of available products. Pesticide monitoring (enforcement of IPM plans) by a golf course or a planned residential community is hampered by the large number of chemicals & breakdown products requiring different assay techniques. The solution, however, is fairly straight-forward: <u>the provision of generous buffer zones to wetlands and watercourses</u>, based on the scientific literature and the best site-specific information available.

5.2 Septic Effluent

As noted in ***Section 4.3***, properly functioning septic systems unavoidably discharge effluent containing elevated concentrations of soluble nitrate-nitrogen. When evaluating development proposals involving septic systems located upgradient of wetlands or watercourses, an important question is whether sufficient distance, travel time, and soil treatment capacity exist to adequately attenuate and dilute nutrients before they reach sensitive receiving waters.

Many local officials and applicants are unaware that the existing septic system placement standards — including the typical 50-foot setback to waterbodies and the 10 mg/L nitrate standard applied at the property boundary — were developed primarily to address ***human health concerns****,* particularly protection of drinking water supplies from methemo-globinemia ("blue baby syndrome"). These standards were not designed specifically to protect wetlands, headwater streams, vernal pools, ponds, or other aquatic ecosystems, many of which are substantially more sensitive to nutrient enrichment.

USEPA draft nutrient criteria[29] developed for streams within ***Ecoregion XIV***, which includes Connecticut, are far lower than human health-based groundwater standards, with recommended values of approximately 31.25 µg/L for total phosphorus and 0.71 mg/L for total nitrogen. Research has demonstrated that ecological impairment of aquatic communities may occur at nutrient concentrations only modestly above these thresholds, particularly within nutrient-sensitive headwater systems and low-nutrient wetlands.

Although nitrate-nitrogen is highly soluble and mobile in groundwater, attenuation mechanisms within naturally vegetated buffer zones may substantially reduce nutrient loading before groundwater discharges into a wetland or watercourse. These mechanisms include plant uptake, microbial assimilation, dilution, and particularly ***denitrification*** within shallow organic-rich and periodically saturated soils. As discussed previously, these processes tend to function most effectively where groundwater remains within biologically active upper soil horizons for extended periods of time, especially in buffers containing moderately well-drained soils, intact topsoil structure, and appreciable organic carbon content.

Phosphorus behaves differently from nitrate because it adsorbs relatively strongly to soil particles and mineral surfaces. However, phosphorus retention capacity within soils is finite. Over long time periods — particularly in older developed lakeside communities or densely developed watersheds — adsorption sites within soils may gradually become saturated, allowing dissolved phosphorus to migrate into adjacent wetlands, ponds, lakes, or streams where it may contribute to algal blooms, excessive aquatic vegetation growth, and eutrophication. Similar long-term reductions in pollutant retention capacity have been

[29] USEPA (2000).

documented for certain metals and other contaminants in heavily urbanized drainage systems.

By contrast, healthy buffer vegetation continues to assimilate dissolved nutrients over time, incorporating them into woody biomass, leaf litter, roots, soil organic matter, and associated microbial communities. In this manner, forested and well-vegetated buffers function not merely as passive filters, but as active and renewable biogeochemical processing systems.

As discussed previously in ***Section 4.2***, certain wetland and stream systems have naturally low nutrient conditions. — including ***bogs, fens, headwater seeps, low-order streams, and some vernal pool systems*** — and are especially vulnerable to ***nutrient enrichment***. These systems are often considerably more sensitive to nitrogen and phosphorus inputs than nutrient-tolerant wetlands such as cattail marshes or disturbed wet meadows. Although precise nutrient thresholds for ecological degradation remain incompletely defined for many wetland types, available research consistently demonstrates that nutrient enrichment may alter vegetation composition, dissolved oxygen dynamics, microbial processes, and aquatic biological communities.

In practice, dilution, diffusion, plant uptake, microbial transformation, and denitrification within vegetated setbacks are relied upon to reduce septic-derived nutrient concentrations before they reach wetlands and watercourses. Consequently, setbacks substantially wider than minimum public health code requirements are often necessary where protection of sensitive aquatic ecosystems is the management objective. Depending on soils, topography, groundwater flow paths, and receiving water sensitivity, septic setbacks of 100 feet or greater from wetlands and watercourses may be warranted to help maintain nutrient concentrations approaching USEPA-recommended ecological criteria.

Large cumulative nutrient inputs into ponds, lakes, estuaries, and embayments such as Long Island Sound are well documented to contribute to eutrophication, algal blooms, hypoxia, and associated degradation of aquatic ecosystem function.

5.3 Chlorine

If an above ground pool were emptied prematurely in the fall, would *chlorine* reach the resource? Chlorine is highly toxic to aquatic life at extremely low concentrations; the acute toxicity standard is 19 ppb (i.e., parts per billion) and the chronic toxicity standard is 11 ppb.

Generous buffers in residential areas prevent the accidental release from swimming pools into wetlands and watercourses.

5.4 Fertilizers

Severe eutrophication frequently occurs in ponds, lakes, and slower-moving watercourses receiving nutrient-enriched runoff from developed residential landscapes, particularly in areas with extensive lawn cover and intensive turf management practices. Excessive nutrient inputs may also substantially alter the composition and ecological function of natural wetland plant communities, particularly in wetlands adapted to naturally low nutrient conditions, as discussed previously.

Nutrient and chemical loading from residential landscapes varies considerably depending on homeowner practices, lawn care service recommendations, fertilizer formulations, irrigation practices, and site conditions. Although low-phosphorus and phosphorus-free fertilizers are available, they are not always widely used in residential settings. In some cases, fertilizers, herbicides, and pesticides may be applied more frequently or at higher rates than necessary to maintain turf health or appearance.

Naturally vegetated buffer areas can substantially reduce the transport of excess nutrients into downgradient wetlands and watercourses by promoting infiltration, filtration, plant uptake, microbial processing, and adsorption within biologically active soil horizons. As noted previously, Woodard and Rock (1995) demonstrated that a buffer approximately 50 feet in width was effective in substantially reducing dissolved phosphorus concentrations in lawn runoff under studied conditions.

Rates of nitrate attenuation from fertilizer runoff and septic leachate are among the primary considerations underlying the approximately 100-foot wetland and watercourse setback recommendations discussed previously from USDA and other scientific sources. Because nitrate-nitrogen is highly soluble and does not strongly adsorb to soil particles, relatively generous setbacks are often necessary — particularly in sandy or excessively drained outwash soils — to allow sufficient residence time for dilution, plant uptake, microbial assimilation, and **denitrification** before groundwater discharges into streams, ponds, or wetlands.

As discussed previously in **Section 3.0**, meta-analyses evaluating nitrate removal across a broad range of buffer widths, vegetation types, and hydrologic settings found that wide, forested buffers consistently achieved the highest nitrate removal efficiencies (Mayer et al., 2007). Reduction of nitrate loading to surface waters remains a major management objective for CT DEEP because excess nitrogen has been identified as a principal contributor to eutrophication and hypoxia within Long Island Sound, as well as a broader ecological threat to aquatic systems worldwide (Yousef et al., 2021).

Septic system spacing requirements contained within the Public Health Code are intended primarily to protect drinking water quality by maintaining nitrate concentrations in groundwater below human health thresholds. However, as discussed previously at the conclusion of **Section 3.0**, nutrient concentrations associated with protection of healthy aquatic ecosystems and diverse macroinvertebrate communities are often substantially lower than the 10 mg/L nitrate standard applied for public health purposes.

Dissolved phosphorus is generally attenuated more effectively than nitrate within naturally vegetated buffers because phosphorus readily adsorbs to soil particles, organic matter, and mineral surfaces. This removal process may be highly effective where soils possess adequate infiltration capacity, low background phosphorus saturation, and sufficient contact time between runoff and biologically active soil horizons. However, phosphorus retention capacity within soils is finite and may become progressively saturated under excessive or prolonged loading conditions, such as intensive fertilizer application or runoff from agricultural fields.

Phosphorus attenuation within buffer soils is particularly important because phosphorus is a major driver of algal blooms and eutrophication in ponds, lakes, reservoirs, and low-gradient stream systems. Elevated phosphorus inputs may also degrade wetlands adapted to low or moderate nutrient conditions by altering vegetation composition and ecological processes.

Surface soils in many residential lawns already contain elevated phosphorus concentrations due to years of fertilizer application. Consequently, sheet runoff flowing across lawns may mobilize dissolved phosphorus at concentrations sufficient to impair downstream water quality if discharged directly into wetlands, drainageways, or watercourses without adequate vegetated treatment areas. In addition, certain erosion and sediment control materials — including decomposing wood-chip mulches and compost-filled silt sock barriers — may themselves release dissolved phosphorus under some conditions, potentially contributing additional nutrient loading to adjacent aquatic systems.

6.0 CONCLUSION

The scientific literature reviewed in this paper consistently demonstrates that naturally vegetated wetland and watercourse buffers perform a wide range of important ecological, hydrologic, and water quality functions. These functions extend well beyond simple sediment filtration and include maintenance of ***hydrologic integrity***, moderation of runoff and groundwater discharge, nutrient attenuation through ***denitrification*** and plant uptake, protection of wetland microclimate, support of wildlife habitat and movement corridors, maintenance of organic soil development, and buffering of wetlands and streams from noise, illumination, temperature fluctuation, and invasive species colonization.

The literature further demonstrates that many wetland and stream systems — particularly ***headwater streams, perennial seeps, vernal pools, bogs, fens, and nutrient-sensitive wetlands*** — are highly vulnerable to relatively small changes in hydrology, nutrient loading, vegetation removal, and adjacent land use intensity. These systems frequently depend upon shallow groundwater inputs, intact forest canopy, organic-rich topsoil, and stable microclimatic conditions that are strongly influenced by adjacent upland buffers.

A recurrent finding throughout the scientific literature is that wider, forested buffers consistently perform better than narrow or sparsely vegetated buffers for protection of water quality, attenuation of nitrate and phosphorus, moderation of hydrologic impacts, and support of ecological integrity. This is especially true where groundwater moves laterally through biologically active upper soil horizons, allowing increased contact time with vegetation roots, organic matter, and microbial communities. Research synthesized in this paper also demonstrates that pollutant attenuation efficiency depends heavily on site-specific conditions including soils, slope, vegetation structure, hydrology, pollutant type, and flow path characteristics.

Importantly, the literature also demonstrates that the existing septic system setback standards contained within public health regulations were developed primarily to protect human drinking water supplies and do not necessarily provide adequate protection for nutrient-sensitive wetlands and aquatic ecosystems. Ecological impairment thresholds for streams and wetlands are often substantially lower than human health standards for nitrate concentrations in groundwater. Likewise, a number of commonly used lawn fertilizers, herbicides, pesticides, and other residential landscape chemicals remain sufficiently mobile and persistent that narrow setbacks may provide limited protection under certain hydrologic conditions.

Based on the available scientific literature, ***a minimum 100-foot-wide upland review area (URA)*** is generally prudent from a regulatory and ecological perspective for protection of wetlands and watercourses. However, no single fixed setback distance can adequately address all site conditions. The width and character of a functional buffer should ultimately be determined based upon three principal site-specific considerations:

1. ***The sensitivity and functional value of the wetland or watercourse resource;***

2. ***The intensity of the proposed land use or regulated activity, including both construction-phase and long-term operational impacts;*** *and*

3. ***The effectiveness and ecological quality of the proposed buffer itself, including soils, slope, vegetation, hydrology, habitat continuity, and pollutant attenuation capacity.***

Examples of highly sensitive resources that frequently warrant wider setbacks include productive ***vernal pools, perennial headwater systems, bogs, fens, wildlife sanctuaries, and high-quality stream corridors***. Conversely, more degraded or highly altered systems may in some circumstances tolerate narrower setbacks with lesser functional impact, particularly where proposed activities are low intensity and additional protective measures are incorporated.

The literature therefore strongly supports a ***site-specific, function-based approach*** to wetland buffer evaluation rather than reliance upon arbitrary minimum setback distances alone. Buffer determination methodologies such as those developed by Diamond and Nilson (1988) and Pawlak and Logan (1995) appropriately recognize that wetland protection depends not only on distance, but also on ecological sensitivity, buffer quality, hydrologic function, and land use intensity.

In the absence of detailed baseline data demonstrating that narrower setbacks will fully protect wetland and watercourse functions, the scientific literature reviewed herein generally supports maintaining naturally vegetated buffers of at least approximately ***80 to 100 feet***, with substantially wider setbacks often warranted for sensitive ecological systems, steep or erosion-prone sites, highly permeable soils, intensive land uses, or areas supporting important wildlife habitat and movement corridors.

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Authors' Note: We consider this to be a *"living document,"* that is, a document that will periodically be revised and updated as the relevant science base and understanding increases.

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A degraded stream in North Haven, Connecticut, with insufficient buffers.