APPENDIX F. Vegetated buffers

This appendix applies to all projects using vegetated buffers for stormwater control. A buffer is a natural vegetated, non-lawn area or areas located down gradient from a project that serves to store and remove pollutants from stormwater runoff flowing from a project. Buffers must not be interrupted by intermittent or perennial stream channels or other drainageways and must have a relatively uniform slope so that stormwater does not concentrate in channels. This appendix describes the design and sizing requirements for vegetated buffers designed to meet the general standards. Requirements are described for four different types of buffers, each of which is appropriate for specific situations.

1. **Types of vegetated buffers.** The applicability of each of the four types of vegetated buffers is as follows.

   (a) **Vegetated buffer with stone bermed level lip spreaders**. A vegetated buffer with stone bermed level lip spreaders must be used when treating stormwater runoff from any of the following:

      (i) An impervious area greater than one acre;

      (ii) Impervious areas where the flow path across the impervious area exceeds 150 feet; or

      (iii) Developed areas, including lawns and impervious surfaces, where runoff is concentrated, intentionally or unintentionally, so that it does not run off in well-distributed sheet flow when it enters the upper end of a buffer, except that road ditch runoff may be treated using a ditch turn-out buffer.

   (b) **Buffer adjacent to the downhill side of a road**. A buffer located along the downhill side of a road may only be used when the runoff from the road surface and shoulder sheets immediately into a buffer. In no instance may runoff from areas other than the adjacent road surface and shoulder be directed to these buffers.

   (c) **Ditch turn-out buffer**. A ditch turn-out buffer may only be used when runoff from a road ditch is diverted to a 20-foot stone bermed level lip spreader that distributes runoff into a buffer. No areas other than the road surface, road shoulder and road ditch may be directed into a buffer. No more than 400 feet of road and ditch may be treated in any ditch turn-out buffer, and no more than 250 feet may be treated if more than one travel lane is draining to the ditch.

   (d) **Buffer adjacent to residential, largely pervious or small impervious areas**. A buffer adjacent to a residential, largely pervious or small impervious area that does not require that runoff be distributed by means of a level spreader may only be used when:

      (i) A buffer is located immediately downhill of the developed area; and

      (ii) Runoff from the developed area is not concentrated and enters a buffer in well distributed sheet flow.

   Only runoff from the following areas may be treated using this type buffer:

      (iii) A single family residential lot;

(iv) A developed area that is less than 10% impervious where the flow path over the portion of the developed area for which treatment is being credited does not exceed 150 feet; or

(v) An impervious area of less than one acre, where the flow path across the impervious area does not exceed 100 feet.

2. **Design requirements for all buffer types.** The following design requirements apply to all types of buffers.

(a) **Topography.** The topography of a buffer area must be such that stormwater runoff will not concentrate as it flows across a buffer, but will remain well-distributed. Flow paths of runoff through a buffer must not converge, but must be essentially parallel or diverging.

(b) **Vegetative cover.** The vegetative cover type of a buffer must be either forest or meadow. In most instances the sizing of a buffer varies depending on vegetative cover type.

(i) **Forest buffer.** A forest buffer must have a well distributed stand of trees with essentially complete canopy cover, and must be maintained as such. A forested buffer must also have an undisturbed layer of duff covering the mineral soil. Activities that may result in disturbance of the duff layer are prohibited in a buffer.

(ii) **Meadow buffer.** A meadow buffer must have a dense cover of grasses, or a combination of grasses and shrubs or trees. A buffer must be maintained as a meadow with a generally tall stand of grass, not as a lawn. It must not be mown more than twice per calendar year. If a buffer is not located on natural soils, but is constructed on fill or reshaped slopes, a buffer surface must either be isolated from stormwater discharge until a dense sod is established, or must be protected by a three inch layer of erosion control mix or other woodwaste material approved by the Department before stormwater is directed to it, with vegetation must be established using an appropriate seed mix.

(iii) **Mixed meadow and forest buffer.** If a buffer is part meadow and part forest, the required sizing of a buffer must be determined as a weighted average, based on the percent of a buffer in meadow and the percent in forest, of the required sizing for meadow and forest buffers.

(c) **Deed restrictions and covenants.** Areas designated as vegetated buffers must be clearly identified on site plans and protected from disturbance by deed restrictions and covenants.

3. **Design specifications and sizing tables for a vegetated buffer with stone bermed level lip spreaders.** Stormwater runoff must be delivered to a vegetated buffer with stone bermed level lip spreaders in either sheet or concentrated flow. These design specifications direct runoff behind a stone berm constructed along the contour at the upper margin of a buffer area. As a result of restriction of flow through the berm, the runoff then spreads out behind the berm so that it seeps through the entire length of the berm and is evenly distributed across the top of a buffer. The stone must be coarse enough that it will not clog with sediment. The berm must be well-graded and contain some small stone and gravel so that flow through the berm will be restricted enough to cause it to spread out behind the berm.

(a) **Stone berm specifications.** The stone berm must be at least 1.5 feet high and 2.0 feet across the top with 2:1 side slopes constructed along the contour and closed at the ends. Unless otherwise approved by the Department, the design must include a shallow, 6-inch deep trapezoidal trough with a minimum bottom width of three feet, and with a level downhill edge excavated along the contour on the uphill edge of the stone berm. Stone for stone bermed level lip spreaders must consist of sound durable rock that will not disintegrate by exposure to water or weather. Fieldstone, rough quarried stone, blasted ledge rock or tailings may be used. The rock must be well-graded within the limits of Table 5, or as otherwise approved by the Department.

Table 5
Percent of Rock Required to Pass Through Square Mesh Sieves

Sieve Designation (Metric)	Sieve Designation (US Customary)	Percent by Weight passing Square Mesh Sieves
300 mm	12 in	100
150 mm	6 in	84-100
75 mm	3 in	68-83
25.4 mm	1 in	42-55
4.75 mm	No. 4	8-12

(b) **Buffer sizing**. The required size of a buffer area below the stone-bermed level lip spreader varies with the size and imperviousness of the developed area draining to a buffer, the type of soil in a buffer area, the slope of a buffer, and the vegetative cover type. The following table indicates the required berm length per acre of impervious area and lawn draining to a buffer for a given length of flow path through a buffer. Required berm length varies by the Hydrologic Soil Group of the soils in a buffer and by the length of flow path through a buffer. If more than one soil type is found in a buffer, the required sizing of a buffer must be determined as weighted average, based on the percent of a buffer in each soil type, of the required sizing for each soil type buffer. Alternative sizing may be allowed if it is determined by a site-specific hydrologic buffer design model approved by the Department. A buffer meeting this standard is not allowed on Hydrologic Soil Group D soils that are identified as wetland soils, unless measures are taken to improve infiltrative capacity, as approved by the Department. A buffer meeting this standard is not allowed on natural slopes in excess of 15% unless a buffer has been evaluated using a site-specific hydrologic buffer design model approved by the Department, and measures have been included to ensure that runoff remains well-distributed as it passes through a buffer.

Table 6 below applies to a buffer with slopes ranging from 0 to 8%. For a buffer with slopes between 9% and 15%, the indicated berm length must be increased by 20%.

NOTE: The following tables were developed using a 1.25 inch, 24 hour storm of type III distribution, giving a maximum unit flow rate of less than 0.009 cfs per foot.

Table 6
Sizing Requirements for buffer with 0–8% slope and stone bermed level lip spreader

Hydrologic Soil Group	Length of flow path through buffer (feet)	Berm length for a forested buffer (feet)		Berm length for a meadow buffer (feet)	
		Per acre of impervious area	Per acre of lawn	Per acre of impervious area	Per acre of lawn
Soil Group A	75	75	25	125	35
	100	65	20	75	25
	150	50	15	60	20
Soil Group B	75	100	30	150	45
	100	80	25	100	30
	150	65	20	75	25
Soil Group C sandy loam or loamy sand	75	125	35	150	45
	100	100	30	125	35
	150	75	25	100	30
Soil Group C silt loam, clay loam or silty clay loam	100	150	45	200	60
	150	100	30	150	45
Soil Group D non-wetland	150	150	45	200	60

4. **Design specifications and sizing tables for a buffer adjacent to the downhill side of a road.** A buffer adjacent to a disturbed area of less than one acre that continues to be a road may only be used when a buffer is located such that the runoff from the road surface and shoulder sheets immediately into a buffer. Required buffer design and sizing for this type of buffer does not vary with soil type or slope, except that a buffer meeting this standard is not allowed on soils identified as wetland soils or on natural slopes in excess of 20%, unless the Department finds that the buffer will have adequate adsorptive capacity, and measures have been included to ensure that runoff remains well-distributed as it passes through the buffer. Sizing depends on the vegetative cover type of a buffer and the number of travel lanes draining to a buffer as indicated in Table 7.

Table 7
Required Flow Path Length of a Buffer Receiving Road Runoff

	Length of flow path for a forested buffer (feet)	**Length of flow path for a meadow buffer (feet)**
One travel lane draining to buffer	35	50
Two travel lanes draining to buffer	55	80

The inslope of the road bed may be included as part of a meadow buffer only if it is designed and constructed to allow infiltration. Design and construction to allow infiltration includes, but is not limited to, the inslope fill material having slopes no steeper than 3:1; loaming and seeding to meadow grasses; and maintaining a buffer area as a meadow buffer.

5. **Design specifications and sizing tables for a ditch turn-out buffer.** A ditch turn-out buffer may only be used when runoff from a road ditch is diverted to a 20-foot stone bermed level lip spreader that distributes runoff into a buffer. No areas other than the road surface, road shoulder, road ditch, and ditch back slopes may be directed to the stone bermed level lip spreader.

   (a) **Stone berm specifications**. The stone berm to which the ditch turn-out delivers the runoff must be at least 20 feet in length and must be constructed along the contour. It must be at least one-foot high and two feet across the top with 2:1 side slopes. Stone for the berm must consist of sound durable rock that will not disintegrate by exposure to water or weather. Fieldstone, rough quarried stone, blasted ledge rock or tailings may be used. The rock must be well-graded with a median size of approximately 3 inches and a maximum size of 6 inches.

   (b) **Buffer sizing**. The required size of a buffer area below the stone bermed level lip spreader varies with the type of soil in a buffer area, the slope of a buffer, the length of road ditch draining to a buffer and the vegetative cover type within a buffer. A buffer meeting this standard is not allowed on Hydrologic Soil Group D soils, unless measures are taken to improve infiltrative capacity, as approved by the Department. A buffer meeting this standard is not allowed on slopes in excess of 15%, unless the Department finds that the buffer will have adequate adsorptive capacity, and measures have been included to ensure that runoff remains well-distributed as it passes through the buffer. Table 8 indicates the required length of the flow path through a buffer for various vegetative covers and ditch lengths. The tables below apply to a buffer with slopes ranging from 0 to 8%. For a buffer with slopes between 9% and 15%, the indicated length of flow path should be increased by 20%. If two travel lanes drain to the ditch, as in the case of a super elevated road, the length of flow path indicated for 400 feet of road must be used, but no more than 250 feet of ditch may drain to each turn-out.

Table 8
Sizing Requirements for Buffer Based on Length of Road or Ditch

Hydrologic soil group of soil in buffer	Length of road or ditch draining to a buffer (feet)	Length of flow path for a forested buffer (feet)	Length of flow path for a meadow buffer (feet)
A	200	50	70
	300	50	85
	400	60	100
B	200	50	70
	300	50	85
	400	60	100
C Loamy Sand or Sandy Loam	200	60	100
	300	75	120
	400	100	Not applicable
C Silt Loam, Clay Loam, or Silty Clay Loam	200	75	120
	300	100	Not applicable
D Non-wetland	200	100	150

6. **Design specifications and sizing tables for a buffer adjacent to a residential lot; developed area that is less than 10% impervious, where the flow path over the portion of the developed area for which treatment is being credited does not exceed 150 feet; or an impervious area where the flow path across the impervious area does not exceed 100 feet.** The design specifications and sizing tables below may only be used when a buffer is located immediately adjacent to the downhill side of a developed area, and where the topography and buildings and other facilities within the developed area do not cause any significant concentration of runoff.

   This design is appropriate for residential lots and other mostly pervious areas with relatively uniform topography and for small impervious areas. This design is not appropriate for treating large impervious areas because, even if pavement is graded evenly, it is likely that some concentration of runoff will occur as the stormwater travels across large areas of pavement. For large areas of pavement where the average path of flow across the pavement exceeds 100 feet, or where runoff will not be evenly distributed across the downhill edge of the pavement, a stone bermed level lip spreader must be used and the berm and buffer must be sized according to the specifications in Section 3 above.

   Table 9 below indicates the required minimum length of the flow path through a buffer for various soil types and vegetative cover types. Unless otherwise approved by the Department, the following apply:

   (a) Length of flow paths defined in this table apply to buffers with slopes between 0 and 8%.

   (b) For buffers with slopes between 9% and 15%, the indicated length of flow path must be increased by 20%.

(c) A buffer meeting this standard is not allowed on slopes in excess of 15% or Hydrologic Soil Group D soils except that a forested buffer is allowed if the D soils in a buffer are not wetland soils.

(d) Buffers described by this section must be located downhill of the entire developed area for which it is providing stormwater treatment, such that all runoff from the entire developed area has a flow path through a buffer at least as long as the required length of flow path.

Table 9
Buffer Size Requirements Based on Soil and Vegetative Cover Types

Hydrologic soil group of soil in buffer	Length of flow path for a forested buffer (feet)	Length of flow path for a meadow buffer (feet)
A	45	75
B	60	85
C **Loamy Sand or Sandy Loam**	75	100
C **Silt Loam, Clay Loam, or Silty Clay Loam**	100	150
D **Non-wetland**	150	Not applicable

7. **Alternative buffer design for residential subdivision lots.** This buffer design may be used as a Department approved alternative treatment measure to meet either the general standards at Section 4(B) or the phosphorus standard using compensation as provided in 06-096 CMR 501, but only under the conditions described below. This design applies only to buffers adjacent to subdivision projects in which all lots are for single or two-family detached, residential housing, common areas or open space where: 1) the buffer is located immediately downhill of the developed area; 2) runoff enters the buffer as sheet flow without a level spreader; and 3) the flow path over the portion of the developed area being treated by the buffer does not exceed 150 feet.

(a) **Slope**: To meet this alternative design, a buffer is not allowed on natural slopes in excess of 15%.

(b) **Soil restrictions**: Such a buffer is allowed on Hydrologic Soil Group D soils only if it is forested and non-wetland unless measures are taken to improve infiltrative capacity, as approved by the Department.

(c) **Buffer sizing**: Table 10 below indicates the required buffer flow path length based on soil types and vegetative cover types. Buffers must be located downhill of the entire developed area for which they are providing stormwater treatment; and with no converging contour, such that all runoff from the developed area passes in sheet flow through the buffer for a distance at least as long as the required length of flow path.

(d) **Minimum sizing for phosphorus standard**. If this buffer standard is being used in a mitigation project to meet the phosphorus standard and its size is being adjusted to provide a specific treatment factor, the minimum sizing for this type of buffer is a flow path of 35 feet.

Table 10
Alternative Buffer Size Requirements for Residential Subdivisions

Required minimum length of flow path through the buffer Based on a slope no greater than 15%		
Hydrologic soil	**For a forested buffer (feet)**	**For a meadow buffer (feet)**
A	35	50
B	45	60
C Loamy sand or sandy loam	50	70
C Silt loam, clay loam or Silty clay loam	70	100
D	100	Not Applicable

GUIDELINES

FOR

EVALUATING AND IMPROVING

THE FUNCTION OF

VEGETATED STORMWATER TREATMENT BUFFERS

April 18, 2017

Stormwater runoff due to heavy rainfall events and/or rapid snowmelt is a concern when that runoff reaches streams, rivers, lakes and ponds or other waterbodies. Stormwater runoff usually carries with it, a number of pollutants and can be very warm which can negatively impact water quality so it is important to either prevent that runoff from reaching a waterbody or treating it first to remove the pollutants. In a forest where the soil and organic duff layer have not been altered, very little runoff is generated. The rate of runoff typically increases as the amount of land in the contributing watershed is altered in such a way that less of the stormwater is able to infiltrate into the soil. When land alteration activities on a property or area reach the point where runoff generated exceeds the ability of the soil to absorb it, measures should be taken to treat the runoff. Stormwater treatment measures include vegetated buffers and structural measures such as detention basins, oil grease and sand separators, detention basins/wet ponds or under drained soil filter basins. Structural measures can be quite costly to install, are difficult to install properly, require maintenance to function properly and are not very aesthetically pleasing. Structural measures require maintenance in order to remove pollutants from the system. Vegetated buffers on the other hand, remove potential pollutants from the system through uptake by vegetation and utilization by soil microbes. Though vegetated buffers do not require annual maintenance to function properly, they do need to be protected from being altered which includes heavy foot traffic. If protected against heavy use or alteration, vegetated buffers generally function indefinitely with no maintenance as compared to structural measures which only work if continually and properly designed, installed and maintained.

The most effective and efficient stormwater buffers are forested lands with relatively unaltered soils that are moderately deep or deeper to hardpan, bedrock or seasonal groundwater table and that have an organic duff layer. Meadow vegetated buffers are generally considered to be less effective and efficient than forested buffers due to: the lack of an organic duff layer, a smoother soil surface, compacted and/or eroded soils and less resistance to overland flow. Relatively unaltered forested soils tend to have lower bulk density in the upper horizons than meadow soils and also have an organic duff layer. The organic duff layer is a very important component of a forest buffer as it acts like a sponge to absorb stormwater runoff and provides significant treatment of the infiltrating water. Stormwater treatment by the organic duff includes physically screening out particles such as soil which is the number one pollutant of water in the world; the highly decomposed component of the duff has a very high cation exchange capacity to absorb negatively charged components of the stormwater including pathogens; and the duff layer is where the greatest amount and variety of microbes can be found as well as many small plant roots which will utilize a number of pollutants found in stormwater. The quality and thickness of the organic duff layer has a direct bearing on its stormwater treatment capacity. As can be expected, the thicker the duff layer the more effective the treatment. Organic duff layers have the best stormwater treatment characteristics when they form in an aerobic environment. In an aerobic environment, soil microbial activity, which is responsible for the development of granular structure, is much higher than if the environment is anaerobic. Duff layers that form in wet environments tend to be anaerobic which reduces microbial activity, inhibiting the development of granular structure. Organic duff layers that form under saturated soil conditions tend to have platy structure or are massive (no soil structure). It is however, not uncommon to find an organic duff layer on wet forest soils which has massive soil structure in the lower part but granular structure in the upper part. These dual condition duff layers are usually found on the dryer end of wetland soils. Careful observation of the organic duff layer in a forested buffer is therefore an important consideration when assessing its treatment potential.

Not all forested buffers are more effective and efficient than meadow buffers. Much of Maine which is now forested was once cleared for agriculture by early settlers. That required the cutting of trees and pulling or burning stumps and then plowing the soil. Plowing the soil incorporated the organic duff into the upper soil horizons creating an "Ap" horizon or what is commonly referred to as "topsoil". This also changed the soil microbiota and many times made the soil bulk density go up (compacted). Soil erosion was also a common occurrence resulting in the depth to hardpan and/or bedrock to decrease. In marine sediments and the finer textured lacustrine (glacial lake) sediments, the texture of the soil that is routinely plowed becomes finer when erosion occurs. This is because the lower horizons of these soils tend to be higher in clay content than the upper soil horizons, before they were eroded. When erosion first occurs, topsoil is lost so the next year when it is plowed, some of the lower horizons are incorporated into the new topsoil layer, making it finer in texture. If erosion is severe enough, the topsoil layer becomes as fine textured as the subsoil layers. When the land was abandoned, it eventually grew back to a forest but not the same forest that was there originally. The original forest took thousands of years to develop into its final successional stage found by the settlers. For the most part, it was softwood trees including fir, spruce, hemlock with a few pines mixed in. Softwood stands tend to be dense with a thick canopy to filter out sunlight which keeps the soil cool. The organic duff layer tends to be thick in dense softwood stands because of the shading and because softwood needles are quite acidic and are hard to decompose. Once the land was abandoned, the altered soils and unlimited sunlight provide a seed bed ideal for favoring the growth of pioneer species such as alder, dogwood, poplar, maple (particularly red), birch (gray and white) with a few white pines. Gray birch is a common pioneer hardwood species the grows on very poor (nutrient poor) sites where the topsoil has been stripped off or poor quality fill has been added. Hardwood species have leaves that are much easier to decompose than softwood needles and agricultural soils usually have worms which feed on decayed leaves as compared to relatively unaltered forest soils which usually do not have a worm population. The result is a very thin or non-existent organic duff layer, typically just a thin layer of undecomposed leaves. It can take a very long time for an abandoned agricultural field to develop a true organic duff layer, depending on soil type, aspect (north vs south facing) and air temperatures (coastal and high elevation soils are cooler and therefore they slow down microbial decomposition). It is not uncommon in Maine today to find a forest growing in soils with an Ap horizon, very little or no organic duff layer and compacted soils. These forested buffers would not be as effective as a good quality meadow buffer with the same soil type.

Soil characteristics that may be affected when land is converted from a forest to agriculture:

Soil characteristics that may be altered when land is converted from a forest to agriculture include; soil texture, soil structure, soil consistence, soil drainage and soil depth.

Soil Texture – Most soils in Maine have a topsoil layer that has a different origin than the subsoil below it. That is because the land in Maine was once covered by a thick sheet of ice, about 10,000 – 12,000 years ago. When the glacier melted and retreated, it left the soil bare and exposed to soil erosion by wind and water until vegetation eventually recolonized the land. Some of the eroded soil material, particularly fine sand and silt, settled on the surface of nearby soils. This layer of soil is most noteworthy when the subsoil texture is significantly coarser or finer. In the case of outwash sands and gravels, the fine sand and silt creates a topsoil layer with greatly improved water holding, cation exchange capacity and a medium for soil microbes and plant roots to live in. If significant erosion occurs on these soils, the topsoil layer may be lost, leaving sand and gravel to the surface. The result is the loss of the layer that supports microbes and plant roots, has a high cation exchange capacity and good water holding capacity. In the case of high clay content soils, typically marine and lacustrine sediments, this layer of fine sand and silt has higher permeability than the heavier subsoils. If it is lost due to erosion, the upper soil horizon increases in clay content and the depth to hardpan decreases. The result is a decrease in the soil permeability and water storage capacity.

Soil Structure – Relatively unaltered, unsaturated, forest soils have well developed soil structure in the upper soil horizons, to the depth they have weathered since the glacier retreated. Agricultural soils, on the other hand, frequently have poorer soil structure than relatively undisturbed forest soils, particularly if they have been eroded and/or have low soil organic matter content. The degradation of soil structure and the interest in restoring it is one of the driving forces behind the recent interest in soil health. Well-developed soil structure in topsoil layers, particularly granular or crumb structure, is responsible for porosity in most soils, (sands and gravels are the exception). Porosity is important because pore spaces provide pathways for air, water and plant root movement throughout the soil and places for soil microbes to inhabit. Approximately 50% of the volume of a well-structured topsoil layer is pore space. If that percentage is decreased, the soils infiltrative capacity is reduced as is its microbial community. Granular structure is created by soil microbes decomposing organic matter in the soil. Their waste products provide the glue which sticks soil particles together into granules. These microbes are the most effective and efficient if they function in an aerobic environment. If a soil is compacted or wet, it will have fewer soil pores and therefore will be less aerobic resulting in reduced development of granular soil structure.

Soil Consistency – Soil consistence is how hard or firm a soil or soil layer is. The harder or firmer a soil is, the lower the soils infiltrative capacity is. It is not uncommon for soils to be compacted by agricultural activities and for those soils to take a long time to regain their former consistency. The finer in texture a soil is, the easier it is to become compacted when it is worked upon, especially when the soil is moist or wet and has low structural integrity.

Soil Drainage – Many former farm lands underwent hydrologic modifications, some on purpose and some that were inadvertent. In some cases, ditches or tile drains were installed to drain the soil and bedding (plowing up furrows with small ditches on either side) was practiced on flat wet fields which could not be drained by gravity. In other cases, diverted or intercepted groundwater was directed to formerly dry areas causing them to become wet. Roads were constructed which can also alter the natural hydrology through road ditches and culverts.

Soil Depth – The depth of soil to bedrock or hardpan significantly impacts the water storage capacity of the soil. It takes a very long time for nature to increase the depth to hardpan and/or bedrock once an area reverts from an agricultural field back to a forest. It is possible though, to mechanically increase the depth to hardpan by plowing deeply of using a subsoiler. It is also possible to increase the water holding capacity of a soil by adding permeable fill or organic material to its surface.

Factors Affecting the Function of a Vegetated Buffer:

The function of a buffer is dependent on a number of factors including soil properties; depth to hardpan, groundwater table or bedrock; slope (both steepness and length); shape of the buffer area (convex, concave, undulating, smooth etc.) contributing watershed size; resistance to overland flow through the buffer area; width of buffer and volume and velocity of water moving into and through the buffer. Traditionally in Maine, stormwater buffer soil properties have been determined on the basis of the hydrologic soil group derived from County Published Soil Survey maps. County Published Soil Survey maps however, were not designed to be used on a site specific basis. They were designed to be used for general planning purposes. Because of the scale of mapping, County Published Soil Survey maps only show different soil types down to about 2.5 – 3.0 acres or more. That means you can have an area (called an inclusion) within a soil map unit that is 2.5 acres in size or larger that is significantly different than the soil series for which the soil map unit is named. Also, many soil series have a wide range of characteristics. The hydrologic soil group for the soil series is based on what is believed to be the average set of soil characteristics for that soil series found within the State. For instance, the Peru soil series can have a seasonal groundwater table as shallow as 7" below the soil surface or as deep as 40". It can also have a depth to hardpan of as little as 12" or as much as 36". It therefore makes sense to do a site specific evaluation of each proposed buffer area to determine its unique soil and site characteristics.

Soil Characteristics which should be evaluated in a proposed vegetated stormwater buffer:

Soil characteristics which should be evaluated in a potential vegetated stormwater buffer include: soil texture, soil structure; soil consistency; soil depth to hardpan or bedrock; seasonal groundwater table (soil drainage class/hydrology); organic duff layer thickness and condition; percent coarse fragments and surface stoniness.

Texture – in general, coarse textured soils have greater permeability (infiltrative capacity) than fine textured soils do. That however, is not always the case and is also dependent on soil structure, coarse fragments and bulk density. On the other hand, fine textured soils have greater cation exchange capacity and therefore provide greater treatment of the stormwater that infiltrates into and through them than do coarse textured soil. The best vegetated buffers have good permeability and enough fines to provide treatment of the stormwater. Stormwater that moves through capillary pores of the upper soil horizons and or organic duff in a buffer also have potential contaminants removed by soil microbes and plant roots which are most numerous in the organic duff layer and/or upper soil horizons. Removal of potential contaminants by soil microbes and plant roots is desirable because they are taken out of the system (if the vegetation is removed) as compared to contaminants removed by cation exchange capacity which may not be taken out of the system if it is below the biologically active zone in the soil.

Soil Structure – Soil structure refers to the arrangement of primary particles into secondary particles or units. Soil structure is the one of the most important soil characteristic responsible for the soils porosity and therefore, its infiltrative capacity. In the case of medium to coarse sands and gravels, soil structure is a function of the texture of the soil. The sand grains are like small stone fragments with void spaces between the relatively large particles. For most soils though, there is a component of "fines" which are fine sands, silts and clays. These fine soil particles can clog voids in the soil and significantly decrease a soils infiltrative capacity. If however, the soil has a healthy microbial community, has a supply of organic matter and is well aerated, the microbes will decompose the organic matter producing waste products that act as a glue to stick particles together into soil structural units. The better the soil structure, the more porosity the soil has and the better is its infiltrative capacity. A well-developed fine textured soil with good granular structure can have very good infiltrative capacity whereas if it has no or poor soil structure, it will have very low infiltrative capacity. It is also important to understand soil structural integrity which refers to how stable the soil structure is. For soils which are dry, the structural integrity is usually very good and is not easily destroyed. The more moist or wet the soil is though, the weaker the soil structural integrity is as the moisture acts like a lubricant between soil particles. Saturated soils have very low structural integrity and therefore, should be protected from anything that could rut or disturb them while they are saturated.

Soil Consistency – soil consistency refers to how friable (not firm) or firm a soil is. Bulk density also is a measure of soil consistency. Firm soil consistency can be due to cementation (a natural process depending on the soil chemistry) but is much more commonly due to compaction, either manmade or natural. Most of our soil in Maine was once under the great weight of over a mile thick sheet of ice. That caused many soils to become very compacted. Over time, after the glacier retreated 10,000 – 12,000 years ago, the upper soil horizons have weathered and become much more permeable. The depth of weathering depends on a number of factors but is typically 18" – 30" below the soil surface to the hardpan. Soil compaction to or near the surface is usually an indication of a soil altered by man's activity. It can be due to being worked on when it was wet or saturated, particularly if the soil is fine textured, had the topsoil layer removed or has been eroded. If the soil is fill material, it likely was purposely compacted to prevent settling in the future. Compacting the soil destroys the soil structure, greatly reducing the pore space volume in the soil. The average volume of the upper soil horizons of unaltered soil is only about 45% mineral and 5% organic matter. The remaining 50% is pore space filled with either air or water. If that percent pore space is decreased by compaction, the porosity of the soil will be proportionally decreased.

Soil Depth – Soil depth refers to the depth of friable soil to a hardpan layer or bedrock, both of which limit the soils ability to store infiltrating water. The degree to which a hardpan or bedrock affects the storage capacity of the soil depends largely on the slope of the land and soil properties such as texture, structure and consistency. On relatively flat land, runoff water infiltrates into the soil but has difficulty moving down or laterally. Once the storage capacity of these soils has been reached, stormwater will just flow over or sit on the surface. If however, the soil in the buffer area is sloping; gravity will pull infiltrating water away from where it enters, continually creating new capacity. The more permeable the soil is and the steeper the slope, the quicker the infiltrating water is removed from the buffer. On steep slopes, the biggest concern is with allowing sufficient time for water to infiltrate into the soil rather than run off across it.

Seasonal Groundwater Table (soil drainage class/hydrology) - Depth to seasonal groundwater table should be considered when evaluating the capacity of a buffer as it will act similar to a hardpan or bedrock in limiting the storage capacity of runoff water (see soil depth above). There are two kinds of seasonal groundwater tables that may be present in the soil, both of which impact the ability of a soil to infiltrate and treat stormwater runoff. The most common seasonal groundwater table is one that is present for long enough to become stagnant and anaerobic creating reducing conditions within the soil. This kind of groundwater table is usually found on level to slightly sloping lands for medium to coarse textured soils and also on steeper slopes for fine textured soils. The other kind of seasonal groundwater table is one that is moving and therefore does not become anaerobic. Aerobic oxygenated) seasonal groundwater tables are most common on medium to coarse textured soils with a restrictive layer and on sloping sites (typically glacial till soils with a hardpan). Both kinds of seasonal groundwater tables affect the ability of a buffer to treat stormwater runoff and should be factored into its design.

Percent Coarse Fragments – Coarse fragments are rocks, anything larger than 2 mm in diameter, in the soil. Coarse fragments in the friable portion of the soil profile help to keep the soil from becoming compacted and provide pathways for infiltrating water to move through the soil profile. All other things being equal, the higher the percentage of coarse fragments in the soil, the higher is its infiltrative capacity.

Organic Duff layer – The organic duff layer which rests on many forested soils has the potential of being the most effective treatment medium of the buffer, depending on thickness and condition. It typically has the greatest amount of biologic activity in a forested soil and has by far, the highest cation exchange capacity of the soil. The thicker the organic duff layer is the better but it also needs to have very low bulk density (so that it is "fluffy"). The best and most effective organic duff layers develop under aerobic conditions which allows for soil microbes to create granular structure. The reason why organic matter accumulates on the forest floor is decreased microbial activity and/or because of the difficulty in decomposing the leaf and woody debris falling on the forest floor (some leaves and twigs (softwoods) are more resistant to decay than others). Climate related reasons for decreased soil microbial activity in Maine are usually either lack of oxygen due to saturation or cool summer temperatures (shading, aspect, elevation and/or proximity to the downeast coast). If the reason for reduced microbial activity is because of soil saturation, the organic duff layer will usually have massive or platy soil structure. These organic duff layers are not as effective a treatment medium as are organic duff layers which form due to cooler temperatures in the summer. In addition, their infiltrative capacity is less than that for a buffer which forms due to cool temperatures. It is not uncommon though to have a thick organic duff layer in a wet area that is saturated in the lower part but aerobic in the upper part (the thickness of the saturated part depends on the wetness of the soil). Dense stands of spruce and fir create the best organic duff layers for the treatment of stormwater runoff. They are coarse on the surface due to recent accumulations of needles and twigs creating high infiltrative capacity and good resistance to compaction but are more decomposed in the lower part to provide for high cation exchange capacity. Organic duff layers composed of hardwood leaves and twigs are usually thinner than for softwood trees in the same area and they are usually more highly decomposed so they compact more easily. Forested buffers with many shallow tree roots in the duff layer can provide good physical support and are therefore more resistant to compaction than forested duff layers without shallow roots.

Surface Stoniness – Our most common soil parent material in the State of Maine is glacial till. Glacial till is a random mixture of sand, silt and clay with stones mixed in. Sometimes, these soils also have many stones on the soil surface which can provide good resistance to overland flow of stormwater in both forested and meadow buffers. When the stones are close enough together in a forested setting, organic duff material will accumulate in the voids between the stones and on top of the stones providing a thickened duff layer that is resistant to compaction and overland flow. Tree roots are also common in these thick duff layers providing additional resistance to overland flow of stormwater . In the Western Maine Mountains and along the Downeast coast these thickened duff layers can be 1' to 2' thick or more and make excellent stormwater treatment buffers.

Large Woody Debris - Lots of large woody debris on the soil surface can function similar to surface stones providing many of the same benefits for stormwater treatment. Woody debris however is not as long lasting as surface stoniness so it will need to be maintained (allowed to continue to accumulate) if it is an important part of the buffer (making sure that stormwater flows across the forested buffer as sheet flow and slows down enough to encourage infiltration onto the soil).

Site Characteristics which should be evaluated in a proposed Vegetated Stormwater Buffer:

Site characteristics of a potential buffer area are also an important consideration when determining the effectiveness of the buffer. Site characteristics include: percent slope and length of slope; resistance to overland flow, shape of the buffer landform, contributing watershed, drainage patterns in the buffer, and soil alterations.

Percent Slope – Flat buffers are most effective when they are comprised of highly permeable soils that have no or are deep to hardpan, bedrock or seasonal groundwater table. Soils which have a shallow depth to bedrock, hardpan or seasonal groundwater table work best when they have a slope across their width to pull infiltrating water away from the buffer. The steeper the slope the better infiltrating water will be pulled away. Steeply sloping buffers though, may allow runoff to water move across them so fast it does not infiltrate into the organic duff or soils so they usually require some form of resistance to overland flow and/or a mechanism to assure the runoff water remains as sheet flow throughout the buffer.

Slope Length (contributing watershed) – All other things being equal, longer slopes will result in more runoff and groundwater being brought to the buffer area. Short slope lengths (small contributing watersheds) are ideal when designing vegetated buffers. If possible, the contributing watershed should be minimized to the extent possible by diverting clean water away from the buffer, both surface and subsurface.

Resistance to Overland Flow – Resistance to overland flow is anything that slows runoff water down as it moves across a vegetated buffer. As can be expected, the steeper the slope across a buffer, the more important resistance to overland flow becomes. In a forested buffer, resistance can be provided by a thick duff layer, stones, woody debris, tree stems, understory vegetation, tree roots and micro-topography (pit and mound topography). In a meadow buffer, resistance is usually only provided by the herbaceous vegetation. The thicker and taller the vegetation, the more resistance it provides. Sometimes though, the surface of a meadow buffer is irregular or stony adding to the resistance to flow across it.

Shape of the Buffer Landform – The best vegetated buffers have a uniform shape across them, level across their length with a slope across their width. Buffer effectiveness is limited when they are convex or concave shaped. Concave landforms are the most problematic landforms due to the presence of drainageways that tend to take sheet flow entering the buffer and convert it to concentrated flow.

Contributing Watershed – The amount of surface and groundwater reaching a buffer depends, to a large degree, on the size and slope of the contributing watershed. The larger the contributing watershed, the more water reaches the buffer. Whenever possible, it is best to limit the amount of watershed area contributing to a buffer, both surface and groundwater. Ideally, the only water reaching a buffer should be the stormwater runoff needing to be treated.

Drainage Patterns in the Buffer – Drainage patterns in a proposed buffer indicate how water moves through the buffer and will likely continue unless measures are taken to change that pattern.

Proposed buffers with numerous channels, rills, rack lines or other flow paths are indications that concentrated flow has or is developing and needs to be addressed. Buffers are designed to treat runoff as sheet flow. Concentrated flow is not treated in vegetated buffers. Buffers with concentrated flow paths need to be modified so that the concentrated flow paths are eliminated.

Soil Alterations – Soil alterations can be anything done to a potential buffer's soil which affects it effectiveness and efficiency. Some alterations may improve the buffer such as adding coarse textured fill material, loosening up a compacted surface soil horizon or making the buffer surface more irregular. Alterations that can make the buffer less effective and efficient include compacting the soil, adding finer textured fill material and making the surface smoother.

Stormwater Vegetated Buffer Design Considerations:

The most effective vegetated stormwater treatment buffers convert all of the runoff water entering them as sheet flow to subsurface groundwater flow (allow it infiltrate into the organic duff layer and/or the soil before the runoff reaches the end of the buffer). This provides physical filtering of many of the potential pollutants and contact with soil and/or organic matter provides further treatment of the water through cation exchange capacity and utilization by soil microbes and plants. Runoff water that flows across the surface of a buffer but which does not infiltrate into the organic duff or soil will get some treatment (depending on the roughness of the buffer and how fast the water moves across the buffer) but not the ideal level of treatment. It is therefore important to design a vegetated buffer so that it only receives sheet flow (not concentrated flow) and the speed of runoff water movement across it is slow enough to allow for infiltration. The buffer soil and/or organic duffer layer must also have the capacity to allow for all of the stormwater runoff to infiltrate into the soil for at least a few feet. Storage capacity of the buffer is dependent upon the length of the buffer as well as soil depth to hardpan, bedrock or seasonal groundwater table and slope of the buffer. Buffers that are on relatively flat slopes need to have greater storage capacity than buffers on sloping sites. That is because gravity will pull water through the buffer's upper soil horizons if it is on a slope but on a flat slope, water can only travel downward until it hits a restrictive layer, bedrock or seasonal groundwater table. How fast water is able to infiltration into the buffer's organic duff and/or soil is dependent upon the quality and thickness of the organic duff and soil texture, structure and bulk density (compaction). A stormwater buffer designer needs to take into consideration:

1. Soil and organic duff layer characteristics in the buffer area
2. Site characteristics of the buffer area
3. Volume and speed of stormwater which will be entering and moving through the buffer: are measures needed to control the volume and speed of runoff entering the buffer?
4. How the stormwater will be entering the buffer (sheet flow or concentrated flow)
5. Clean runoff water from above the project area
6. Clean groundwater from above the project area
7. Protecting the buffer from being altered by human activity

Designing the Stormwater Buffer - Site Characteristics:

The first step in designing a stormwater buffer is to evaluate soil and site characteristics. If the site has a steep slope, little resistance to overland flow and/or has concentrated flow channels, modifications will be needed to correct for those limitations. Modification options include:

1. Install a stone level lip spreader(s) at the beginning edge of the buffer to slow down the velocity of stormwater and spread it out over the full length of a vegetated buffer. The size of the stone used should be based upon the volume and velocity of stormwater. Larger stone is needed to pass larger volumes of water. Small diameter stone will release stormwater more slowly but cannot handle the volume that large stone can. It may be necessary to install another stone level lip spreader(s) in the buffer to collect stormwater flow that has gone back to concentrate flow and spread it out again as sheet flow.
2. Install an erosion control mulch berm to slow down the velocity of stormwater and spread it out over the full length of the buffer. Erosion control mulch berms are not as porous as stone level spreaders so they can't handle as much water. The berm itself however, can provide partial treatment of the stormwater whereas a stone level spreader provides almost no treatment at all. A stone level spreader slows down the velocity of the stormwater which may result in the settling out of some of the larger soil particles it is carrying. Erosion control mulch berms contain woody material with some soil mixed in which can remove some of the pollutants in stormwater. As with the stone level lip spreader, it may be necessary to install a second row inside the buffer to take any of the stormwater that has concentrated and spread it out again as sheet flow.
3. Road ditch turnouts collect stormwater runoff from roads, slowing down the velocity of the runoff water and then distributing it as sheet flow to a buffer. Sometimes, a stone level lip spreader or erosion control mulch berm is needed in conjunction with a ditch turnout, particularly when the turnout is on a steep slope.
4. Stormwater runoff can also be collected and then discharged to the entire length of the buffer through a perforated header pipe. For a short buffer with highly permeable soils, shallow infiltrations trenches can be installed to put the stormwater into the soil for treatment. The best treatment though is provided for stormwater runoff that infiltrates into the entire soil profile, including the organic duff layer, if present.
5. Resistance to overland flow can be added to a forested buffer that has little or no organic duff or groundcover by applying a layer of erosion control mulch to the soil surface. Erosion control mulch is long lasting, will not wash away by the stormwater runoff and will add to the water storage capacity of the soil in the buffer. When erosion control mulch eventually decomposes, it will provide a good seed bed for plants (become like an organic duff layer) which will add resistance and provide additional treatment.

6. Resistance can be added to a forested buffer by laying slash down on the forest floor. Slash can come from the lower limbs of trees in the buffer or from off-site. Slash will eventually decompose and may need to be replace periodically until a suitable duff layer has developed.
7. Resistance can be added to an existing meadow buffer by rototilling the buffer soils and then leaving them as is. This will also "fluff up" the soil increasing its storage capacity. The broken plant roots will sprout new plants and the soil surface will be very rough.

Designing the Stormwater Buffer – Soil Characteristics:

If the soils and/or organic duff layer in a proposed stormwater buffer area do not appear to be adequate to accommodate all of the stormwater runoff the buffer will receive, modifications can be made to improve its capacity. Modifications include:

1. Divert all clean surface runoff water flows away from the project area. That will reduce the volume of runoff water that has to be treated.
2. Divert groundwater flows away from the site by use of a ditch or curtain drain. This will lower the seasonal groundwater table of the buffer soils, increasing its water holding capacity.
3. Add a layer of erosion control mulch. This will provide resistance to overland flow as well as adding storage capacity. Erosion control mulch is quite resistant to compaction by human activity such as continually walking over a buffer so it is a good measure to use in urban settings. It will eventually become vegetated but provides immediate protection of underlying soil in the meantime with additional water storage capacity.
4. In a proposed meadow buffer, the soil can be roughened up and its water holding capacity improved by rototilling it and leaving it as is. Vegetation will sprout from the cut roots quickly stabilizing the soil in its new roughened state.
5. Rototilling can also be used to loosen up a compacted topsoil layer in a proposed meadow buffer.
6. If the soils in a proposed meadow buffer are fine textured and compacted and/or have poor structure, coarse textured fill material or erosion control mulch can be mixed into the original soil to improve its porosity.
7. In a proposed meadow buffer with a shallow depth to hardpan, a subsoiler (ditch witch) could be used to dig into the hardpan layer along the contour, with little soil surface disturbance. This will increase the storage capacity of the soil and add resistance to overland flow.
8. A meadow buffer can be plowed more deeply to increase water holding capacity but that will result in a very unstable area until vegetation becomes reestablished. Such areas should have an erosion control blanket put on top of the plowed area until vegetation is well established. Erosion control mulch can also be placed on top of the disturbed soil if it is not necessary for the area to become a meadow.
9. Coarse textured fill can be placed on a soil with depth and/or water storage capacity limitations. If coarse textured fill is used, a topsoil layer should be used to grow vegetation

or a layer of erosion control mulch should be added. The original soil surface should also be scarified and a transition horizon installed (mix some of the coarse textured fill material into the original soil) to encourage infiltration and to slow down the travel of infiltrated water to the toe of fill.

10. If there are inadequate soils that can't be improved or the buffer is not wide enough, coarse textured fill material can be added to a building site to provide stormwater treatment. Stormwater can be encouraged to infiltrate into the fill material by the installation of a berm near the edge of fill or infiltration trenches can be installed near the fill edge. Topsoil will need to be placed on top of the fill material that is not going to be covered by something impervious so that it becomes vegetated. Fill material should be coarse textured because it retains its porosity even when handled. Fine textured fill material is not suitable for this purpose because it depends on soil structure for its porosity. Soil structure is destroyed when it is handled and compacted leaving no void spaces open for the infiltration of water.