*Attachment 1*

**COMMONWEALTH OF VIRGINIA**
**DEPARTMENT OF ENVIRONMENTAL QUALITY**
**DIVISION OF WATER PERMITTING**

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# VIRGINIA RUNOFF REDUCTION METHOD
# Compliance Spreadsheet User's Guide & Documentation
## (Version 4.0, *June* 2023)

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## DISCLAIMER

This User Guide is in a draft format. As a draft it incorporates expected revisions to the governing regulations that will become effective July 1, 2024. Citations to those regulations, the Virginia Erosion and Stormwater Management Regulation, 9VAC25-875, are included and replace corresponding requirements that are in the Virginia Stormwater Management Program (VSMP) Regulation, 9VAC25-870, which will be repealed, effective July 1, 2024. This draft assumes DEQ will complete a regulatory action prior to July 1, 2024 that will change the total phosphorus load of new development projects from 0.41 pounds per acre per year (9VAC25-870-63 A.1, lbs/acre/yr) to 0.26 lbs/acre/yr.

## 1.0 INTRODUCTION

The Virginia Erosion and Stormwater Management Regulation (VESMR) requires the use of the Virginia Runoff Reduction Method (VRRM) to demonstrate compliance with the water quality technical criteria in the regulations (*9VAC25-875-590*). The VRRM is supported by stormwater research for runoff reduction and pollutant removal capabilities of various stormwater Best Management Practices (BMPs). Information and documentation concerning the development of the VRRM can be obtained from *Technical Memorandum: The Runoff Reduction Method* prepared by the Center for Watershed Protection (CWP) (www.cwp.org) and the Chesapeake Stormwater Network (CWP, 2008).

DEQ has developed two spreadsheets to assist in determining compliance with the VRRM; one spreadsheet is for new development and the other is for redevelopment. The spreadsheets are designed to help users see the benefits of environmental site design (ESD) and allow iterative design with various stormwater BMPs on a particular site. Selected stormwater BMPs can also be evaluated in series (e.g., treatment trains) to meet the water quality standards in the regulations.

Each VRRM compliance spreadsheet is meant to serve as a tool for determining compliance and does not limit the use of other tools or methods consistent with the water quality requirements, as approved by the VESMR Authority. It is important to note that quality compliance determination is only the first step in the design process. The suitability of ESD features and BMP design specifications to a project site are not determined by the spreadsheets. When a BMP is selected in the spreadsheet, the designer will locate and design the BMP according to the design criteria provided in the Stormwater Design Specifications included in the Virginia Stormwater Management Handbook.

Version 4.0 integrates the concept of loading rates for nutrient load computations instead of the Simple Method that has been integrated in past versions. The loading rate concept will enable the VRRM method to become more aligned with the Commonwealth's Chesapeake Bay nutrient management goals, as modeled using the Chesapeake Assessment and Scenario Tool (CAST)

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[CBP, 2022]. For detailed information regarding application of CAST to VRRM, see Appendices D through F in this document.

Originally launched in 2011, the CAST modeling tool is a web-based application that allows users to estimate nitrogen, phosphorus, and sediment loads within the Chesapeake Bay watershed. The tool has a wide range of user scenarios that can be modified to yield aggregated estimates of loads for 49 different land covers at Edge of Stream (EOS) and Edge of Tide (EOT) locations. The model has been built using both monitoring data and results from other models to create its modeling engine.

To compute the loads used in the VRRM spreadsheet, a CAST scenario using no integrated BMPs was run. The purpose was to create a model that generates the equivalent of post-development nutrient loads prior to BMP integration. EOS loading rates were used in the VRRM spreadsheet since these most closely replicate those found on site. See Appendix E for description of methodology used to assign loading rates based on values from CAST scenario runs.

### *Key Features of* New Development and Redevelopment VRRM *spreadsheets:*

- Provide a summary of land cover statistics that includes a composite runoff coefficient for the entire site area in post-development condition, the pollutant load (Total Phosphorus [TP] and Total Nitrogen [TN]), and the corresponding Treatment Volume (Tv).
- Allow the designer to evaluate the effectiveness of different BMPs and BMP combinations with respect to water quality compliance using up to five different drainage area tabs within a site.
- Provide a summary for each drainage area tab that includes the land cover, runoff volume and pollutant load generated from development, the BMPs selected, and the runoff volume and pollutant load reduced by the selected BMPs.
- Track the volume reduction that can be counted towards compliance with water quantity control requirements in each drainage area tab.
- Provide an overall compliance summary report that itemizes BMP implementation in each drainage area tab, as well as overall site compliance.

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# 2.0 BASICS FOR USING SPREADSHEET AND GUIDANCE

## 2.1. SPREADSHEET BASICS

The VRRM New Development and Redevelopment Compliance Spreadsheets are each composed of seven different types of tabs. The **Site tab** calculates a nutrient load for the site and runoff treatment volume based on the proposed land cover characteristics. The five **Drainage Area tabs (A through E)**, which are identical, can represent different drainage areas discharging to different outfalls located within the site, or BMPs can be grouped together on a single **Drainage Area tab** for more complex designs. BMPs applied to the site within user defined drainage areas for water quality compliance are selected within the **Drainage Area tabs**. The **Water Quality Compliance tab** provides the site treatment volume, drainage area nutrient loads and runoff reduction volumes, and a summary of nutrient loads achieved and remaining reduction required. This tab's primary function is to indicate whether compliance with phosphorus load limitations has been achieved. The **Runoff Volume and CN tab** provides the user with volume tracking information, runoff depth, and Curve Number (CN) adjustments associated with runoff volume-reducing BMPs. The **Summary tab** organizes and displays the information entered and calculated on the other tabs. The **Constants tab** provides the constants, runoff coefficients and curve numbers, as well as phosphorus and nitrogen loading rates for the equations used in the spreadsheet. The final tab, the **Notes tab**, is a running list of the changes associated with the different released versions of the spreadsheet including changes and corrections made in Version 4.0.

The Redevelopment Spreadsheet and the New Development Spreadsheet are essentially the same with a few exceptions reflected in two of the spreadsheet tabs. The **Site tabs** look dissimilar due to differences in data inputs and compliance requirements. Similarly, the **Summary tab** differs given the respective reporting of each spreadsheet's data inputs and calculated results. The **Site tab** for the Redevelopment Spreadsheet requires data input on the existing site and proposed site conditions and incorporates different compliance computations in accordance with the regulations, *9VAC25-875-580 A 2*. The nutrient loads and volumes are calculated for both the existing site and the proposed site, and the regulatory phosphorus load reduction requirement for the site is comprised of both a reduction to the existing nutrient load and meeting the new development compliance phosphorus limitation for new net impervious areas. Once the load reduction requirements are determined, the procedures for selecting the BMPs and verifying compliance are the same as those for new development. Instructions on using the **Site tab** for redevelopment (including site area versus disturbed area) are included in Section 4.

Both spreadsheets use the Design Specifications provided in the Virginia Stormwater Management Handbook.

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**Using the VRRM spreadsheet**

Functional spreadsheet **cells** are color-coded as follows:

**Green Cells** ***(unlocked)*** are for user data entries.

**Yellow Cells** ***(locked)*** are fixed constant values.

**Grey Cells** ***(locked)*** are calculated values.

**Indigo Cells** ***(locked)*** are final results (Total Phosphorus reduction requirement).

## 2.2. SOFTWARE SPECIFICATIONS

The spreadsheet files (Version 4.0) are Excel documents and were developed using Microsoft Excel 365 in a macro-enabled workbook format (.xlsm). **Users must enable macros** in order for the spreadsheets to function properly (Fig. 1)

**Figure 1. Enabling Macros**

## 2.3. GUIDANCE BASICS

The basic components and terms of the VRRM compliance spreadsheets are discussed in the sections below and presented along with step-by-step user instructions. This guidance applies to Version 4.0 of the spreadsheets. Version 4.0 provides a new methodology for computation of nutrient loads that is based on data from the Chesapeake Assessment and Scenario Tool (CAST). In addition, a new land cover type, 'Mixed Open' is present in Version 4.0, to distinguish between forest cover and infrequently maintained open space areas.

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## 3.0 SITE TAB (NEW DEVELOPMENT)

The **Site tab** requires site data inputs and provides overall site information. The main purpose of this tab is to compute the required TP reduction for the site based on the proposed site land cover characteristics. Using the land cover data entered by the user and the fixed constant values, the site TP loading is calculated using the CAST loading rates (Eq. 4). The required load reduction is based on the difference between the post-development site load and the load limit of 0.26 pounds TP per acre per year (see Appendix F). The calculated values used to derive the required site load reduction can be found on the **Constants tab** in the table labeled ***Constants***. The data input cells used in the nutrient load calculations are described below and shown on the **Site tab** screenshot in Fig. 2.

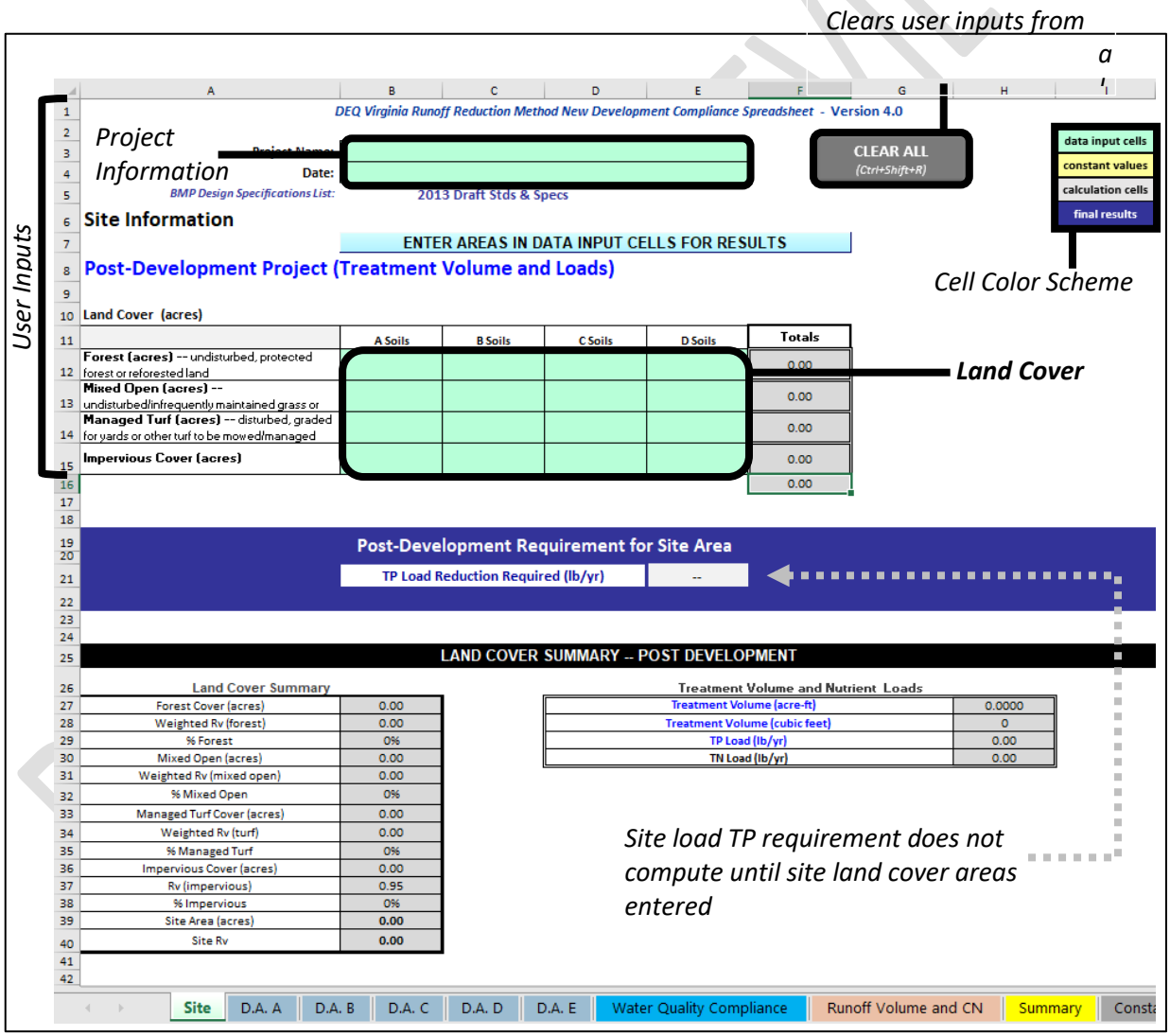


**Figure 2. VRRM New Development Compliance Spreadsheet – Site Tab with No User Inputs**

Figure 3 shows a screenshot of the **Site tab** when land cover data has been entered.

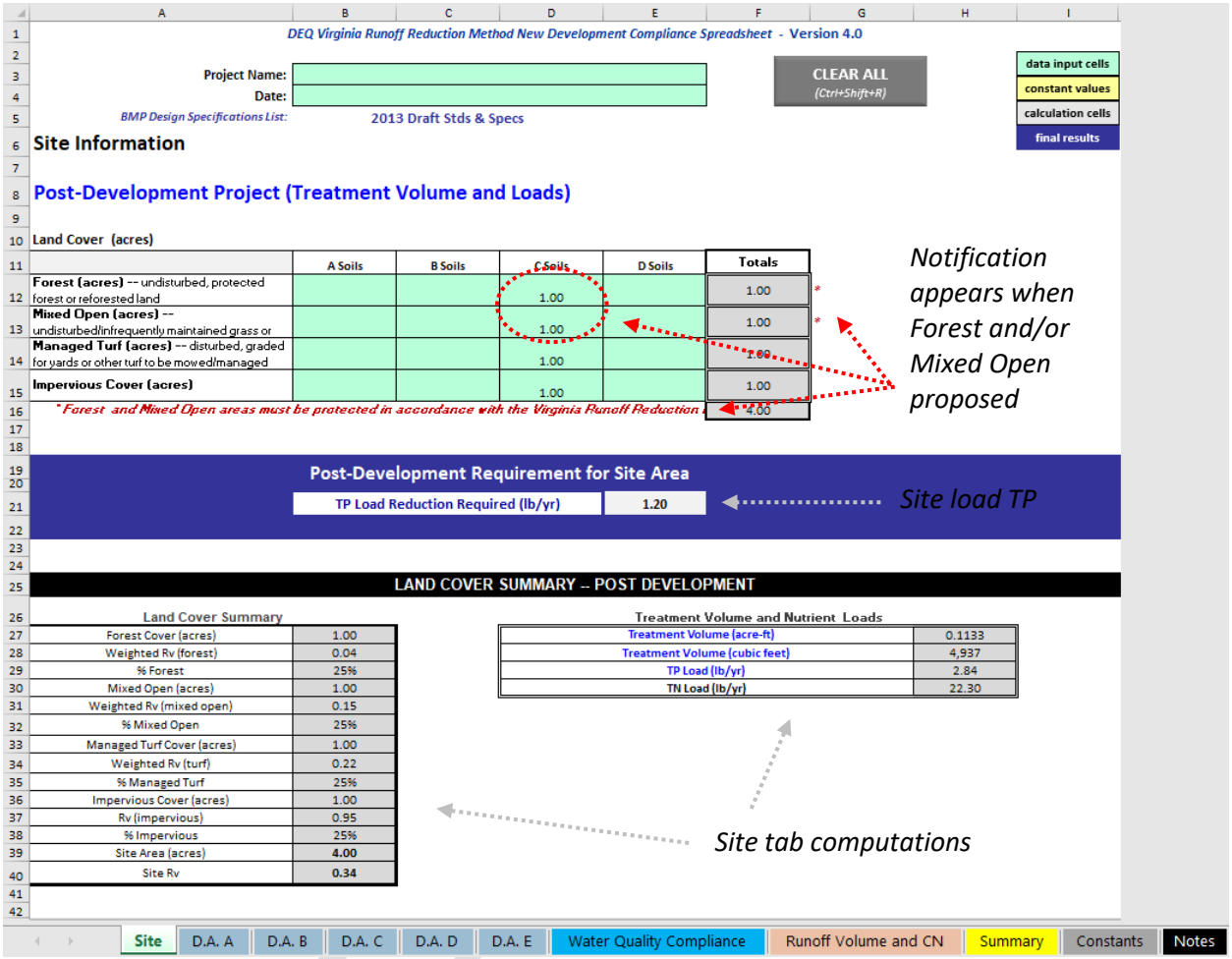


**Figure 3. VRRM New Development Compliance Spreadsheet – Site Tab with User Land Cover Inputs**

**Using the VRRM spreadsheet *(Site tab)***

1. Enable macros to allow access between worksheets (tabs).
2. Use the **CLEAR ALL** button to delete all prior used data inputs from entire spreadsheet.
3. Enter project name (**cell B3**) and date (**cell B4**) in the provided spaces.

## 3.1. SITE TAB – LAND COVER

The **green cells** in the ***Land Cover*** table of the **Site tab** are where the user enters the land cover type by hydrologic soil group (HSG) for the entire site area (in acres) for the post-developed condition. There are four categories of developed land: *Forest (F)*, *Mixed Open (MO)*, *Managed Turf (MT)*, and *Impervious Cover (IC).* Definitions of the four categories of land cover and the basic qualifications for each are provided in Table 1. The Site area acreages, including drainage area tabs, are limited to areas where the operator and/or owner are legally able to make changes to the land cover. Offsite run-on from adjacent parcels outside of operational control should not be used for quality reduction. HSG determinations can be made using the National Resources Conservation Service (NRCS) web soil surveys or site soil investigations (See the Virginia Stormwater Management Handbook and/or Chapter 7 of the National Engineering Handbook, Part 630 for additional information). Runoff coefficients (Rv) by land cover and HSGs can be found in the ***Runoff Coefficients*** table of the **Constants tab** as fixed constants in **yellow cells**. A composite runoff coefficient for the site is then computed from the user acreage inputs and the fixed Rv.

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**Table 1. Land Cover Guidance for VRRM Compliance Spreadsheets**

| **FOREST** |
|---|
| **Land that will remain undisturbed[1]:**<br>• Portions of the site that will NOT be disturbed during construction.<br>• Surface area of stormwater BMPs that are NOT wet ponds, have some type of vegetative cover, and that do not replace an otherwise impervious surface[2].<br>  ○ BMPs in this category include bioretention, dry swale, grass channel, stormwater wetland, soil amended areas that are vegetated, and infiltration practices that have a vegetated cover.<br>• Other areas of existing forest, including wetlands, that will be protected during construction and that will remain undisturbed.<br>**Operational & management conditions for land cover in the Forest category:**<br>• Areas that will be considered as forest must be shown outside the limits of disturbance (LOD) on an approved erosion and sediment control plan AND clearly demarcated in the field (e.g., fencing and/or posted signage) prior to commencement of construction.<br>• All areas that will be considered forest for stormwater purposes must have documentation which prescribes that the area will remain in a natural, vegetated state in perpetuity via the use of one of the following:<br>  ○ Appropriate documentation includes subdivision covenants and restrictions; deeded operation and maintenance agreements and plans; parcel of common ownership with maintenance plan; third-party protective easement; or other documentation approved by the VESMR authority.<br>• Although the goal is to have forest areas remain undisturbed, some activities may be prescribed in the appropriate documentation, as approved by the VESMR authority:<br>  ○ Forest management (harvesting of trees through the Virginia Department of Forestry with the intent of regenerating another crop of trees, either naturally or artificially in the future), control of invasive species, replanting and revegetating, passive recreation (e.g., trails), etc. |
| **MIXED OPEN** |
| **Land that will remain undisturbed OR restored to a hydrologically functional state:**<br>• Portions of residential lots that will NOT be disturbed during construction.<br>• Portions of roadway rights-of-way that, following construction, will be used as filter strips, grass channels, or stormwater treatment areas; MUST include soil restoration or placement of engineered soil mix as per design specifications.<br>• Community open space areas that will not be mowed routinely but left in a natural vegetated state (can include areas bush hogged no more than four times per year).<br>• Utility rights-of-way that will be left in a natural vegetated state (can include areas bush hogged no more than four times per year). |

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*[Table 1…continued]*

- Surface area of extended detention (ED) pond that is not mowed routinely.
- Other areas of existing mixed open that will be protected during construction and that will remain undisturbed.

**Operational & management conditions for land cover in the Mixed Open category:**

- Undisturbed portions of yards, community open space, and other areas that will be considered as mixed open must be shown outside the limits of disturbance (LOD) on approved erosion and sediment control plans AND clearly demarcated in the field (e.g., fencing) prior to commencement of construction.
- Portions of mixed open space areas that will be disturbed during construction must follow the most recent design specifications for soil restoration, as well as other relevant specifications if the area will be used as a filter strip, grass channel, bioretention, or other BMP.
- Portions of roadway rights-of-way that will count as mixed open are assumed to be disturbed during construction, and must follow the most recent design specifications for soil restoration, as well as other relevant specifications if the area will be used as a filter strip, grass channel, bioretention, or other BMP.
- All areas that will be considered mixed open for stormwater purposes must have documentation that prescribes that the area will remain in a natural, vegetated state via the use of one of the following:
    - Appropriate documentation includes subdivision covenants and restrictions; deeded operation and maintenance agreements and plans; parcel of common ownership with maintenance plan; third-party protective easement; within public right-of-way or easement with maintenance plan; or other documentation approved by the local program authority.
    - For utility rights-of-way that will be left in a natural vegetated state, a detailed decompaction and planting plan indicating no areas will be bush hogged more than four times per year.
- Although the goal is to have mixed open areas remain undisturbed, some activities may be prescribed in the appropriate documentation, as approved by the local program authority:
    - Control of invasive species, replanting and revegetating, passive recreation (e.g., trails), limited bush hogging to maintain desired vegetative community, etc.

**MANAGED TURF**

**Land disturbed and/or graded for eventual use as managed turf:**

- Portions of residential yards that are graded or disturbed, including yard areas, septic fields, residential utility connections, etc.
- Roadway rights-of-way that will be mowed and maintained as turf.
- Turf areas intended to be mowed and maintained as turf within residential, commercial, industrial, and institutional settings.

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*[Table 1….continued]*

| IMPERVIOUS COVER |
|---|
| • Roadways, driveways, rooftops, parking lots, sidewalks, and other impervious areas.<br>• This category also includes the surface area of stormwater BMPs that: (1) are wet ponds OR (2) replace an otherwise impervious surface (e.g., green roof, pervious parking) [1]. |
| [1]Pre-redevelopment areas that are undisturbed and naturally vegetated are considered forest in the redevelopment spreadsheet.<br>[2]Certain stormwater BMPs are considered impervious with regard to the land cover computations. These BMPs are still assigned Runoff Reduction and/or Pollutant Removal rates within the spreadsheet, so their "values" for stormwater management are still accounted for. The reason they are considered impervious is that they either do not reduce runoff volumes (e.g., wet ponds) OR their Runoff Reduction rates are based on comparison to a more conventional land cover type (e.g., green roofs, pervious parking). |

Whenever post-development land cover is entered in the *Forest* or *Mixed Open* rows of the ***Land Cover*** table, a notification will appear below the table reminding the user that Forest and Mixed Open areas must be protected in accordance with the Virginia Runoff Reduction Method (see Fig. 3). Users should review the Forest and Mixed Open definitions and be familiar with protection and maintenance requirements if these land cover types are proposed (see Table 1).

**Using the VRRM spreadsheet *(Site tab)***

**5.** Enter the post-development acreages of each land cover type by soil group (**cells B12 to E15**).

*Emphasis should be placed on environmental design principles during the early phases of project development. If Forest or Mixed Open is used, take note of pop-up message in **cell A16**.*

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## 3.2. SITE TAB – COMPUTATIONS

This section addresses the intermediate and final calculated results related to the site nutrient loads (**grey cells** and **indigo cells**, respectively). These include the post-development site land cover summary, as well as the treatment volume, TP and TN loads, and TP load reduction requirement for the site (Table 2).

**Table 2. Site Tab Computations (New Development)**

| Site Tab Computations | Cell Reference |
|---|---|
| **Land Cover Summary**<br>Totals of user inputs for each land cover type | **Grey Cells** |
| **Totals: Forest, Mixed Open, Managed Turf, Impervious Cover (acres)**<br>Sums of each land cover type area across HSGs | **F12 & B27** (F)<br>**F13 & B30** (MO)<br>**F14 & B33** (MT)<br>**F15 & B36** (IC) |
| **Weighted Rv for Forest, Mixed Open, Managed Turf, Impervious Cover***<br>Runoff coefficient weighted across land cover types and HSGs<br>**Runoff coefficient for impervious cover is independent of HSGs*<br>*Equation 1.1a, 1.2a, 1.3a* | **B28** (F)<br>**B31** (MO)<br>**B34** (MT)<br>**B37** (IC) |
| **%Forest, %Mixed Open, %Managed Turf, %Impervious Cover**<br>Percentage coverage for each land cover type across HSGs<br>*Equation 1.1b,1.2b,1.3b* | **B29** (F)<br>**B32** (MO)<br>**B35** (MT)<br>**B38** (IC) |
| **Total Site Area (acres)**<br>Area summed across land cover types and HSGs | **F16 & B39** |
| **Site Rv**<br>Composite runoff coefficient across land cover types and HSGs<br>*Equation 2* | **B40** |
| **Treatment Volume**<br>Post-development treatment volumes in acre-feet and cubic feet calculated using the target rainfall event, site Rv, and site area<br>*Equation 3* | **H27** (acre-ft)<br>**H28** (cf) |
| **Site Loads** (lb/yr)<br>Site post-development TP load and TN load (informational only). Loads are computed using the ***Land Cover*** table (**cells B12-E15**) and the ***Phosphorus*** and ***Nitrogen Loading Rate*** tables in the Constants tab.<br>*Equation 4* | **H29** (TP load)<br>**H30** (TN load) |
| **Post-development requirement for Total Site Area** (lb/yr)<br>The total TP load reduction required for compliance for the total site. This is the difference between the post-development TP load and the site-based load limit of 0.26 lb TP/ac/yr established by the VESMR regulations (*9VAC25-875-580*).<br>*Equation 5* | **Indigo Cells**<br>**E21**<br>*Land cover data must be entered for result to calculate* |

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**Using the VRRM spreadsheet *(Site tab)***

**6.** Take note of the post-development TP reduction requirement in **cell E21**.

a. This requirement is a site-based water quality requirement and unlike water quantity control requirements, which must be met at each of the site's stormwater discharge points (per *9VAC25-875-600*), the TP load reduction requirement may be met using various **Drainage Area tab** load reduction combinations, unless restricted as per *9VAC25-875-590 E.*

b. Depending on the post-development land cover type and HSGs, the site may or may not require further TP load reduction to meet the water quality compliance requirements.

If the computed TP load reduction requirement (**cell E21**) is:

i. Less than or equal to zero (site is at or below the 0.26 lb/ac/yr load limit), the site's TP load meets water quality compliance requirements. A message will appear in **cell G21**: **TP load reduction is not required;**

ii. Greater than zero (site is above the 0.26 lb/ac/yr load limit), **cell E21** will reflect the TP load reduction required for site compliance.

**7.** If **cell E21** is greater than zero, proceed to **Drainage Area tab**.

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## 4.0 SITE TAB (REDEVELOPMENT)

The VESMR regulations refer to redevelopment as development on prior developed lands. In accordance with *9VAC25-875-10*:

> "Prior developed lands" means land that has been previously utilized for residential, commercial, industrial, institutional, recreation, transportation, or utility facilities or structures, and that will have the impervious areas associated with those uses altered during a land-disturbing activity."

The water quality requirements for redevelopment (*9VAC25-875-580 A 2*) apply to those projects where impervious areas, as part of the existing conditions, are altered during the course of construction, as applicable to regulated land-disturbing activities.

The basic structure of the VRRM Redevelopment Compliance Spreadsheet and the VRRM New Development Compliance Spreadsheet are similar. One of the main differences between the two spreadsheets is the computation of the site TP load reduction requirement on the **Site tab**, which for redevelopment projects, other than linear projects, is determined by whether there is an increase in net impervious cover.

When there is *no net increase* in impervious cover from the predevelopment condition, the post-development TP load must simply be reduced to below the predevelopment TP load by either 10 or 20% depending on the total area of land disturbance in accordance with *9VAC25- 875-580 A 2 a and A 2 b*.

When there is a *net increase* in impervious cover from the predevelopment condition, the new net impervious area must meet the TP new development load limitation of 0.26 lb/ac/yr in accordance with *9VAC25-875-580 A 2 c*, and the post-development TP load for the remaining area of the site must be reduced to below the predevelopment TP load of the same area by either 10 or 20% depending on the total area of land disturbance (per *9VAC25-875-580 A 2 a and A 2 b*).

When the redevelopment project is a linear project, the post-development TP load must be reduced to 20% below the predevelopment TP load irrespective of any increase in impervious cover per *9VAC25-875-580 A 2 d*. It should be noted that impervious areas included within the site of a linear redevelopment project must be undergoing alteration during the land disturbing activity as per the definition of "prior developed lands" (*9VAC25-875-10*) provided above. Users should also note the definition of routine maintenance, which is not considered redevelopment in *§ 62.1-44.15:34.G.2* for the purposes of compliance with the water quantity and water quality technical criteria:

> "Routine maintenance that is performed to maintain the original line and grade, hydraulic capacity, or original construction of the project. The paving of an existing road with a

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compacted or impervious surface and reestablishment of existing associated ditches and shoulders shall be deemed routine maintenance if performed in accordance with this subsection;[…]"

**Summary**

- Any new net impervious areas must meet 0.26 lb TP/acre/year
- Total disturbed area < 1 acre, 10% TP load reduction required for remainder of site
- Total disturbed area ≥ 1 acre, 20% TP load reduction required for remainder of site
- Linear projects, 20% TP load reduction required for site

Compared to the New Development Site tab, the TP load computations for the Redevelopment **Site tab** require additional user inputs and result in a more complex look for the tab. The Redevelopment **Site tab** also has different cell references (locations of cells or cell ranges within sheet tabs) for similar elements. This section highlights and describes the similarities and differences between the two spreadsheets.

Once the load reduction requirement for the redevelopment site has been determined, the procedures for using the spreadsheet (**Drainage Area tabs**, **Water Quality Compliance tab**, **Runoff Volume and CN tab**, **Summary tab, Constants tab, and Notes tab**) are the same as those of for the New Development Compliance Spreadsheet described in this document. Any **Summary tab** dissimilarities reflect the distinct regulatory requirements and computations between new development and redevelopment.

## 4.1. WHAT'S SIMILAR?

The land cover categories of *Forest, Mixed Open, Managed Turf,* and *Impervious Cover* and the corresponding definitions are the same as those for the new development computations (see Table 1 in Section 3.1).

The constants, **yellow cells**, as found on the 'Constants' tab are similarly used and defined in both spreadsheets. For the full list of constants and their cell references in both the New Development and Redevelopment spreadsheets, see Section 9.0.

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## 4.2. WHAT'S DIFFERENT?

### *4.2.1. SITE TAB (REDEVELOPMENT) – LAND COVER AREA INPUTS*

Whereas the New Development Spreadsheet requires the user to input post-development land cover areas, the Redevelopment Spreadsheet requires the user to input existing (*prior to redevelopment*) and post-development (*following redevelopment*) land cover areas, as well as the total disturbed area (Table 3). Consequently, area checks are included in the **Site tab** along with an error notification summary to the right of the ***Land Cover*** tables for user inputs that are missing or in error. Furthermore, spreadsheet calculated results will not populate until all user errors are reconciled (See Figs. 4 to 7).

As noted in Section 4.0, the redevelopment water quality criteria include a percent reduction requirement (for existing site areas not replaced by new net impervious cover), which is dependent on the total land disturbance acreage being either (i) less than or (ii) greater than or equal to one acre.

It is important for the user to understand that both spreadsheets (Redevelopment and New Development) use the site area for load calculations. In the case of redevelopment, the site area may or may not be the same as the total disturbed area. For example, if post-development areas are being preserved as forest or mixed open, then the site area will be greater than the disturbed acreage. The user should check with the VESMR authority for any applicable restrictions that could limit available options.

One feature included in the Redevelopment Spreadsheet is the option to indicate a linear development project by selecting "Yes" from the dropdown menu directly below the ***Date*** field of the **Site tab**. This will set the TP percent load reduction requirement at 20% (final TP load must be at least 20% below the pre-redevelopment TP load). (See Figs. 8 and 9). A separate section for linear project water quality compliance results will appear in both the **Water Quality Compliance tab** and the **Summary tab** when a linear project is indicated on the **Site tab** (See related figures in Sections 6 and 8).

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**Table 3. Redevelopment Spreadsheet – Site Tab, Land Cover Areas**

| Redevelopment Land Cover Areas | Cell Reference |
|---|---|
| **Total Disturbed Acreage**<br>User input for the redevelopment percent reduction standard (< 1 acre requires 10%, ≥1 acre requires 20% reduction).<br>*Acreage entered can be limited to land disturbance or extended to a larger site area.*<br>Results will not calculate (**rows 44-67**) and message prompts appear in **cell E65** and **row 10** if disturbed acreage not entered (Fig. 7). | Green Cells<br>**F10** |
| **Final results/compliance information** per *9VAC25-875-580 A 2*.<br>**Maximum reduction required** (10 or 20%)<br>**Site's net increase in impervious cover (acres)**<br>**Post-Development TP Load Reduction for Site (lb/yr)** | Indigo Cells<br>**F12**<br>**F13**<br>**F14** |
| **Pre-Redevelopment Land Cover (acres)**<br>User inputs for existing conditions (prior developed lands):<br>**Forest, Mixed Open, Managed Turf, Impervious Cover (acres)**<br>Entries of each existing land cover type area across HSGs | Green Cells<br>**B17 - E17** (F)<br>**B18 - E18** (MO)<br>**B19 - E19** (MT)<br>**B20 – E20** (IC) |
| **Pre-Redevelopment Land Cover Totals (acres)**<br>Sums of each land cover type area across HSGs | Grey Cells<br>**F17** (F), **F18** (MO)<br>**F19** (MT), **F20** (IC)<br>**F21** (Total) |
| **Post-Development Land Cover (acres)**<br>User inputs for post-development conditions:<br>**Forest, Mixed Open, Managed Turf, Impervious Cover (acres)**<br>Entries of each proposed land cover type area across HSGs | Green Cells<br>**B25 - E25** (F)<br>**B26 - E26** (MO)<br>**B27 - E27** (MT)<br>**B28 - E28** (IC) |
| **Post-Development Land Cover Totals (acres)**<br>Sums of each land cover type area across HSGs | Grey Cells<br>**F25** (F), **F26** (MO)<br>**F27** (MT), **F28** (IC)<br>**F29** (Total) |
| **AREA CHECK**<br>Pre-Redevelopment and Post-Development land cover areas must equal for each HSG (soil type does not change).<br>**OK.** message when area totals are equal.<br>**Check Areas!** message when area totals are not equal. Results (**rows 44 to 67**) will not appear until all area errors resolved.<br>**Cells H10-K14** provide summary of user input errors | Grey Cells<br>**B29** (A Soils)<br>**C29** (B Soils)<br>**D29** (C Soils)<br>**E29** (D Soils) |

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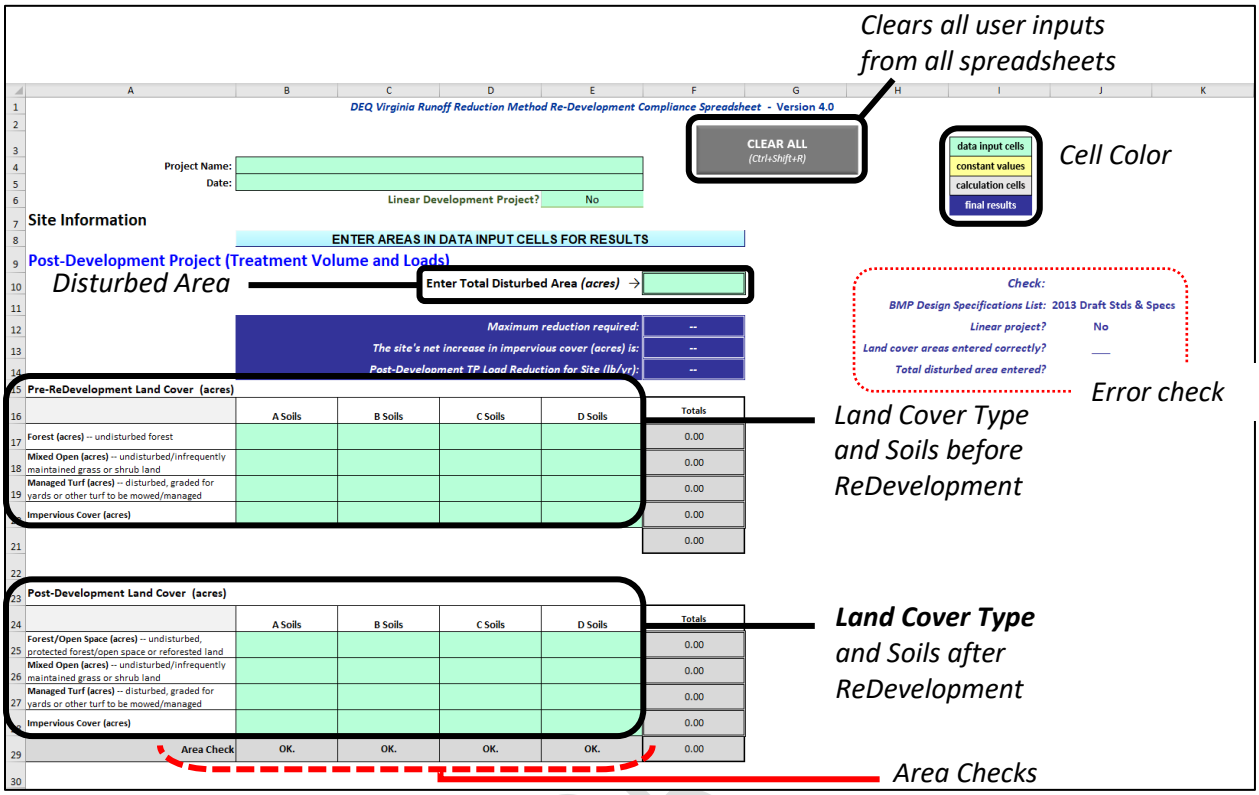


**Figure 4. VRRM Redevelopment Compliance Spreadsheet – Site Tab (upper cells).**

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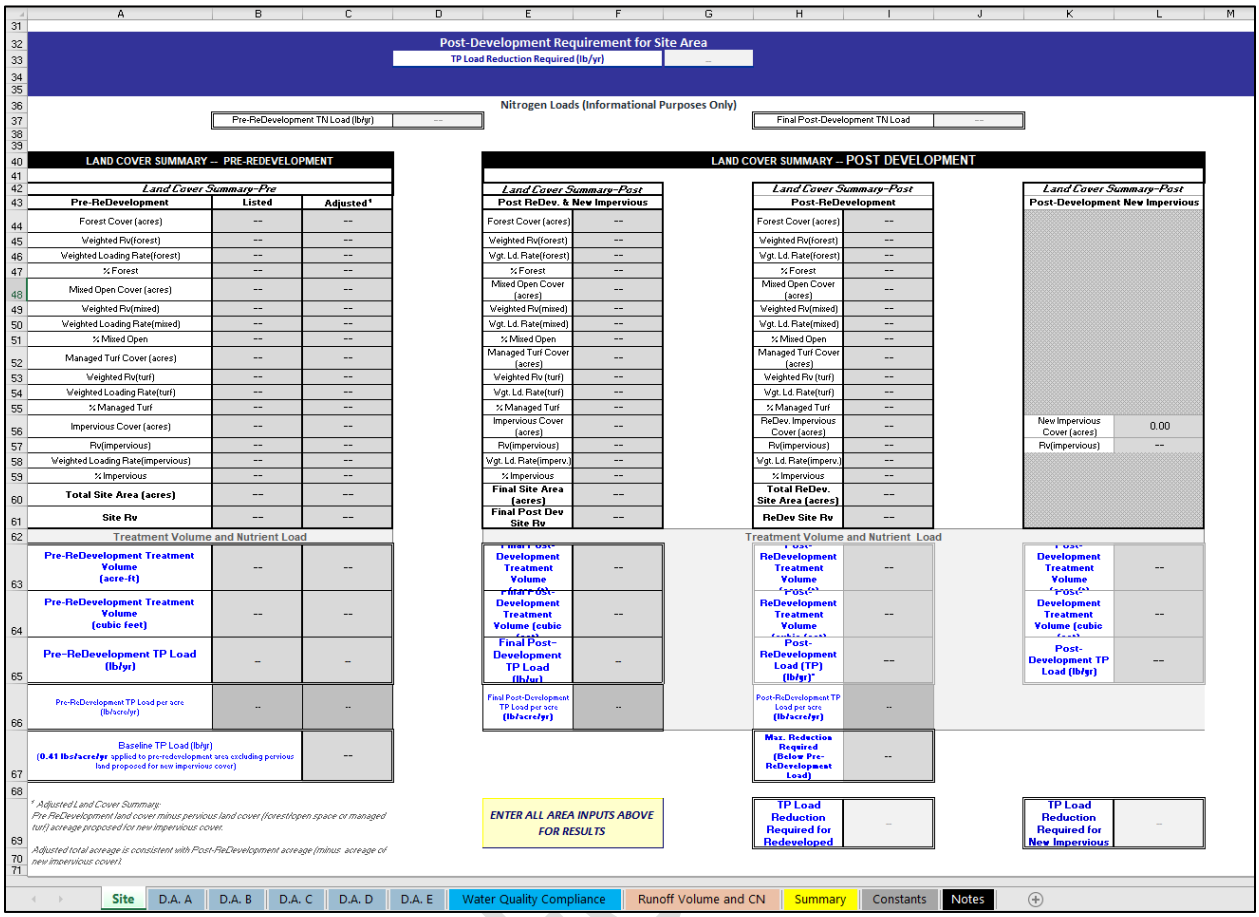

Post-Development Requirement for Site Area

| TP Load Reduction Required (lb/yr) | -- |
|---|---|

Nitrogen Loads (Informational Purposes Only)

| Pre-ReDevelopment TN Load (lb/yr) | -- |
|---|---|

| Final Post-Development TN Load | -- |
|---|---|

LAND COVER SUMMARY -- PRE-REDEVELOPMENT

| *Land Cover Summary-Pre* Pre-ReDevelopment | Listed | Adjusted* |
|---|---|---|
| Forest Cover (acres) | -- | -- |
| Weighted Rv(forest) | -- | -- |
| Weighted Loading Rate(forest) | -- | -- |
| % Forest | -- | -- |
| Mixed Open Cover (acres) | -- | -- |
| Weighted Rv(mixed) | -- | -- |
| Weighted Loading Rate(mixed) | -- | -- |
| % Mixed Open | -- | -- |
| Managed Turf Cover (acres) | -- | -- |
| Weighted Rv(turf) | -- | -- |
| Weighted Loading Rate(turf) | -- | -- |
| % Managed Turf | -- | -- |
| Impervious Cover (acres) | -- | -- |
| Rv(impervious) | -- | -- |
| Weighted Loading Rate(impervious) | -- | -- |
| % Impervious | -- | -- |
| **Total Site Area (acres)** | -- | -- |
| **Site Rv** | -- | -- |
| Treatment Volume and Nutrient Load | | |
| **Pre-ReDevelopment Treatment Volume (acre-ft)** | -- | -- |
| **Pre-ReDevelopment Treatment Volume (cubic feet)** | -- | -- |
| **Pre-ReDevelopment TP Load (lb/yr)** | -- | -- |
| Pre-ReDevelopment TP Load per acre (lb/acre/yr) | -- | -- |
| Baseline TP Load (lb/yr) (**0.41 lbs/acre/yr** applied to pre-redevelopment area excluding pervious land proposed for new impervious cover) | | -- |

* *Adjusted Land Cover Summary:*
*Pre ReDevelopment land cover minus pervious land cover (forest/open space or managed turf) acreage proposed for new impervious cover.*

*Adjusted total acreage is consistent with Post-ReDevelopment acreage (minus acreage of new impervious cover).*

LAND COVER SUMMARY -- POST DEVELOPMENT

| *Land Cover Summary-Post* Post-ReDev. & New Impervious | |
|---|---|
| Forest Cover (acres) | -- |
| Weighted Rv(forest) | -- |
| Wgt. Ld. Rate(forest) | -- |
| % Forest | -- |
| Mixed Open Cover (acres) | -- |
| Weighted Rv(mixed) | -- |
| Wgt. Ld. Rate(mixed) | -- |
| % Mixed Open | -- |
| Managed Turf Cover (acres) | -- |
| Weighted Rv (turf) | -- |
| Wgt. Ld. Rate(turf) | -- |
| % Managed Turf | -- |
| Impervious Cover (acres) | -- |
| Rv(impervious) | -- |
| Wgt. Ld. Rate(imperv.) | -- |
| % Impervious | -- |
| **Final Site Area (acres)** | -- |
| **Final Post Dev Site Rv** | -- |
| Treatment Volume and Nutrient Load | |
| **Final Post-Development Treatment Volume (acre-ft)** | -- |
| **Final Post-Development Treatment Volume (cubic feet)** | -- |
| **Final Post-Development TP Load (lb/yr)** | -- |
| Final Post-Development TP Load per acre (lb/acre/yr) | -- |

| *Land Cover Summary-Post* Post-ReDevelopment | |
|---|---|
| Forest Cover (acres) | -- |
| Weighted Rv(forest) | -- |
| Wgt. Ld. Rate(forest) | -- |
| % Forest | -- |
| Mixed Open Cover (acres) | -- |
| Weighted Rv(mixed) | -- |
| Wgt. Ld. Rate(mixed) | -- |
| % Mixed Open | -- |
| Managed Turf Cover (acres) | -- |
| Weighted Rv (turf) | -- |
| Wgt. Ld. Rate(turf) | -- |
| % Managed Turf | -- |
| ReDev. Impervious Cover (acres) | -- |
| Rv(impervious) | -- |
| Wgt. Ld. Rate(imperv.) | -- |
| % Impervious | -- |
| **Total ReDev. Site Area (acres)** | -- |
| **ReDev Site Rv** | -- |
| Treatment Volume and Nutrient Load | |
| **Post-ReDevelopment Treatment Volume (acre-ft)** | -- |
| **Post-ReDevelopment Treatment Volume (cubic feet)** | -- |
| **Post-ReDevelopment Load (TP) (lb/yr)*** | -- |
| Post-ReDevelopment TP Load per acre (lb/acre/yr) | -- |
| **Max. Reduction Required (Below Pre-ReDevelopment Load)** | -- |
| **TP Load Reduction Required for Redeveloped** | -- |

| *Land Cover Summary-Post* Post-Development New Impervious | |
|---|---|
| New Impervious Cover (acres) | 0.00 |
| Rv(impervious) | -- |
| **Post-Development Treatment Volume (acre-ft)** | -- |
| **Post-Development Treatment Volume (cubic feet)** | -- |
| **Post-Development TP Load (lb/yr)** | -- |
| **TP Load Reduction Required for New Impervious** | -- |

***ENTER ALL AREA INPUTS ABOVE FOR RESULTS***

Site | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Water Quality Compliance | Runoff Volume and CN | Summary | Constants | Notes

**Figure 5. VRRM Redevelopment Compliance Spreadsheet – Site Tab (lower cells) – *Land Cover Areas and Total Disturbed Acreage not entered.***

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*Pre-Redevelopment Land Cover Summary (listed and adjusted)*

*Post-Development Land Cover Summary*

| Post-Development Requirement for Site Area | |
|---|---|
| TP Load Reduction Required (lb/yr) | 6.85 |

*Site Load Reduction*

Nitrogen Loads (Informational Purposes Only)

| | |
|---|---|
| Pre-ReDevelopment TN Load (lb/yr) | 62.09 |
| Final Post-Development TN Load | 103.33 |

**LAND COVER SUMMARY -- PRE-REDEVELOPMENT**

| *Land Cover Summary-Pre* | | |
|---|---|---|
| Pre-ReDevelopment | Listed | Adjusted[1] |
| Forest Cover (acres) | 3.00 | 2.00 |
| Weighted Rv(forest) | 0.02 | 0.02 |
| Weighted Loading Rate(forest) | 0.05 | 0.05 |
| % Forest | 25% | 22% |
| Mixed Open Cover (acres) | 3.00 | 2.00 |
| Weighted Rv(mixed) | 0.15 | 0.15 |
| Weighted Loading Rate(mixed) | 0.34 | 0.34 |
| % Mixed Open | 25% | 22% |
| Managed Turf Cover (acres) | 3.00 | 2.00 |
| Weighted Rv(turf) | 0.15 | 0.15 |
| Weighted Loading Rate(turf) | 0.34 | 0.34 |
| % Managed Turf | 25% | 22% |
| Impervious Cover (acres) | 3.00 | 3.00 |
| Rv(impervious) | 0.95 | 0.95 |
| Weighted Loading Rate(impervious) | 2.16 | 2.16 |
| % Impervious | 25% | 33% |
| **Total Site Area (acres)** | **12.00** | **9.00** |
| **Site Rv** | **0.32** | **0.39** |

Treatment Volume and Nutrient Load

| | | |
|---|---|---|
| Pre-ReDevelopment Treatment Volume (acre-ft) | 0.3175 | 0.2908 |
| Pre-ReDevelopment Treatment Volume (cubic feet) | 13,830 | 12,669 |
| **Pre-ReDevelopment TP Load (lb/yr)** | **8.68** | **7.95** |
| Pre-ReDevelopment TP Load per acre (lb/acre/yr) | 0.72 | 0.88 |
| Baseline TP Load (lb/yr) (0.41 lbs/acre/yr applied to pre-redevelopment area excluding pervious land proposed for new impervious cover) | | 3.69 |

[1] *Adjusted Land Cover Summary:*
*Pre ReDevelopment land cover minus pervious land cover (forest/open space or managed turf) acreage proposed for new impervious cover.*

*Adjusted total acreage is consistent with Post-ReDevelopment acreage (minus acreage of new impervious cover).*

**LAND COVER SUMMARY -- POST DEVELOPMENT**

*Post-Redevelopment & New Impervious*

| *Land Cover Summary-Post (Final)* | |
|---|---|
| Post ReDev. & New Impervious | |
| Forest Cover (acres) | 2.00 |
| Weighted Rv(forest) | 0.02 |
| Wgt. Ld. Rate(forest) | 0.05 |
| % Forest | 17% |
| Mixed Open Cover (acres) | 2.00 |
| Weighted Rv(mixed) | 0.15 |
| Wgt. Ld. Rate(mixed) | 0.34 |
| % Mixed Open | 17% |
| Managed Turf Cover (acres) | 2.00 |
| Weighted Rv (turf) | 0.15 |
| Wgt. Ld. Rate(turf) | 0.34 |
| % Managed Turf | 17% |
| Impervious Cover (acres) | 6.00 |
| Rv(impervious) | 0.95 |
| Wgt. Ld. Rate(imperv.) | 2.16 |
| % Impervious | 50% |
| **Final Site Area (acres)** | **12.00** |
| **Final Post Dev Site Rv** | **0.53** |

*Post-Redevelopment (not including new net*

| *Land Cover Summary-Post* | |
|---|---|
| Post-ReDevelopment | |
| Forest Cover (acres) | 2.00 |
| Weighted Rv(forest) | 0.02 |
| Wgt. Ld. Rate(forest) | 0.05 |
| % Forest | 22% |
| Mixed Open Cover (acres) | 2.00 |
| Weighted Rv(mixed) | 0.15 |
| Wgt. Ld. Rate(mixed) | 0.34 |
| % Mixed Open | 22% |
| Managed Turf Cover (acres) | 2.00 |
| Weighted Rv (turf) | 0.15 |
| Wgt. Ld. Rate(turf) | 0.34 |
| % Managed Turf | 22% |
| ReDev. Impervious Cover (acres) | 3.00 |
| Rv(impervious) | 0.95 |
| Wgt. Ld. Rate(imperv.) | 2.16 |
| % Impervious | 33% |
| **Total ReDev. Site Area (acres)** | **9.00** |
| **ReDev Site Rv** | **0.39** |

*Post-development (not including new net impervious)*

| *Land Cover Summary-Post* | |
|---|---|
| Post-Development New Impervious | |
| New Impervious Cover (acres) | 3.00 |
| Rv(impervious) | 0.95 |

***Site tab***

Treatment Volume and Nutrient Load

| | | | | | |
|---|---|---|---|---|---|
| Final Post-Development Treatment Volume (acre-ft) | 0.5283 | Post-ReDevelopment Treatment Volume (acre-ft) | 0.2908 | Post-Development Treatment Volume (acre-ft) | 0.2375 |
| Final Post-Development Treatment Volume (cubic feet) | 23,014 | Post-ReDevelopment Treatment Volume (cubic feet) | 12,669 | Post-Development Treatment Volume (cubic feet) | 10,346 |
| **Final Post-Development TP Load (lb/yr)** | **14.44** | Post-ReDevelopment Load (TP) (lb/yr)* | **7.95** | Post-Development TP Load (lb/yr) | **6.49** |
| Final Post-Development TP Load per acre (lb/acre/yr) | 1.20 | Post-ReDevelopment TP Load per acre (lb/acre/yr) | 0.88 | | |
| | | Max. Reduction Required (Below Pre-ReDevelopment Load) | 20% | | |
| | | TP Load Reduction Required for Redeveloped Area (lb/yr) | **1.59** | TP Load Reduction Required for New Impervious Area (lb/yr) | **5.26** |

**Figure 6. VRRM Redevelopment Site Tab (lower cells) – *Land Cover Areas and Total Disturbed Acreage entered.***

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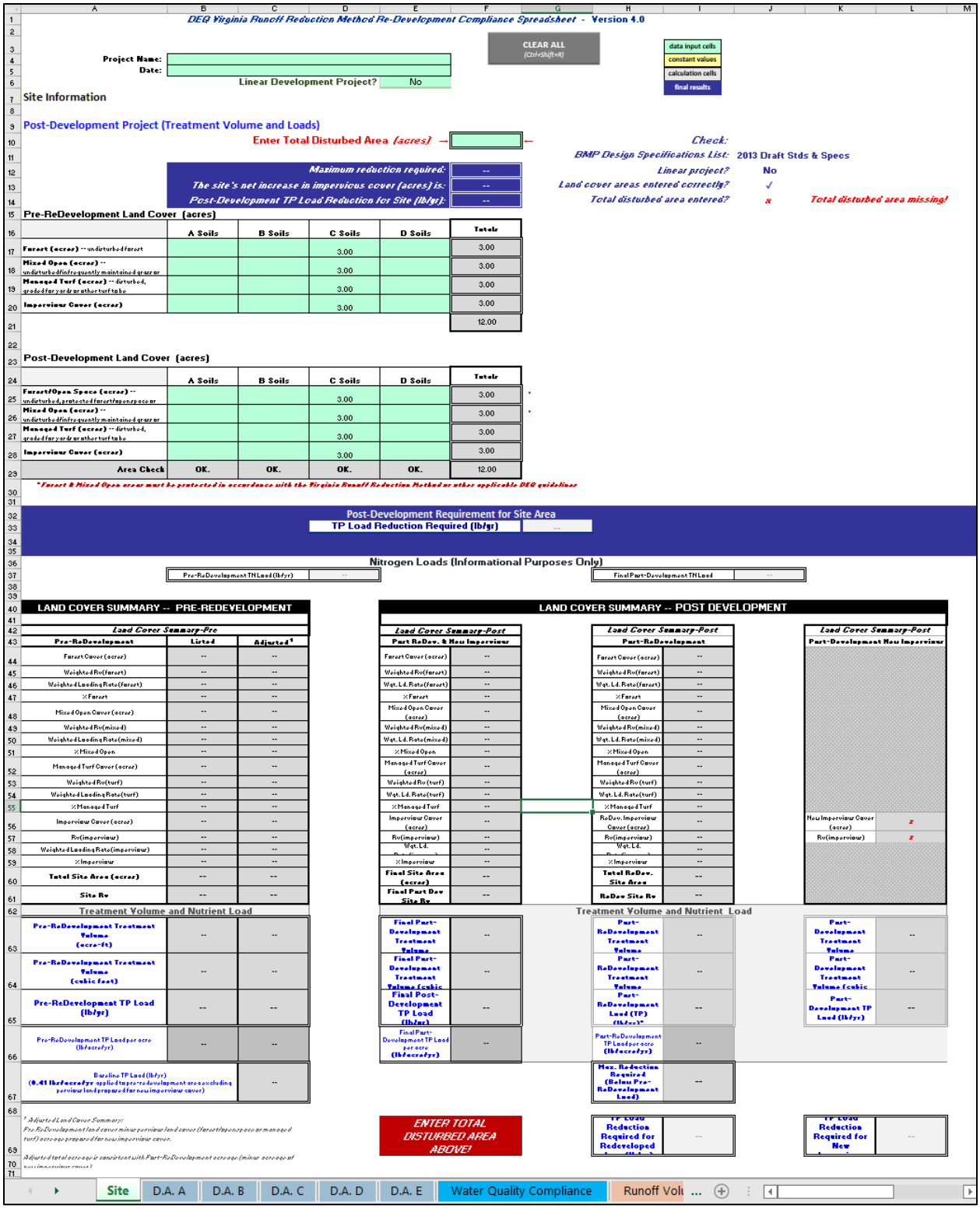


**Figure 7. VRRM Redevelopment Site Tab (lower cells) –** ***Land Cover Areas entered; Total Disturbed Acreage not entered.***

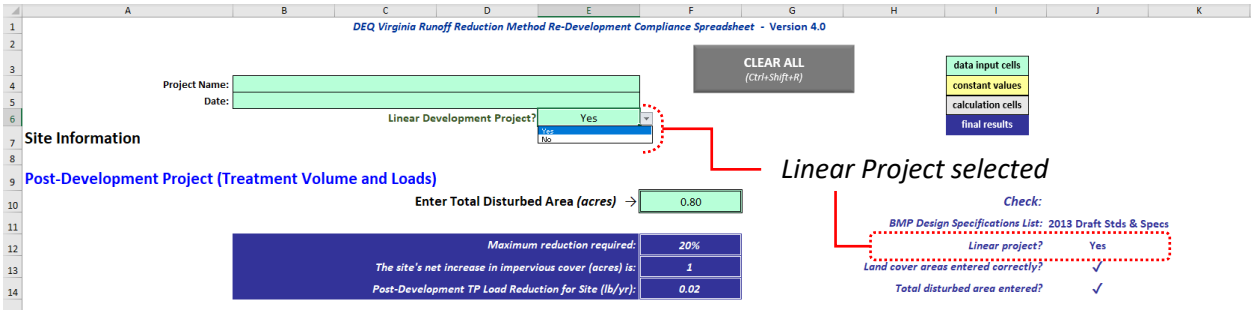


**Figure 8. VRRM Redevelopment Site Tab (upper cells) – *Linear Development Project selected.***

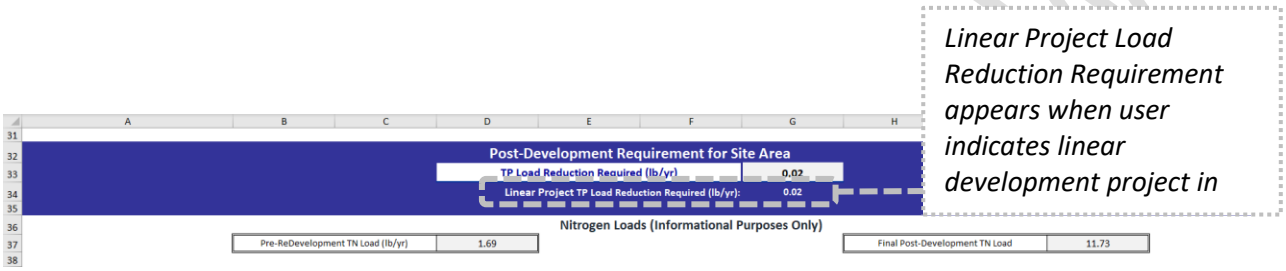


**Figure 9. VRRM Redevelopment Site Tab (lower cells) – *Linear Development Project selected.***

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### *4.2.2. SITE TAB (REDEVELOPMENT) – LAND COVER SUMMARIES*

The ***Redevelopment Spreadsheet*** differs from the New Development Spreadsheet in that the Land Cover Summaries, found at the lower portion of the **Site tab**, are organized into land cover summary information for the pre-redevelopment condition (***Land Cover Summary-Pre***) and the post-redevelopment condition (***Land Cover Summary-Post***) (Figs. 6 and 7). In addition, both pre-redevelopment and post-development are further subdivided as follows:

***Land Cover Summary-Pre***

- ***Pre-Redevelopment – Listed:*** Cells B44-B61 represent information derived directly from the pre-redevelopment land cover areas entered in the ***Pre-Redevelopment Land Cover*** table. See Table 4 for computations and cell references.
- ***Pre-Redevelopment – Adjusted:*** Cells C44-C61 reflect the pre-redevelopment land cover areas after excluding pervious areas (Forest, Mixed Open, and/or Managed Turf) that will be converted to new net impervious cover (Table 5). If there is no post-development increase in net impervious cover, then there is no adjustment to the land cover areas entered by the user for pre-redevelopment, and the adjusted cells are the same as the listed cells.
  The Adjusted Pre-Redevelopment data are needed to compute the site's baseline TP load (cell C67, based on 0.26 lb/acre/year applied to the pre-redevelopment area excluding pervious land proposed for new impervious cover).

***Land Cover Summary-Post***

- ***(Final) Post-Redevelopment & New Impervious:*** Cells F44-F61 represent the entire post-development site, which is the combination of the post-redevelopment land cover areas and any new net impervious cover area (Table 6).
- ***Post-Redevelopment:*** Cells I44-I61 represent the post-development land cover areas entered in the ***Post-Development Land Cover*** table, excluding any new net impervious cover area (Table 7).
- ***Post-Development New Impervious:*** Cells L56-L57 represent the post-development new net impervious cover (Table 8).

The ***Listed*** and ***Adjusted Pre-Redevelopment*** computed site data in the ***Land Cover Summary-Pre*** section of the **Site tab** is needed to facilitate the computation of distinct water quality criteria applicable to different portions of the site in a single spreadsheet, without overlap.

Tables 4 to 8 list the computational areas of the ***Redevelopment*** **Site tab** with cell references. Brief descriptions are included where differences exist with the ***New Development*** **Site tab**.

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**Table 4. Site Tab Computations for Land Cover Summary (Pre-Redevelopment, Listed)**

| Site Tab Computations<br>**Land Cover Summary – Pre Redevelopment (Listed)** | Cell Reference<br>**Column B** |
|---|---|
| The land cover summary for the existing conditions (prior developed lands): | |
| **Totals: Forest, Mixed Open, Managed Turf, Impervious Cover (acres)** | **B44** (F)<br>**B48** (MO)<br>**B52** (MT)<br>**B56** (IC) |
| **Weighted Rv for Forest, Mixed Open, Managed Turf, Impervious Cover** | **B45** (F)<br>**B49** (MO)<br>**B53** (MT)<br>**B57** (IC) |
| **Weighted Nutrient Loading Rate for Forest, Mixed Open, Managed Turf, Impervious Cover** | **B46** (F)<br>**B50** (MO)<br>**B54** (MT)<br>**B58** (IC) |
| **%Forest, %Mixed Open, %Managed Turf, %Impervious Cover** | **B47** (F)<br>**B51** (MO)<br>**B55** (MT)<br>**B59** (IC) |
| **Total Site Area (acres)** | **B60** |
| **Site Rv** | **B61** |
| **Treatment Volume** | **B63** (acre-ft)<br>**B64** (cf) |
| **Pre-Redevelopment TP Load**<br>Site pre-redevelopment TP load computed using land cover areas and the ***Phosphorus Loading Rates*** table in the **Constants tab** | **B65** (lb/yr) |
| The lb/acre/yr TP loading rate is also included for comparison purposes. | **B66** (lb/acre/yr) |

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**Table 5. Site Tab Computations for Land Cover Summary (Pre-Redevelopment, Adjusted)**

| Site Tab Computations<br>**Land Cover Summary – Pre Redevelopment (Adjusted)** | Cell Reference<br>**Column C** |
|---|---|
| Where redevelopment results in a net increase in impervious cover, the existing land cover data is adjusted by subtracting out any pervious acreage proposed for new net impervious cover, if applicable. For redevelopment that does *not* result in a net increase in impervious cover, the Adjusted and Listed Land Cover Summaries are the same. | |
| **Totals: Forest, Mixed Open, Managed Turf, Impervious Cover (acres)** | **C44** (F)<br>**C48** (MO)<br>**C52** (MT)<br>**C56** (IC) |
| **Weighted Rv for Forest, Mixed Open, Managed Turf, Impervious Cover** | **C45** (F)<br>**C49** (MO)<br>**C53** (MT)<br>**C57** (IC) |
| **Weighted Nutrient Loading Rate for Forest, Mixed Open, Managed Turf, Impervious Cover** | **C46** (F)<br>**C50** (MO)<br>**C54** (MT)<br>**C58** (IC) |
| **%Forest, %Mixed Open, %Managed Turf, %Impervious Cover** | **C47** (F)<br>**C51** (MO)<br>**C55** (MT)<br>**C59** (IC) |
| **Total Site Area (acres)** | **C60** |
| **Site Rv** | **C61** |
| **Treatment Volume** | **C63** (acre-ft)<br>**C64** (cf) |
| **Pre-Redevelopment TP Load**<br>Adjusted site pre-redevelopment TP load using the adjusted land cover areas.<br>The lb/acre/yr TP loading rate is also included for comparison purposes. | **C65 (lb/yr)**<br><br>**C66 (lb/acre/yr)** |
| **Baseline TP Load (lb/yr)**<br><br>The new development TP standard of 0.26 lb/acre/yr is applied to the adjusted pre-redevelopment total site area (existing area excluding pervious areas proposed as new net impervious cover). This is also the baseline TP load for the post-redevelopment area excluding new net impervious cover. | **C67** |

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**Table 6. Site Tab Computations for Land Cover Summary (Final Post-Development)**

| Site Tab Computations<br>**Land Cover Summary – Post *(Final)*** | Cell Reference<br>**Column F** |
|---|---|
| The final post-development land cover summary represents the total site area (all land cover areas including new net impervious cover). | |
| **Totals: Forest, Mixed Open, Managed Turf, Impervious Cover (acres)** | **F44** (F)<br>**F48** (MO)<br>**F52** (MT)<br>**F56** (IC) |
| **Weighted Rv for Forest, Mixed Open, Managed Turf, Impervious Cover** | **F45** (F)<br>**F49** (MO)<br>**F53** (MT)<br>**F57** (IC) |
| **Weighted Nutrient Loading Rate for Forest, Mixed Open, Managed Turf, Impervious Cover** | **F46** (F)<br>**F50** (MO)<br>**F54** (MT)<br>**F58** (IC) |
| **%Forest, %Mixed Open, %Managed Turf, %Impervious Cover** | **F47** (F)<br>**F51** (MO)<br>**F55** (MT)<br>**F59** (IC) |
| **Final Site Area (acres)** | **F60** |
| **Final Post Dev Site Rv** | **F61** |
| **Final Post-Development Treatment Volume** | **F63** (acre-ft)<br>**F64** (cf) |
| **Final Post-Development TP Load**<br><br>Site post-redevelopment TP load (excluding new net impervious cover). The TP loading rate (lb/acre/yr) is also included for comparison purposes. | **F65** (lb/yr)<br><br>**F66** (lb/acre/yr) |

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**Table 7. Site Tab Computations for Land Cover Summary (Post-Redevelopment)**

| Site Tab Computations<br>**Land Cover Summary – Post-Redevelopment** | Cell Reference<br>**Column I** |
|---|---|
| The post-redevelopment land cover summary represents land cover area entered by the user as post-redevelopment, not including new net impervious cover. | |
| **Totals: Forest, Mixed Open, Managed Turf, Impervious Cover (acres)** | **I44** (F)<br>**I48** (MO)<br>**I52** (MT)<br>**I56** (IC) |
| **Weighted Rv for Forest, Mixed Open, Managed Turf, Impervious Cover** | **I45** (F)<br>**I49** (MO)<br>**I53** (MT)<br>**I57** (IC) |
| **Weighted Nutrient Loading Rate for Forest, Mixed Open, Managed Turf, Impervious Cover** | **I46** (F)<br>**I50** (MO)<br>**I54** (MT)<br>**I58** (IC) |
| **%Forest, %Mixed Open, %Managed Turf, %Impervious Cover** | **I47** (F)<br>**I51** (MO)<br>**I55** (MT)<br>**I59** (IC) |
| **Total ReDev Site Area (acres)** | **I56** |
| **ReDev Site Rv** | **I57** |
| **Post-Redevelopment Treatment Volume** | **I60** (acre-ft)<br>**I61** (cf) |
| **Final Post-Development TP Load**<br>Site post-redevelopment TP load (excluding new net impervious cover). The TP loading rate (lb/acre/yr) is also included for comparison purposes. | **I65** (lb/yr)<br>**I66** (lb/acre/yr) |
| **Max. Reduction Required (Below Pre-Redevelopment Load)**<br>The applicable percent reduction standard (based on the Total Disturbed Acreage **(cell F10)** entered by the user). | **I67**<br>(10 or 20%) |
| **TP Load Reduction Required for Redeveloped Area (lb/yr)**<br>The TP load reduction requirement for the redeveloped area (proposed site not including new net impervious cover)<br>If the adjusted pre-redevelopment TP load after application of the required percent reduction is below the baseline load for the adjusted pre-redevelopment area, then:<br>- The required post-development load cannot be less than the baseline load unless a more stringent standard has been established by a local VESMR authority.<br>- A notification just below **cell I65** will appear:<br>***Reduction below baseline TP Load (0.26 lb/acres) not required** | **I69**<br><br>*Equations 22a & 22b* |

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**Table 8. Site Tab Computations for Land Cover Summary (Post-Redevelopment, New Impervious)**

| Site Tab Computations<br>**Land Cover Summary – Post Redevelopment New Impervious** | **Cell Reference**<br>**Column L** |
|---|---|
| The post-redevelopment land cover summary for any new net impervious cover (populates only when there is an increase in net impervious cover). | |
| **Totals: New Impervious Cover (acres)** | **L56** |
| **Rv for Impervious Cover** | **L57** |
| **Post-Development Treatment Volume** | **L63** (acre-ft)<br>**L64** (cf) |
| **Post-Development TP Load**<br>Post-development TP load for new net impervious cover. | **L65** (lb/yr) |
| **TP Load Reduction for New Impervious Area (lb/yr)**<br>The required TP load reduction for new net impervious area based on the new development TP load limit of 0.26 lb/acre/yr (*9VAC25-875-580 A 2 c*).<br><br>*Equations 19 and 20* | **L69** |

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### *4.2.3. SITE TAB (REDEVELOPMENT) – WATER QUALITY REQUIREMENTS*

There are two water quality criteria for redevelopment projects under the VESMR regulations (*9VAC25-875-580 A 2 a to c*). Compliance is achieved as follows:

- For new net impervious cover (cell L56), the total phosphorus load must be reduced to meet the new development criteria of 0.26 lb TP/acre/yr, and
- For the remaining site area (not including any new net impervious cover), the total phosphorus load must be reduced to either 10 or 20% below the pre-redevelopment total phosphorus load, depending on the project's total disturbed acreage (cell F10). The reduction requirement is either:
    - 10% if the total disturbed acreage is less than 1 acre, or
    - 20% if the total disturbed acreage is greater than or equal to 1 acre.
    - *Both of these reduction requirements are limited, in that a reduction to below the applicable standard for new development (0.26 lb TP/acre/yr) cannot be required unless a more stringent standard is established by a local VESMR authority (9VAC25-875-580 A 2 e).*

The ***Redevelopment spreadsheet*** automatically calculates the required reductions as soon as the total disturbed area and land cover areas are entered with no errors (See Table 9).

The rest of this section further explains and highlights the logic used for the redevelopment load computations. The area and load equations (Eq. 19-23), and a decision flowchart for the spreadsheet computations (Fig. 28) are provided in Section 9.4.

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**Table 9. Site Tab Computations for Total Site Area Post-Development**

| Site Tab Computations<br>**Post-Development Requirement for Total Site Area** | Cell Reference<br>Indigo Cells |
|---|---|
| **TP Load Reduction Required (lb/yr)**<br>The total phosphorus load reduction that must be met to comply with the water quality requirements for redevelopment:<br>The post-development load reduction requirement equals the reduction required for the redeveloped area (excluding pervious area conversions to net impervious cover) listed in **cell I65** plus the reduction required to meet the new development standard for any new net impervious cover listed in **cell L65**.<br><br>The required post-development load cannot be less than the post-development baseline load (0.26 lb TP/acre/yr) unless a more stringent standard has been established by a local VESMR authority.<br>- A notification in **cells H33-I33** or **H34-I34 (**for linear projects) will appear when:<br>***** TP LOAD REDUCTION NOT REQUIRED***<br><br>*Equation 23* | **G33**<br>**G34 (linear)** |
| **Nitrogen Summary (Informational Purposes) (lb/yr)**<br>TN loads provided for informational purposes only: | |
| Pre-Redevelopment TN load | **D37** |
| Post-Redevelopment + Post-Development (New Impervious) TN load | **J37** |

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In order to calculate the TP load requirement for the redevelopment project, it is necessary to establish:

1) The increase in net impervious cover proposed (if applicable).
2) The pervious land cover areas (Forest, Mixed Open, and/or Managed Turf) that will be converted to new net impervious cover (if any), as applicable.
3) The minimum regulatory (or baseline) TP load for the adjusted total site area (pre-redevelopment site area not including pervious areas converted to impervious cover).
4) The least stringent TP load requirement for the post-redevelopment site area (not including any new net impervious area, if applicable).

These three necessary steps for the computation of the TP load requirement are explained in detail below:

1) ***The increase in net impervious cover proposed (if applicable)*** (cell L56) is determined in order to apply the new development 0.26 lb/acre/yr TP load limitation to any new net increases in impervious cover as per *9VAC25-875-580 A 2 c*. (see also Eq. 19 in Section 9.4).
2) ***The pervious land cover areas (Forest, Mixed Open, and/or Managed Turf) that will be converted to new net impervious cover (if applicable)*** are determined for exclusion from the pre-redevelopment TP load calculation (adjusted pre-redevelopment) to ensure that both water quality criteria are not simultaneously applied to new net impervious cover areas.
   The net decrease in pervious land cover areas occurs as a result of the net increase in impervious cover (Fig. 10). *The total pre-redevelopment and post-development site acreages (cell F21 and F29), which sum the user input pre- and post-redevelopment land cover areas (rows 17-20 and 25-28, respectively), must be equal in order to enable the spreadsheet computation of the appropriate load requirements.*

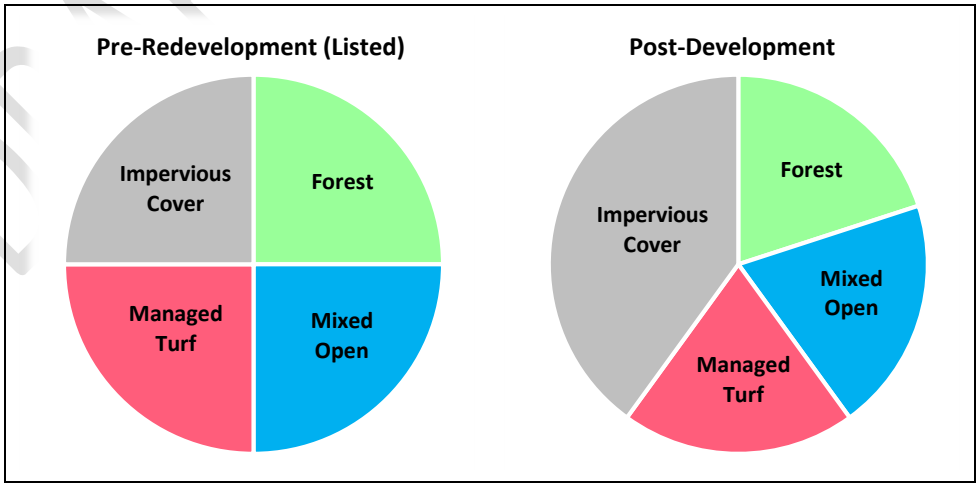


**Figure 10. User listed pre-development and post-development land cover areas.**

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The pervious areas that are converted to impervious cover are excluded from the adjusted pre-redevelopment areas (cells C44, C48, and C52) and the pre-redevelopment TP load (Fig. 11). The equation used to determine the net decrease in pervious areas (Eq. 21) and decision flowchart (Fig. 28) for the spreadsheet computation are presented in Section 9.4.1.

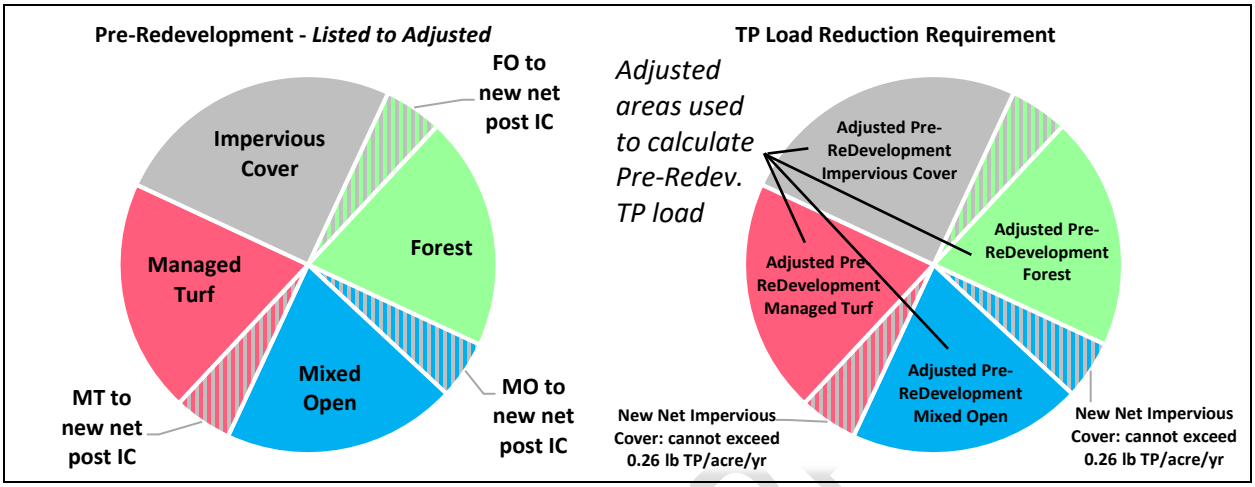


**Figure 11. Pre-redevelopment land cover areas showing changes from *Listed* to *Adjusted* spreadsheet land cover areas and applicable TP load reduction requirements.**

3) ***The minimum regulatory (or baseline) TP load for the adjusted pre-redevelopment area*** is the new development standard of 0.26 lb TP/acre/yr multiplied by the adjusted total site acreage, cell C67. The adjusted pre-redevelopment area equals the post-redevelopment area minus any new net impervious area, if applicable. This baseline TP load is the most stringent load that can be required for water quality compliance of the post-redevelopment area (not including any new net impervious area, if applicable).
4) The target TP load of the pre-redevelopment adjusted area (*the TP load after 10 or 20% reduction, i.e., 80 or 90% of the TP load for the pre-redevelopment adjusted area, respectively*), is compared to the baseline TP load, and the least stringent becomes the required compliance load for the post-redevelopment area, not including any new net impervious area, if applicable.

The regulations do not require a post-development TP load below the new development standard of 0.26 lb TP/acre/yr for any part of the site, unless a more stringent standard has been established by the VESMR authority.

Two examples are graphically represented in Fig. 12 to illustrate when each of the two different load reduction requirements apply. Both examples show TP loads for re-development sites with more than one acre of disturbance. Example 1 in Fig. 12 shows a site where the adjusted pre-redevelopment TP load reduced by 20% (orange, short-dashed line) is the required post-development compliance load (with no net increases in impervious cover). Example 2 in Fig. 12 shows a site where the new development criteria

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of 0.26lb TP/acre/yr (black, long-dashed line) applied to the pre-redevelopment adjusted site area is the required post-development compliance load (with no net increases in impervious cover). See also Eqns. 22a and 22b in Section 9.4.1.

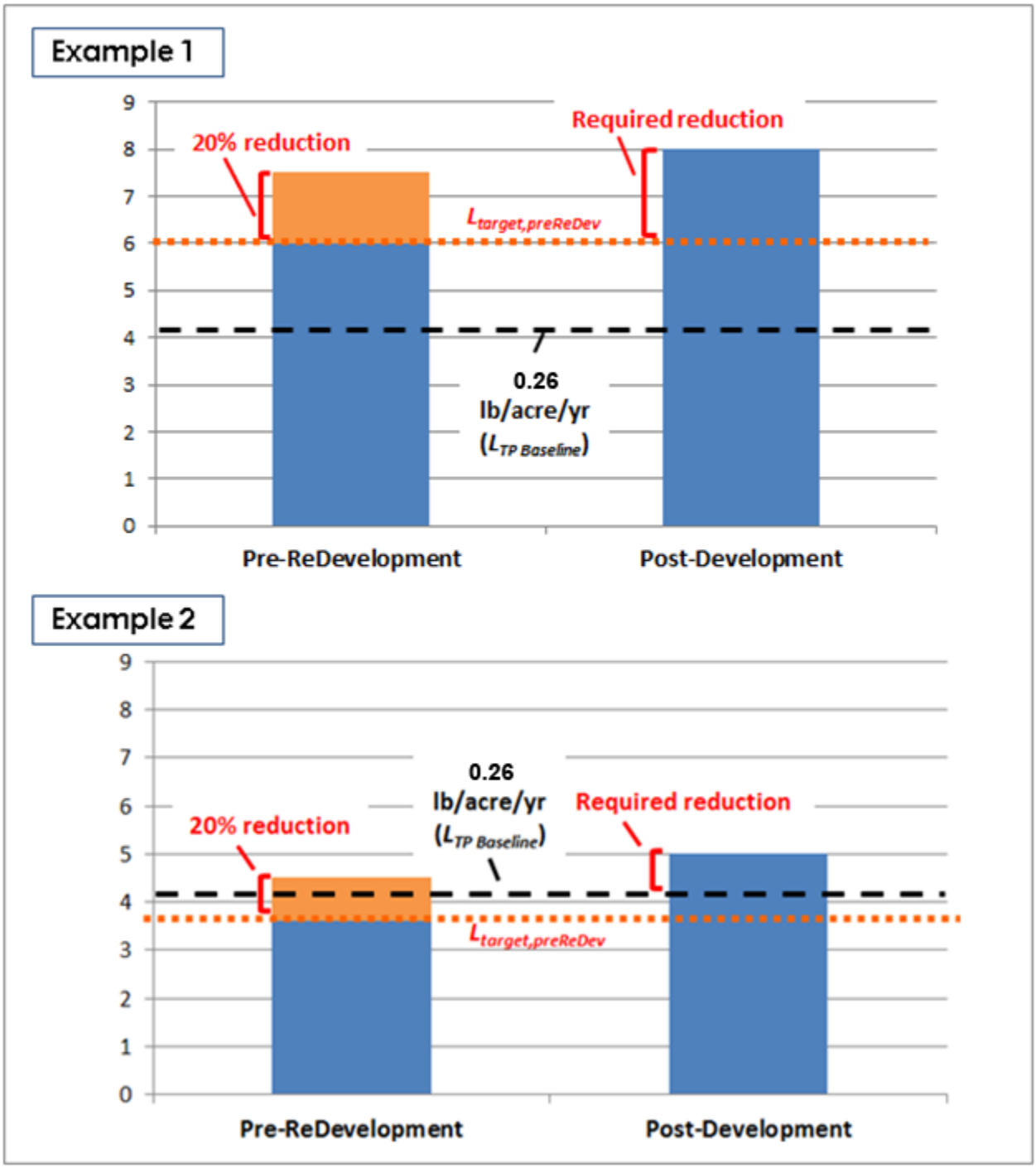



**Figure 12. Reduction requirements for redevelopment projects (no new net impervious cover).**

**Using the VRRM spreadsheet *(Redevelopment Site tab)***

RD1. Enter Total Disturbed Acreage (**cell F10**)

RD2. Enter Pre-Redevelopment land cover based on existing conditions (conditions at the time an application is submitted).

RD3. Enter Post-Redevelopment Land Cover based on proposed conditions.

RD4. Any error notifications (**cells H10-K14**) or Check Areas! messages (**row 29**) must be resolved before proceeding.

RD5. Take note of the **Indigo Cells** indicating maximum reduction required (**cell F12**), the site's net increase in impervious cover (**cell F13**), the post-development TP reduction requirement in **cell F14,** and also **G33** within the indigo results section (**rows 32-35**).

a. As noted in Step 6 for New Development, the post-development TP reduction requirement is a site-based water quality requirement and can be met using various **Drainage Area tab** load reduction combinations.

b. Depending on the post-development and pre-redevelopment land cover areas, TP load reduction within the **Drainage Area tabs** may or may not be needed to meet water quality compliance requirements.

If the post-redevelopment TP load, **cell I65**, (which excludes new net impervious cover) is less than the target pre-redevelopment TP load or the TP baseline (see Equations 22a and 22b), then no further TP load reduction is required for the redevelopment portion of the site, and:

i. A TP load credit will appear as a negative value in **cell I69** *(see Section 9.4 for more information).*

ii. If sufficient, such load credit will be applied to offset TP reduction requirements for any new net impervious cover (**cell L69**), which will reduce the TP load reduction requirement for the total site (**cell G33**).

## 5.0 DRAINAGE AREA (D.A.) TABS

The VRRM spreadsheet contains five **Drainage Area tabs (D.A. A to E)** that allow the user to enter land cover data (land cover type by HSGs) for separate **Drainage Area tabs (D.A. tabs)** and to select stormwater BMPs for water quality compliance via runoff volume reduction, pollutant removal, or both (Fig. 13). The **D.A. tabs** do not reference each other, but the information and computations within each **Drainage Area tab** are combined in the **Water Quality Compliance tab**, the **Runoff Volume and CN tab**, and the **Summary tab**.

**Using the VRRM spreadsheet *(Drainage Area tab)***

**8.** Determine how many **Drainage Area tabs** are to be used to evaluate site water quality compliance. Site compliance may be achieved within one drainage area, a portion of a drainage area, or in multiple drainage areas (limited by the TP load available per drainage area):

a. Each **Drainage Area tab** can reflect a site drainage area with a distinct discharge point from the site, or

b. Similar BMP credit areas for the same type of practice(s) (areas of the site draining to specific BMPs or BMP treatment trains) can be grouped together on one **Drainage Area tab** even if they exist within different site drainage areas as long as:

   i. Treatment volumes for each individual BMP ($TV_{BMP}$) are calculated separately; and

   ii. Any managed turf areas draining to separate BMPs within a grouping must have the same runoff coefficient, i.e., different managed turf areas must all have the same HSG configurations (total areas per HSG*)* in order to be grouped together.
   *(only applied when managed turf areas are draining to more than one practice in the grouping)*.

c. Nutrient removal within each **Drainage Area tab** is limited by the nutrient available for removal within that **Drainage Area tab** (varies with load generated for that **Drainage Area tab**, which is based on user inputs for **D.A. tab** land cover types by HSGs). TP available for removal is computed in **cell N8** within each **Drainage Area tab**.

d. Discretion should be exercised if drainage areas or sub-drainage areas with different flow path times of concentration (Tc) are grouped together in a single **D.A. tab.**

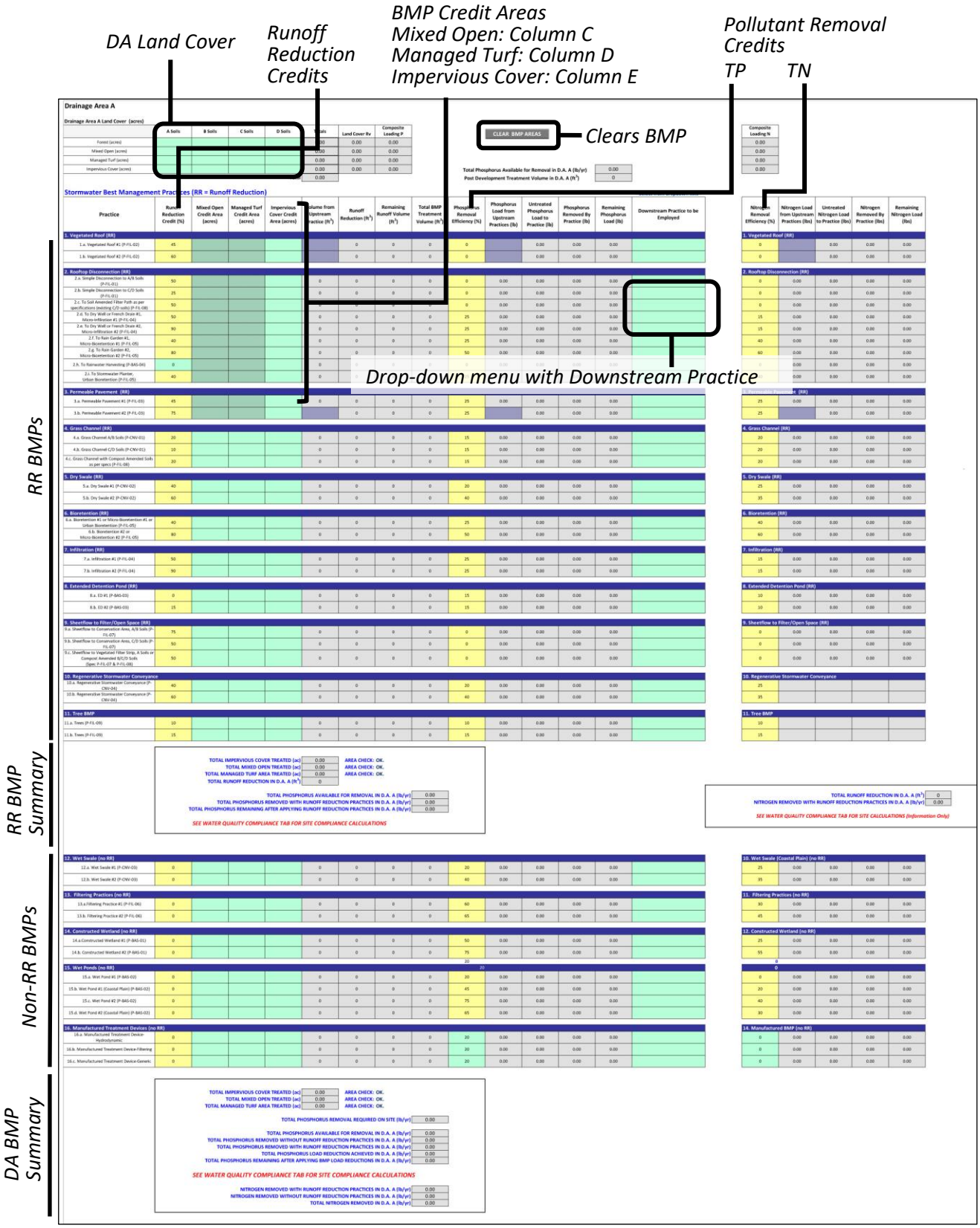
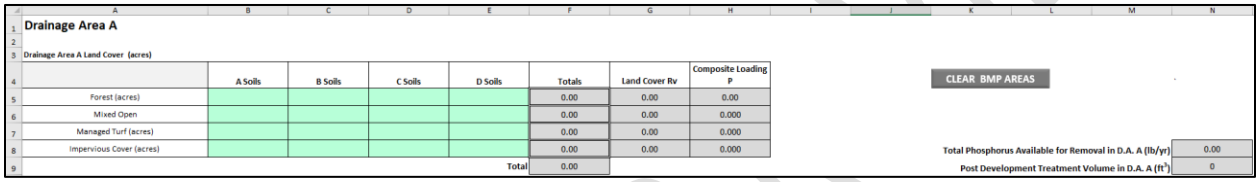



**Figure 13. Drainage Area Tab (sections).**

## 5.1. DRAINAGE AREA TAB LAND COVER AREAS

The land cover data at the top of the **Drainage Area tab** is similar to that on the **Site tab** in that acreages are entered for each land cover type by HSGs (Fig. 14). Land cover area input should be made using HSG determinations reflecting the ultimate pre-development soil conditions (i.e. soil types adjusted for compaction and/or soil importing). If only one **Drainage Area tab** is used to evaluate water quality compliance for the entire site, then the land cover data on the **Drainage Area tab** should match the land cover data on the **Site tab, with the exception of the HSG which should be adjusted as previously indicated, if applicable**. Alternatively, the sum of the total land cover data entered on multiple **Drainage Area tabs** should equal the total land cover data entered on the **Site tab**. For the Redevelopment Spreadsheet, the total land cover inputs **on all Drainage Area tabs** used should equal the total post-development land cover data entered on the **Site tab**.



**Drainage Area A**

Drainage Area A Land Cover (acres)

| | A Soils | B Soils | C Soils | D Soils | Totals | Land Cover Rv | Composite Loading P |
|---|---|---|---|---|---|---|---|
| Forest (acres) | | | | | 0.00 | 0.00 | 0.00 |
| Mixed Open | | | | | 0.00 | 0.00 | 0.000 |
| Managed Turf (acres) | | | | | 0.00 | 0.00 | 0.000 |
| Impervious Cover (acres) | | | | | 0.00 | 0.00 | 0.000 |
| | | | | Total | 0.00 | | |

CLEAR BMP AREAS

Total Phosphorus Available for Removal in D.A. A (lb/yr) 0.00

Post Development Treatment Volume in D.A. A ($ft^3$) 0

**Figure 14. Drainage Area Tab, Land Cover Areas.**

**Using the VRRM spreadsheet *(Drainage Area tab – Land Cover Areas)***

9. Click on the **CLEAR BMP AREAS** button to reset all BMP credit areas to zero.
10. Enter land cover data in **cells B5 to E8** at the top of the **Drainage Area tab** (acreages entered for each land cover type by HSGs). The land cover data must be entered on the **Drainage Area tab** in order to allow all of the **grey cells** to auto-calculate in this tab and within other tabs (e.g., **Water Quality Compliance tab, Runoff Volume and CN tab**).
    *Note that the* **CLEAR BMP AREAS** *button does not clear land cover data (***B5 to E8***), which may only change slightly if users are trying different BMP configurations within the* **Drainage Area tab**.

## 5.2. DRAINAGE AREA LAND COVER SUMMARY

The computations at the top of the **Drainage Area tab** (Fig. 14 and Table 10) provide land cover summary information, treatment volume, and total phosphorus loading for the overall **Drainage Area tab**.

**Table 10. Drainage Area Tab Computations for Land Cover Summary**

| Drainage Area Tab Computations – Land Cover Summary | Cell Reference<br>Grey Cells |
|---|---|
| **Forest/Open Space, Managed Turf, Impervious Cover (acres)**<br>Sums of each land cover type area across hydrologic soil groups | **F5** (F)<br>**F6** (MO)<br>**F7** (MT)<br>**F8** (IC) |
| **Total Land Cover Area (acres)**<br>Area summed across land cover types and HSGs | **F9** |
| **Weighted Rv for Forest, Mixed Open, Managed Turf, Impervious Cover***<br>Runoff coefficient for each land cover type weighted across HSGs<br>**Runoff coefficient for impervious cover is independent of HSGs* | **G5** (F)<br>**G6** (MO)<br>**G7** (MT)<br>**G8** (IC) |
| **Composite Nutrient Loadings for Forest, Mixed Open, Managed Turf, Impervious Cover***<br>Composite nutrient loading for each land cover type weighted across HSGs<br>**Composite Loading for impervious cover is independent of HSGs* | **TP** **N**<br>**H5** (F) **R5** (F)<br>**H6** (MO) **R6** (MO)<br>**H7** (MT) **R7** (MT)<br>**H8** (IC) **R8** (IC) |
| **Total Phosphorus Available for Removal in DA (lb/yr)**<br>The post-development TP load generated from MT and IC areas and, thus available for removal from the Drainage Area tab.<br>Similar to loads calculated on the Site tab, D.A. loads are computed using the CAST loading rates. This D.A. TP load available for removal does not include loads generated from Forest areas.<br>*Equation 7*<br>*(Note: It is unlikely that TP releases from Forest areas are in a form that can be practically removed via current BMPs; computed TP loads from Forest areas are approximately 0.01 lb TP/acre/yr and far below the new development load limit of 0.26 lb TP/acre/yr).* | **N8** |
| **Post-Development Treatment Volume from DA ($ft^3$)**<br>Post-development treatment volume available for runoff reduction within the D.A. tab land cover area (MO, MT and IC areas only**).<br>*Equation 6*<br>***Forest areas used for curve number calculations computed on the Runoff Vol CN tab.* | **N9** (cf) |

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## 5.3. DRAINAGE AREA TAB STORMWATER BMPS

Whereas ESD principles can be applied to a site, in terms of proposed land cover types (i.e., maximizing forest, mixed open and permeable soils, and minimizing managed turf and impervious cover over impacted soils), often additional measures are required to meet water quality compliance. All or a portion of a site or site's drainage area can be treated using non-proprietary or proprietary stormwater management BMPs approved by DEQ for use in Virginia. Stormwater management BMP's are listed along with their approved runoff removal credits, treatment efficiencies and design specifications in the Virginia Stormwater Management Handbook (see Section 1.0).

The approved BMPs are listed in two groups: I) Stormwater BMPs with Runoff Reduction (RR) (see 5.3.2, Table 11), and II) Stormwater BMPs with No Runoff Reduction (No RR) (see 5.3.3, Table 12). Group I practices reduce the pollutant load through volume reduction of the site's runoff or treatment volume, and possibly also through a reduction of the runoff pollutant concentration via non-volumetric pollutant removal treatment (e.g., settling or filtration). Group II practices are limited to non-volumetric pollutant removal treatment for pollutant load reductions. The BMPs are thus grouped to highlight those practices that provide runoff volume reduction (first half) and those that do not. This grouping is used in the BMP list provided in Tables 11 and 12, reflected in both VRRM spreadsheets.

### *5.3.1. BMP DESIGN LEVELS*

Several of the BMPs can be constructed to two different design level standards, typically with differing runoff removal credits and/or treatment removal efficiencies. The Level 1 and Level 2 design standards are included in the BMP design specifications and are individually indicated after the BMP name where they apply as #1 (Level 1) and #2 (Level 2) in column A of the **Drainage Area tab**. Each BMP's approved runoff removal credit is listed in column B. The approved treatment removal efficiencies are listed in column J (Total Phosphorus) and column R (Total Nitrogen).

It is important to review and understand the design criteria associated with the Level 1 and Level 2 designations. Level 2 practices will generally provide greater load reductions; they may also require a larger footprint, specific soil conditions, greater engineering effort, and other factors for correct implementation. BMP selection and design guidance, including designated Level 1 and Level 2 criteria, can be found in the BMP Specifications.

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### *5.3.2. RUNOFF REDUCTION BMPS*

**Table 11. Stormwater Best Management Practices – with Runoff Reduction**

| **I. Stormwater BMPs with Runoff Reduction**<br>(Pollutant removal via runoff reduction w/wo non-volumetric treatment) | **BMP Design Spec. (DA Tab Cell Ref.)** |
|---|---|
| **1. Vegetated Roof**<br>a. Vegetated Roof #1<br>b. Vegetated Roof #2 | Spec. P-FIL-02<br>**(rows 14-15)** |
| **2. Rooftop Disconnection**<br>a. Simple Disconnection to A/B Soils<br>b. Simple Disconnection to C/D Soils<br>c. Alternative Practice Disconnection to C/D soils with Soil Amended Filter Path<br>d. Alternative Practice Disconnection to Dry Well/French Drain #1<br>e. Alternative Practice Disconnection to Dry Well/French Drain #2<br>f. Alternative Practice Disconnection to Rain Garden #1<br>g. Alternative Practice Disconnection to Rain Garden #2<br>h. Alternative Practice Disconnection to Rainwater Harvesting*<br>i. Alternative Practice Disconnection to Stormwater Planter | Spec. P-FIL-01<br>**(rows 18-26)** |
| **3. Permeable pavement**<br>a. Permeable pavement #1<br>b. Permeable pavement #2 | Spec. P-FIL-03<br>**(rows 29-30)** |
| **4. Grass channel**<br>a. Grass Channel A/B Soils<br>b. Grass Channel C/D Soils<br>c. Grass Channel with Compost Amended Soils | Spec. P-CNV-01<br>**(rows 33-35)** |
| **5. Dry swale**<br>a. Dry swale #1<br>b. Dry swale #2 | Spec. P-CNV-02<br>**(rows 38-39)** |
| **6. Bioretention**<br>a. Bioretention #1 or Micro-Bioretention #1 or Urban Bioretention<br>b. Bioretention #2 or Micro-Bioretention #2 | Spec. P-FIL-05<br>**(rows 42-43)** |
| **7. Infiltration**<br>a. Infiltration #1<br>b. Infiltration #2 | Spec. P-FIL-04<br>**(rows 46-47)** |
| **8. Extended detention pond**<br>a. ED #1 b. ED #2 | Spec. P-BAS-03<br>**(rows 50-51)** |
| **9. Sheetflow to Filter/Open Space**<br>a. Sheetflow to Conservation Area with A/B Soils<br>b. Sheetflow to Conservation Area with C/D Soils<br>c. Sheetflow to Vegetated Filter Strip in A Soils or Compost Amended B/C/D Soils (and Spec. No. 4) | Spec. P-FIL-07<br>**(rows 54-56)** |

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| | |
|---|---|
| **10. Regenerative Stormwater Conveyance**<br>a. Regenerative Stormwater Conveyance #1<br>b. Regenerative Stormwater Conveyance #2 | Spec. P-CNV-04<br>**(rows 59-60)** |
| **11. Trees**<br>a. Trees #1<br>b. Trees #2 | Spec. P-FIL-09<br>**(rows 63-64)** |

**** Rainwater Harvesting BMP (Spec.6) restricted to rooftop disconnection option (see 2h above & VRRM spreadsheets).***

### *5.3.3. NON-RUNOFF REDUCTION BMPS*

**Table 12. Stormwater Best Management Practices – No Runoff Reduction**

| **II. Stormwater BMPs with No Runoff Reduction**<br>(Pollutant removal through non-volumetric treatment) | **BMP Design Spec. (DA Tab Cell Ref.)** |
|---|---|
| **12. Wet Swale**<br>a. Wet Swale #1<br>b. Wet Swale #2 | Spec. P-CNV-03<br>**(rows 82-83)** |
| **13. Filtering Practices**<br>a. Filtering Practice #1<br>b. Filtering Practice #2 | Spec. P-FIL-06<br>**(rows 86-87)** |
| **14. Constructed Wetland**<br>a. Constructed Wetland #1<br>b. Constructed Wetland #2 | Spec. P-BAS-01<br>**(rows 90-91)** |
| **15. Wet Ponds**<br>a. Wet Pond #1<br>b. Wet Pond #1 (Coastal Plain)<br>c. Wet Pond #2<br>d. Wet Pond #2 (Coastal Plain) | Spec. P-BAS-02<br>**(rows 94-97)** |
| **16. Manufactured Treatment Devices (MTDs)**<br>a. Manufactured Treatment Device-Hydrodynamic<br>b. Manufactured Treatment Device-Filtering<br>c. Manufactured Treatment Device-Generic | Links to individual MTD specifications available on: VA SWM BMP Clearinghouse<br>**(rows 100-102)** |

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**Using the VRRM spreadsheet *(Drainage Area tab – BMP selection)***

**11.** Select runoff reduction BMPs (top half of **Drainage Area tab**) and then, if necessary, non-runoff reduction pollutant removal BMPs (bottom half of **Drainage Area tab**), which can include proprietary BMPs listed as Manufactured Treatment Devices.

*Starting the BMP selection process with runoff reducing BMPs followed by non-runoff reducing pollutant removal BMPs (and then utilizing a stepwise iterative process back to ESD principles) is consistent with the VRRM.*

**12.** Find the appropriate **rows** for the selected BMP(s) and enter the contributing drainage areas in acres to each of the selected BMP(s) in the Credit Area **cells** (**column C** for Mixed Open, **column D** for Managed Turf, and **column E** for Impervious Cover). Mixed Open, Managed Turf, and Impervious Cover areas must be entered separately for each BMP:

a. Forest is not treated by BMPs in accordance with the VRRM, but surface areas of certain BMPs can qualify as Forest per the VRRM land cover type definitions (Table 1), and should be entered accordingly in the Land Cover Area sections within both the **Drainage Area tab** and the **Site tab**.

   i. Natural undisturbed vegetated areas can be preserved and protected for certain BMP installations in accordance with design specifications (e.g., sheetflow to Forest, BMP Design Spec. 2); or

   ii. Land cover conversions can be performed to transform areas to one of the non-proprietary BMPs (e.g., existing buffer areas can be reforested as conservation areas or vegetated filter strips, existing mixed open or managed turf areas can be transitioned to forest via soil amendments and natural vegetation; see VRRM Land Cover Definitions and BMP Specifications for additional details).

   iii. Increasing Forest results in a reduction of generated runoff volume and consequently nutrient load for the individual **Drainage Area tab(s)** and **Site tab.**

b. Vegetated Roof, Rooftop Disconnection, and Permeable Pavement allow credit area entries for only impervious areas.

*Continued on next page…*

**Using the VRRM spreadsheet *(Drainage Area tab – BMP selection)***

c. Rooftop Disconnection to Rainwater Harvesting (2.h., Spec. No. 1) requires the user to enter a runoff volume reduction credit (**cell B25**), which is determined separately using the Cistern Design Spreadsheet (see Virginia Stormwater Handbook) or a similar method that configures storage sizing with water budget development.

d. Manufactured Treatment Devices (MTDs) (**rows 100-102**) require user entries for phosphorus removal efficiencies. The efficiencies entered for specific MTD(s) planned for use should match the DEQ approved efficiencies published on the Virginia Stormwater BMP Clearinghouse (under Proprietary BMPs section):

**13.** If BMPs are to be used in series (e.g., treatment trains):

a. The credit area draining directly to a BMP should be entered only once. The next BMP in the treatment train is selected in the same **row** as the previous receiving practice from the pull-down menu of the Downstream Practice (**columns O-P**).

*A down arrow will appear at the bottom right of the* **cell** *Downstream Practice to be Employed once that* **cell** *is selected. Clicking the arrow will allow the user to scroll and select from the menu of practice options applicable to the upstream BMP.*

b. The previous step can be repeated if additional BMPs are used in the treatment train.

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### *5.3.4. DRAINAGE AREA TAB BMP COMPUTATIONS*

As the user inputs BMP Credit Areas (columns C through E), volume and loading information for the selected BMP auto-populate in the **grey cells** of the same worksheet row (Tables 13-15). Runoff/treatment volumes and pollutant loads generated by contributing drainage area to each practice are calculated using weighted land cover coefficients for Managed Turf, Mixed Open, and Impervious Cover only. Under VRRM, BMPs do not receive credit for treating Forest areas.

**Table 13. Drainage Area Tab Volume Computations per BMP**

| **Drainage Area *Volume* Computations for each selected BMP** | **Cell References Grey Cells** |
|---|---|
| **Volume from Upstream RR Practice ($ft^3$)**<br>The runoff volume entering the selected BMP from an upstream practice (provided only when BMPs used in series).<br>*If upstream practice used: Equals remaining runoff volume (**column H**) from applicable upstream practice (auto-populates).*<br>*If **no** upstream practice used: Equals zero.* | **Column F** |
| **Runoff Reduction ($ft^3$)**<br>The runoff volume reduction achieved by the selected BMP.<br>*Equals the volume entering the practice multiplied by the runoff reduction credit.*<br>*Equation 9* | **Column G** |
| **Remaining Runoff Volume ($ft^3$)**<br>The runoff volume exiting the selected BMP (for non-RR BMPS, this is the same as the runoff volume entering practice).<br>*Equals the volume entering the practice multiplied by the proportion of runoff not being reduced (1 – runoff reduction credit).*<br>*Equation 10* | **Column H** |
| **Total BMP Treatment Volume ($ft^3$)**<br>The total runoff volume entering the practice (runoff generated by the contributing drainage area [managed turf, mixed open, and impervious areas only] to the selected BMP plus the runoff volume being received by an upstream practice [if any]).<br>*Reflects the minimum volume that the BMP must be sized for water quality treatment. Water quantity considerations will also need to be considered.***<br>*Equation 11* | **Column I** |

*****Rainwater Harvesting cistern sizing is in accordance with the Cistern Design Spreadsheet or a similar methodology rather than based on BMP Treatment Volume.***

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**Table 14. Drainage Area Tab TP Load Computations per BMP**

| Drainage Area *TP Load* Computations for each selected BMP | Cell References |
|---|---|
| **Phosphorus load from upstream practice(s) (lb)**<br>The total phosphorus load entering the selected BMP from an upstream practice (if BMPs used in series).<br>*If upstream practice used: Equals remaining phosphorus load* (**column N**) *from applicable upstream practice (auto-populates).*<br>*If **no** upstream practice used: Equals zero.* | **Column K** |
| **Untreated phosphorus load to practice (lb)**<br>The total phosphorus load generated by the contributing drainage area (or BMP credit area).<br>*The load calculated using the Phosphorus Loading Rates table in the Constants tab, as derived from Loading Rates from CAST.*<br>*Equation 12* | **Column L** |
| **Phosphorus Removed By Practice (lb)**<br>The total phosphorus load removed by the practice through any combination of runoff reduction and pollutant (treatment) reduction applicable to the selected BMP.<br>*The TP removal treatment efficiency* (**column J**) *is used to compute the proportion of phosphorus removed from the total phosphorus entering the practice.*<br>*The TP entering the practice is the sum of both the phosphorus load generated directly by the contributing drainage area (or BMP credit area) to the practice* (**column L**) *and TP contributions (or remaining phosphorus load) from any upstream practice(s)* (**column K**).<br>*Equation 13* | **Column M** |
| **Remaining Phosphorus Load (lb)**<br>The total phosphorus load that exits the practice.<br>*The total phosphorus load entering the practice (from* **column K** *and* **column L**) *minus the total phosphorus load removed by the practice (from* **column M**).<br>*Equation 14* | **Column N** |

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**Table 15. Drainage Area Tab TN Load Computations per BMP**

| Drainage Area *TN Load* Computations for each selected BMP | Cell References |
|---|---|
| **Nitrogen load from upstream practice(s) (lb)**<br>The total nitrogen load entering the selected BMP from an upstream practice (if BMPs used in series).<br>*If upstream practice used: Equals remaining nitrogen load* (**column V**) *from applicable upstream practice (auto-populates).*<br>*If **no** upstream practice used: Equals zero.* | **Column S** |
| **Untreated nitrogen load to practice (lb)**<br>The total nitrogen load generated by the contributing drainage area (or BMP credit area).<br>*The load is calculated using the Nitrogen Loading Rates table in the Constants tab, as derived from Loading Rates from CAST.*<br>*Equation 12* | **Column T** |
| **Nitrogen Removed By Practice (lb)**<br>The total nitrogen load removed by the practice through any combination of runoff reduction and pollutant (treatment) reduction applicable to the selected BMP.<br>*The TN removal treatment efficiency* (**column R**) *is used to compute the proportion of nitrogen removed from the total nitrogen entering the practice.*<br>*The TN entering the practice is the sum of both the nitrogen load generated directly by the contributing drainage area (or BMP credit area) to the practice* (**column T**) *and TN contributions (or remaining nitrogen load) from any upstream practice(s)* (**column S**).<br>*Equation 13* | **Column U** |
| **Remaining Nitrogen Load (lb)**<br>The total nitrogen load that exits the practice.<br>*The total nitrogen load entering the practice (from* **column S** *and* **column T***) minus the total nitrogen load removed by the practice (from* **column U***).*<br>*Equation 14* | **Column V** |

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### *5.3.5. DRAINAGE AREA TAB COMPUTATION SUMMARIES (RUNOFF REDUCTION BMPS AND ALL BMPS)*

There are two locations within each **Drainage Area tab** where summary information on treated areas and nutrient loads is provided: one summary for the Runoff Reduction (RR) BMPs only (rows 58-69); and one general summary for all BMPs (rows 97-115). These summaries are described in Tables 16 and 17 and shown in Figs. 15 and 16.

**Table 16. Drainage Area Tab Runoff Reduction BMP Summary**

| Drainage Area Tab – *Runoff Reduction (RR)* BMP Summary | Cell Reference |
|---|---|
| **Total Impervious Cover Treated (acres)**<br>The total impervious areas in the D.A. tab included within all selected Runoff Reduction (RR) BMP contributing areas (or BMP credit areas)<br>***Area Check*** *indicates (***OK.** *or* **AREA EXCEEDED!***) to notify if sum of all RR BMP impervious credit areas (***F59***) exceeds D.A. tab land cover inputs (***F8***)* | **F67**<br>**H67** |
| **Total Mixed Open Area Treated (acres)**<br>The total mixed open areas in the D.A. tab included within all selected RR BMP contributing areas (or BMP credit areas)<br>***Area Check*** *indicates (***OK.** *or* **AREA EXCEEDED!***) to notify if sum of all RR BMP mixed open credit areas (***F60***) exceeds D.A. tab land cover inputs (***F6***)* | **F68**<br>**H68** |
| **Total Managed Turf Area Treated (acres)**<br>The total managed turf areas in the D.A. tab included within all selected RR BMP contributing areas (or BMP credit areas)<br>***Area Check*** *indicates (***OK.** *or* **AREA EXCEEDED!***) to notify if sum of all RR BMP turf credit areas (***F61***) exceeds D.A. tab land cover inputs (***F7***)* | **F69**<br>**H69** |
| **Total Runoff Reduction ($ft^3$)**<br>The total runoff reduction volume achieved within D.A. tab by all selected RR BMPs. | **F70** |
| **Total Phosphorus Available for Removal (lb/yr)**<br>The post-development total phosphorus load generated from MO, MT, and IC areas and available for removal within D.A. tab.<br>*Repeated from* **cell N8** *and explained in more detail in Section 5.2.* | **I72** |
| **Total Phosphorus Removed With Runoff Reduction Practices (lb/yr)**<br>The total phosphorus load removed through RR BMPs within D.A. tab. | **I73** |
| **Total Phosphorus Remaining After Applying Runoff Reduction Practices (lb/yr)**<br>The total phosphorus load that still remains after user selection and application of RR BMPs in D.A. tab. | **I74** |
| **Nitrogen Summary for Runoff Reduction in D.A. Tab**<br>**Total Runoff Reduction in D.A. ($ft^3$)** *(from* **F62***)*<br>**Nitrogen Removed With Runoff Reduction Practices (lb/yr)**<br>*(similar to TP removed with RR BMPs above)* | **W72**<br>**W73** |

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**Table 17. Drainage Area Tab Total BMP Summary**

| Drainage Area Tab – *Total* BMP Summary | Cell Reference |
|---|---|
| **Total Impervious Cover Treated (acres)**<br>The total impervious areas in the D.A. tab included within all selected (RR and non-RR) BMP contributing areas (or BMP credit areas)<br>***Area Check*** *indicates (***OK.** *or* **AREA EXCEEDED!***) to notify if sum of all (RR and non-RR) BMP impervious credit areas (***F98***) exceeds D.A. tab land cover inputs (***F8***)* | **F106**<br>**H106** |
| **Total Mixed Open Area Treated (acres)**<br>The total mixed open areas in the D.A. tab included within all selected (RR and non-RR) BMP contributing areas (or BMP credit areas)<br>***Area Check*** *indicates (***OK.** *or* **AREA EXCEEDED!***) to notify if sum of all* (RR and non-RR) BMP *mixed open credit areas* (**F99**) *exceeds D.A. tab land cover inputs* (**F6**) | **F107**<br>**H107** |
| **Total Managed Turf Area Treated (acres)**<br>The total turf areas in the D.A. tab included within all selected (RR and non-RR) BMP contributing areas (or BMP credit areas)<br>***Area Check*** *indicates (***OK.** *or* **AREA EXCEEDED!***) to notify if sum of all* (RR and non-RR) BMP *turf credit areas* (**F100**) *exceeds D.A. tab land cover inputs* (**F7**) | **F108**<br>**H108** |
| **Total Phosphorus Removal Required on Site (lb/yr)**<br>The total phosphorus removal requirement for entire site (from **Site tab G33**). | **I110** |
| **Total Phosphorus Available for Removal in D.A. Tab (lb/yr)**<br>The post-development total phosphorus load generated from MO, MT and IC areas and available for removal within D.A. tab.<br>*Repeated from* **cell N8** *(and* **cell I64***) and explained in more detail in Section 5.2.* | **I112** |
| **Total Phosphorus Removed Without Runoff Reduction Practices (lb/yr)**<br>The total phosphorus load removed through non-RR BMPs within D.A. tab. | **I113** |
| **Total Phosphorus Removed With Runoff Reduction Practices (lb/yr)**<br>The total phosphorus load removed through RR BMPs within D.A. tab.*(***I65***)* | **I114** |
| **Total Phosphorus Load Reduction Achieved (lb/yr)**<br>The total phosphorus load removed through all BMPs (RR and non-RR) within the D.A. tab. *(Sum of RR and non-RR BMP TP load reductions,* **I105+I106***)* | **I115** |
| **Total Phosphorus Remaining After Applying BMP Load Reductions (lb/yr)**<br>The total phosphorus load remaining after application of all selected BMPs in D.A. tab. | **I116** |
| **Nitrogen Removal Summary for Runoff Reduction in D.A. Tab (lb/yr):**<br>**Nitrogen Removed With Runoff Reduction Practices** (from **cell W65***)*<br>**Nitrogen Removed Without Runoff Reduction Practices**<br>**Total Nitrogen Removed** | <br>**I120**<br>**I121**<br>**I122** |

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| | | |
|---|---|---|
| TOTAL IMPERVIOUS COVER TREATED (ac) | 0.00 | AREA CHECK: OK. |
| TOTAL MIXED OPEN TREATED (ac) | 0.00 | AREA CHECK: OK. |
| TOTAL MANAGED TURF AREA TREATED (ac) | 0.00 | AREA CHECK: OK. |
| TOTAL RUNOFF REDUCTION IN D.A. A ($ft^3$) | 0 | |
| TOTAL PHOSPHORUS AVAILABLE FOR REMOVAL IN D.A. A (lb/yr) | 0.00 | |
| TOTAL PHOSPHORUS REMOVED WITH RUNOFF REDUCTION PRACTICES IN D.A. A (lb/yr) | 0.00 | |
| TOTAL PHOSPHORUS REMAINING AFTER APPLYING RUNOFF REDUCTION PRACTICES IN D.A. A (lb/yr) | 0.00 | |

*SEE WATER QUALITY COMPLIANCE TAB FOR SITE COMPLIANCE CALCULATIONS*

**Figure 15. Drainage Area Tab, RR BMP Summary**

| | | |
|---|---|---|
| TOTAL IMPERVIOUS COVER TREATED (ac) | 0.00 | AREA CHECK: OK. |
| TOTAL MIXED OPEN TREATED (ac) | 0.00 | AREA CHECK: OK. |
| TOTAL MANAGED TURF AREA TREATED (ac) | 0.00 | AREA CHECK: OK. |
| TOTAL PHOSPHORUS REMOVAL REQUIRED ON SITE (lb/yr) | -- | |
| TOTAL PHOSPHORUS AVAILABLE FOR REMOVAL IN D.A. A (lb/yr) | 0.00 | |
| TOTAL PHOSPHORUS REMOVED WITHOUT RUNOFF REDUCTION PRACTICES IN D.A. A (lb/yr) | 0.00 | |
| TOTAL PHOSPHORUS REMOVED WITH RUNOFF REDUCTION PRACTICES IN D.A. A (lb/yr) | 0.00 | |
| TOTAL PHOSPHORUS LOAD REDUCTION ACHIEVED IN D.A. A (lb/yr) | 0.00 | |
| TOTAL PHOSPHORUS REMAINING AFTER APPLYING BMP LOAD REDUCTIONS IN D.A. A (lb/yr) | 0.00 | |

*SEE WATER QUALITY COMPLIANCE TAB FOR SITE COMPLIANCE CALCULATIONS*

| | |
|---|---|
| NITROGEN REMOVED WITH RUNOFF REDUCTION PRACTICES IN D.A. A (lb/yr) | 0.00 |
| NITROGEN REMOVED WITHOUT RUNOFF REDUCTION PRACTICES IN D.A. A (lb/yr) | 0.00 |
| TOTAL NITROGEN REMOVED IN D.A. A (lb/yr) | 0.00 |

**Figure 16. Drainage Area Tab, BMP Summary (All BMPs).**

**Using the VRRM spreadsheet *(Drainage Area tab – Summary sections)***

**14.** Check the **Drainage Area tab** summaries for performance of Runoff Reduction BMPs (**rows 66-77**), and for performance of all BMPs combined (non-RR BMPs and RR BMPS), (**rows 105-116**). Summary information here includes runoff volume reductions achieved, TP load reductions achieved and TP remaining. **Drainage Area tab** area checks should also be reviewed in both summary locations to ensure BMP credit areas do not exceed **Drainage Area tab** land cover type totals (**cells F6, F7, and F8**). See summary tables above for additional details.

Similar summaries are also provided for Total Nitrogen loading (**cells W72-W73** for RR-BMPs and **cells I120-I122** for all BMPs).

**15.** If other **Drainage Area tabs** are used, repeat steps 9 through 14 for each **Drainage Area tab**.

**16.** Proceed to the **Water Quality Compliance tab** for additional area checks and to verify compliance with water quality requirements for entire site.

## 6.0 WATER QUALITY COMPLIANCE TAB

The **Water Quality Compliance tab** provides the user with water quality site results and area checks drawn from user inputs on the **Site tab** and **Drainage Area tabs**. The information is presented in four sections: Area Checks (rows 3-10), Runoff Reduction Volume and TP (and TN) by Drainage Area (rows 16-21), Total Phosphorus (rows 24-28), and Total Nitrogen (rows 31- 33). These main sections are described along with the related user instructions in the following tables (Tables 18-20).

**Table 18. Water Quality Compliance Tab Site Results (Areas and Checks)**

| Site Results (Water Quality Compliance), Area Checks | Cell Reference |
|---|---|
| **Forest (acres)**<br>*Forest areas totaled across HSGs for each Drainage Area tab* | **B3-F3**<br>**D.A. Tab F5** |
| **Mixed Open Area (acres)**<br>*Mixed open cover areas totaled across HSGs for each Drainage Area tab* | **B4-F4**<br>**D.A. Tab F6** |
| **Mixed Open Area Treated (acres)**<br>*Total treated mixed open cover (BMP Credit Areas) for each Drainage Area tab* | **B5-F5**<br>**D.A. Tab F99** |
| **Impervious Cover (acres)**<br>*Impervious cover areas totaled across HSGs for each Drainage Area tab* | **B6-F6**<br>**D.A. Tab F8** |
| **Impervious Cover Treated (acres)**<br>*Total treated impervious cover (BMP Credit Areas) for each Drainage Area tab* | **B7-F7**<br>**D.A. Tab F98** |
| **Managed Turf Area (acres)**<br>*Turf cover areas totaled across HSGs for each Drainage Area tab* | **B8-F8**<br>**D.A. Tab F7** |
| **Managed Turf Area Treated (acres)**<br>*Total treated turf cover (BMP Credit Areas) for each Drainage Area tab* | **B9-F9**<br>**D.A. Tab F100** |
| **Area Check per D.A. Tabs**<br>*Checks to ensure treated impervious cover, mixed open, and managed turf areas do not exceed available impervious cover, mixed open, and managed turf areas, respectively, within each Drainage Area tab.*<br>*Indicates (**OK.** or **AREA EXCEEDED!**)* | **B10-F10** |
| **Area Check per Site Tab**<br>*Checks to ensure each land cover area totaled across Drainage Area tabs do not exceed land cover areas entered on **Site tab**.*<br>*Indicates (**OK.** or **AREA EXCEEDED!**)* | **G3** (F)<br>**G4** (MO)<br>**H6** (IC)<br>**H8** (MT) |
| **Area Check for Treated Impervious Cover, Treated Mixed Open, and Treated Managed Turf**<br>*Checks to ensure treated impervious cover, treated mixed open, and treated managed turf areas totaled across Drainage Area tabs do not exceed available impervious cover, mixed open, and managed turf areas totaled across Drainage Area tabs.*<br>*Indicates (**OK.** or **AREA EXCEEDED!**)* | **G7** (IC)<br>**G5** (MO)<br>**H9** (MT) |
| **Site Treatment Volume ($ft^3$)**<br>*Total Treatment Volume for the post-development site area* | **B12** |

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**Using the VRRM spreadsheet *(Water Quality Compliance Site Results) – Area Checks***

**17.** Check the Water Quality Compliance Area Checks (**B10-F10** and **G3-G9**) to ensure:

a. Treated land cover areas do not exceed land cover areas available within each **Drainage Area tab**, and

b. Areas entered on **Drainage Area tabs** do not exceed areas entered on **Site tab**.

**18.** If **AREA EXCEEDED!** messages appear, check information entered on **Drainage Area tabs** (land cover information and BMP Credit Areas) and **Site tab**. Error messages on these tabs will help direct the user to problem entries.

**Table 19. Water Quality Compliance Tab Site Results (Volume, TP, and TN* by DA Tabs)**

| Site Results (Water Quality Compliance), Runoff Reduction Volume and TP By Drainage Area | Cell Reference |
|---|---|
| **Runoff Reduction Volume Achieved ($ft^3$)**<br>*Runoff Reduction Volumes summed within each Drainage Area tab*<br>**Total**<br>*Across Drainage Area Tabs* | **B16-F16**<br>**D.A. Tab F62**<br>**G16** |
| **TP Load Available For Removal (lb/yr)**<br>*Total phosphorus load available for removal within each Drainage Area tab*<br>**Total**<br>*Across Drainage Area Tabs* | **B17-F17**<br>**D.A. Tab N8**<br>**G17** |
| **TP Load Reduction Achieved (lb/yr)**<br>*Total phosphorus load reduction achieved within each Drainage Area tab*<br>**Total**<br>*Across Drainage Area Tabs* | **B18-F18**<br>**D.A. Tab I107**<br>**G18** |
| **TP Load Remaining (lb/yr)**<br>*Total phosphorus load remaining within each Drainage Area tab (difference between TP Load Available and TP Load Reduced)*<br>**Total**<br>*Across Drainage Area Tabs* | **B19-F19**<br>**G19** |
| **Nitrogen Load Reduction Achieved (lb/yr)***<br>*Total nitrogen load reduction achieved within each Drainage Area tab*<br>**Total**<br>*Across Drainage Area Tabs* | **B21-F21**<br>**D.A. Tab I114**<br>**G21** |

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**Table 20. Water Quality Compliance Tab Site Results (Total Phosphorus, Total Nitrogen)**

| Site Results (Water Quality Compliance), Total Phosphorus | Cell Reference |
|---|---|
| **Final Post-Development TP Load (lb/yr)**<br>*Total phosphorus load reduction achieved across all Drainage Area tabs* | **B24** |
| **TP Load Reduction Required (lb/yr)**<br>*Total phosphorus load reduction required for site compliance (based on 0.26 lb TP/acre/yr new development load limitation)* | **B25** |
| **TP Load Reduction Achieved (lb/yr)**<br>*Total phosphorus load reduction achieved across all Drainage Area tabs* | **B26** |
| **TP Load Remaining (lb/yr)**<br>*Total phosphorus load reduction achieved across all Drainage Area tabs* | **B27** |
| **Remaining TP Load Reduction Required (lb/yr)**<br>*Phosphorus load reduction that is still required for site compliance (difference between TP required and TP achieved).*<br><br>**B29** *Indicates:*<br>****No further TP load reduction required**<br>*if TP load reduction achieved on site equals compliance requirements or*<br>**TARGET TP REDUCTION EXCEEDED BY __LB/YEAR****<br>*if TP load reduction achieved on site exceeds compliance requirements.* | **B28** |
| **Total Nitrogen (lb/yr)***<br>*Total nitrogen summary for entire site includes:*<br>*Post-Development Load*<br>*Nitrogen Load Reduction Achieved*<br>*Remaining Post-Development Nitrogen Load* | <br><br>**B31**<br>**B32**<br>**B33** |

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**Using the VRRM spreadsheet *(Site Results Water Quality Compliance)***

***– Runoff Reduction Volume and TP By Drainage Area***

**19.** Check to see if water quality compliance has been achieved on the site by going to the Remaining TP Load Reduction Required result in **cell B28**:

c. If the result indicates anything greater than zero lb/yr, then the user must continue to reduce the TP load by the amount indicated in **cell B28** (which is the difference between the site-based TP load reduction required in **B25** and the reduction which is so far achieved in **cell B26**):

i. Check the runoff reduction volumes and total phosphorus loadings (**cells B16-G19**) for where additional opportunities to reduce the TP load may be found and optimized.

ii. Return to **Site tab** and **Drainage Area tabs** to possibly reconfigure the site layout and/or revise the on-site BMP strategy (change BMP credit areas and/or BMP selections).

d. If the result indicates that either:

**No further TP reduction required**

OR

**TARGET TP REQUIRED EXCEED BY _____LB/YR,**

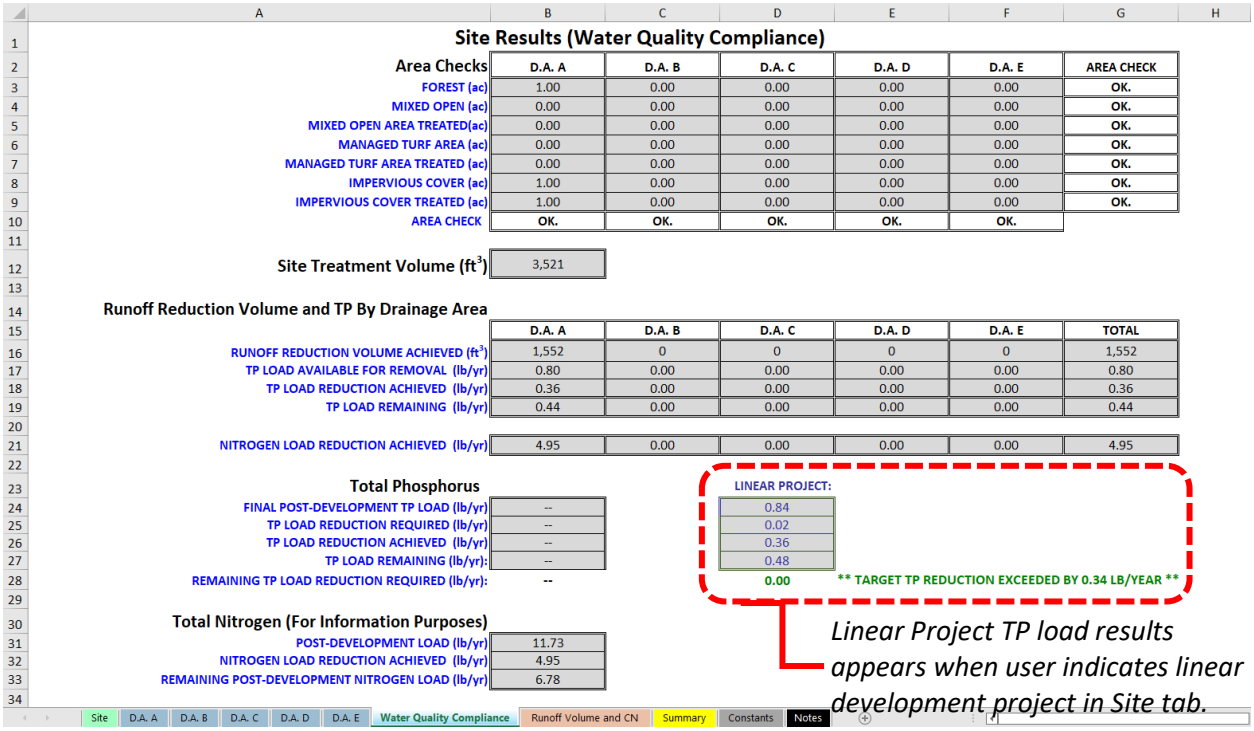
then the user can proceed with the proposed site layout and selected BMPs per **Drainage Area tab** to begin the site design.

**20.** If information on nitrogen loads is desired, check the Total Nitrogen sections (**cells B21-G21 and B31-B33**).

**21.** Proceed to the **Runoff Volume and CN tab** if the spreadsheet results for runoff (watershed-inches) and/or curve number adjustments will be used in subsequent water quantity calculations.

**22.** Proceed to the **Summary tab** to view and print a VRRM Spreadsheet Compliance Report.

The layout of the **Water Quality Compliance tab** for the Redevelopment spreadsheet differs from New Development spreadsheet only with the inclusion of a TP load results section for linear projects in **cells E24-I28** as shown in Figure 17 below.



**Site Results (Water Quality Compliance)**

| Area Checks | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | AREA CHECK |
|---|---|---|---|---|---|---|
| FOREST (ac) | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | OK. |
| MIXED OPEN (ac) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | OK. |
| MIXED OPEN AREA TREATED(ac) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | OK. |
| MANAGED TURF AREA (ac) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | OK. |
| MANAGED TURF AREA TREATED (ac) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | OK. |
| IMPERVIOUS COVER (ac) | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | OK. |
| IMPERVIOUS COVER TREATED (ac) | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | OK. |
| AREA CHECK | OK. | OK. | OK. | OK. | OK. | |

Site Treatment Volume ($ft^3$): 3,521

**Runoff Reduction Volume and TP By Drainage Area**

| | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | TOTAL |
|---|---|---|---|---|---|---|
| RUNOFF REDUCTION VOLUME ACHIEVED ($ft^3$) | 1,552 | 0 | 0 | 0 | 0 | 1,552 |
| TP LOAD AVAILABLE FOR REMOVAL (lb/yr) | 0.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 |
| TP LOAD REDUCTION ACHIEVED (lb/yr) | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| TP LOAD REMAINING (lb/yr) | 0.44 | 0.00 | 0.00 | 0.00 | 0.00 | 0.44 |
| NITROGEN LOAD REDUCTION ACHIEVED (lb/yr) | 4.95 | 0.00 | 0.00 | 0.00 | 0.00 | 4.95 |

| Total Phosphorus | | LINEAR PROJECT: |
|---|---|---|
| FINAL POST-DEVELOPMENT TP LOAD (lb/yr) | -- | 0.84 |
| TP LOAD REDUCTION REQUIRED (lb/yr) | -- | 0.02 |
| TP LOAD REDUCTION ACHIEVED (lb/yr) | -- | 0.36 |
| TP LOAD REMAINING (lb/yr): | -- | 0.48 |
| REMAINING TP LOAD REDUCTION REQUIRED (lb/yr): | -- | 0.00 |

** TARGET TP REDUCTION EXCEEDED BY 0.34 LB/YEAR **

| Total Nitrogen (For Information Purposes) | |
|---|---|
| POST-DEVELOPMENT LOAD (lb/yr) | 11.73 |
| NITROGEN LOAD REDUCTION ACHIEVED (lb/yr) | 4.95 |
| REMAINING POST-DEVELOPMENT NITROGEN LOAD (lb/yr) | 6.78 |

*Linear Project TP load results appears when user indicates linear development project in Site tab.*

Site | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Water Quality Compliance | Runoff Volume and CN | Summary | Constants | Notes

**Figure 17. Water Quality Compliance Tab, Redevelopment spreadsheet with linear project results section.**

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# 7.0 RUNOFF VOLUME AND CN TAB

The **Runoff Volume and CN tab** calculates the runoff volume reduction benefit in terms that can be applied to the water quantity control requirements of the VESMR regulations (Channel protection and Flood protection, *9VAC25-875-600*).

When designed to manage the water quality target rainfall event (one-inch of rainfall), the volume reduction achieved by the runoff reduction practices will provide some degree of benefit or credit when complying with any of these water quantity control requirements. This volume credit is applied in the form of a CN reduction based on the Natural Resource Conservation Service (NRCS) runoff equations provided in *Urban Hydrology for Small Watersheds: TR-55* (NRCS 1986).

It is important to note that the **Runoff Volume and CN tab** results do not indicate whether water quantity compliance has been achieved. Further computations and/or analyses are required for this determination. The user should carefully review the water quantity control regulations (*9VAC25-875-600*) to ensure understanding of compliance requirements.

It is also important to note that the spreadsheet calculates the volume reduction credit assuming that each BMP is designed and sized according to the minimum requirements of the BMP Design Specifications. If the user has oversized a practice, the spreadsheet will not reflect additional volume reduction credit for the purpose of meeting the water quantity technical criteria of the VESMR Regulations (see Section 7.3). Routing of BMPs can be a complex task given all the hydrologic and hydraulic variables associated with volume storage and reduction, and therefore, needs to be performed outside of the spreadsheet using acceptable hydrologic and hydraulic methodologies (9VAC25-875-620).

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## 7.1. RUNOFF VOLUME AND CN TAB USER INPUTS AND LIMITATIONS

There are a maximum of three entries on the Runoff Volume and CN Tab for design storm rainfall depths in inches (**cells E6 to G6**):

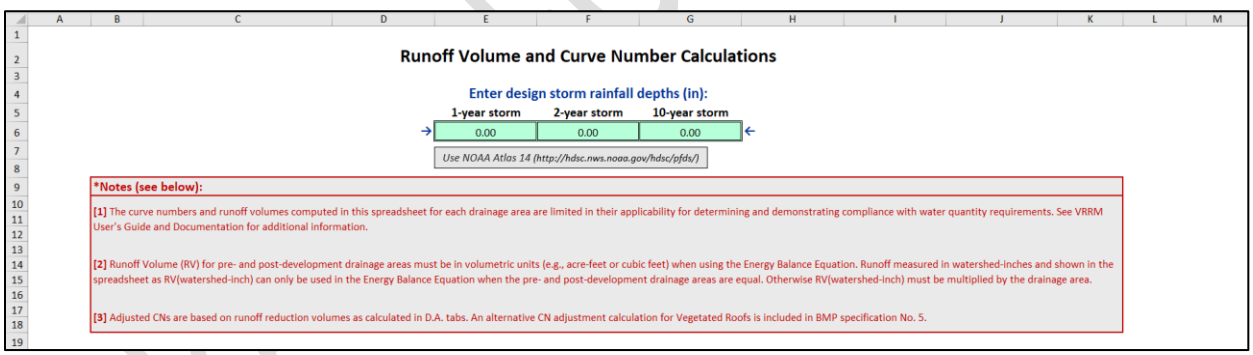
**Using the VRRM spreadsheet *(Runoff Volume and CN) – User Inputs***

**23.** Enter the 24-hour rainfall depth for the Target Rainfall Event (inches) which can be the 1-year, 2-year and/or 10-year frequency storm events:

a. The rainfall depths can be found using NOAA Atlas 14 (https://hdsc.nws.noaa.gov/pfds/)

b. Remember that **Drainage Area tab** land cover data must be entered before calculations can be performed on this tab.

Just below the user input cells is a list of three notes (dark red font) which provide the user with some of the limitations of the spreadsheet and the **Runoff Volume and CN tab** computations (Fig. 18, Table 21).



**Runoff Volume and Curve Number Calculations**

Enter design storm rainfall depths (in):

| 1-year storm | 2-year storm | 10-year storm |
|---|---|---|
| 0.00 | 0.00 | 0.00 |

*Use NOAA Atlas 14 (http://hdsc.nws.noaa.gov/hdsc/pfds/)*

***Notes (see below):**

[1] The curve numbers and runoff volumes computed in this spreadsheet for each drainage area are limited in their applicability for determining and demonstrating compliance with water quantity requirements. See VRRM User's Guide and Documentation for additional information.

[2] Runoff Volume (RV) for pre- and post-development drainage areas must be in volumetric units (e.g., acre-feet or cubic feet) when using the Energy Balance Equation. Runoff measured in watershed-inches and shown in the spreadsheet as RV(watershed-inch) can only be used in the Energy Balance Equation when the pre- and post-development drainage areas are equal. Otherwise RV(watershed-inch) must be multiplied by the drainage area.

[3] Adjusted CNs are based on runoff reduction volumes as calculated in D.A. tabs. An alternative CN adjustment calculation for Vegetated Roofs is included in BMP specification No. 5.

**Figure 18. Runoff and CN Tab, Limitations.**

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**Table 21. Runoff Volume and CN Tab Limitations**

| Runoff Volume and CN (Limitations) | Cell Reference |
|---|---|
| **[1] The curve numbers and runoff volumes computed in this spreadsheet for each drainage area are limited in their applicability for determining and demonstrating compliance with water quantity requirements. See VRRM User's Guide and Documentation for additional information.**<br>*This note is to inform the user that sites which have more than one drainage area converging to a common point of analysis is too complex of a drainage network for this tab to calculate CN values and runoff depths correctly. Hydrologic modeling is required for these and other types of complex configurations.* | **B10-K12** |
| **[2] Runoff Volume (RV) for pre- and post-development drainage areas must be in volumetric units (e.g., acre-feet or cubic feet) when using the Energy Balance Equation. Runoff measured in watershed-inches and shown in the spreadsheet as RV (watershed-inch) can only be used in the Energy Balance Equation when the pre- and post-development drainage areas are equal. RV (watershed-inch) must be multiplied by the drainage area.**<br>*The Runoff Volume (RV) provided in watershed inches is a depth measurement and not volume. When comparing forested, pre-, and post- development drainage area volumes for energy balance calculations, the volume units must be in acre-feet or cubic feet unless the drainage areas are the same.* | **B13-K16** |
| **[3] Adjusted CNs are based on runoff reduction volumes as calculated in D.A. tabs. An alternative CN adjustment calculation for Vegetated Roofs is included in BMP P-FIL-02 Vegetated Roof.**<br>*The runoff reduction volumes calculated in the D.A. tabs are used for CN adjustments. The vegetated roof practice allows a pre-determined curve number adjustment that is listed in Table 5.1 of the BMP Specification.* | **B17-K18** |

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## 7.2. RUNOFF VOLUME AND CN TAB RESULTS

The **Runoff Volume and CN tab** results primarily show (for each **Drainage Area tab**) the volume reduction achieved and the **Drainage Area tab** composite curve number ($CN_{(D.A.)}$) before and after accounting for achieved volume reduction (Adjusted CN, Fig. 19, Table 22). Each of the **Drainage Area tabs** is represented in a separate table of results (for a total of five results tables).

Each **D.A. tab** results table includes constants, namely assigned CNs for each land cover type by HSGs, computations carried over from **Drainage Area tabs** (acreages and volumes), and CN calculations as represented in Fig. 19.

The user should consult the VA SWM Handbook for additional information and details on computational procedures.

**Drainage Area Curve Numbers and Runoff Depths***

| Drainage Area A | | A Soils | B Soils | C Soils | D Soils |
|---|---|---|---|---|---|
| Forest -- undisturbed, protected forest or reforested land | Area (acres) | 0.00 | 0.00 | 0.00 | 0.00 |
| | CN | 30 | 55 | 70 | 77 |
| Mixed Open -- undisturbed/infrequently maintained grass or shrub land | Area (acres) | 0.00 | 0.00 | 0.00 | 0.00 |
| | CN | 30 | 58 | 71 | 78 |
| Managed Turf -- disturbed, graded for yards or other turf to be mowed/managed | Area (acres) | 0.00 | 0.00 | 0.00 | 0.00 |
| | CN | 39 | 61 | 74 | 80 |
| Impervious Cover | Area (acres) | 0.00 | 0.00 | 0.00 | 0.00 |
| | CN | 98 | 98 | 98 | 98 |

| | |
|---|---|
| Total Area (acres): | 0.00 |
| Runoff Reduction Volume ($ft^3$): | 0 |

| $CN_{(D.A. A)}$ |
|---|
| 0 |

| | 1-year storm | 2-year storm | 10-year storm |
|---|---|---|---|
| $RV_{Developed}$ *(watershed-inch)* with no Runoff Reduction* | 0.00 | 0.00 | 0.00 |
| $RV_{Developed}$ *(watershed-inch)* with Runoff Reduction* | 0.00 | 0.00 | 0.00 |
| Adjusted CN* | 0 | 0 | 0 |

*See Notes above

**Figure 19. Runoff and CN Tab, Drainage Area A Summary.**

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**Table 22. Runoff Volume and CN Tab Results**

| Runoff Volume and CN (Results for D.A. A Tab) | Cell Reference |
|---|---|
| **Land Cover Areas by HSGs**<br>*Areas of land cover type by hydrologic soil groups (HSGs) is carried over from the Drainage Area tab.* | **E24-H24** (F)<br>**D.A. Tab B5-E5**<br>**E26-H26** (MO)<br>**D.A. Tab B6-E6**<br>**E28-H28** (MT)<br>**D.A. Tab B7-E7**<br>**E30-H30** (IC)<br>**D.A. Tab B8-E8** |
| **Total Area (acres)**<br>*The sum of all areas within the Drainage Area tab (across land cover type and HSGs)* | **K23**<br>**D.A. Tab F9** |
| **Runoff Reduction Volume ($ft^3$)**<br>*The total runoff reduction volume for the Drainage Area tab via runoff reduction BMPs.* | **K25**<br>**D.A. Tab F62** |
| **CN**<br>*Assigned curve numbers (CN) for each land cover type by HSGs within the Drainage Area tab.* | **E25-H25** (F)<br>**E27-H27** (MO)<br>**E29-H29** (MT)<br>**E31-H31** (IC) |
| **$CN_{(D.A. A)}$**<br>*The composite curve number for the Drainage Area tab (across land cover types and HSGs).*<br>*Equation 15* | **H33** |
| **$RV_{Developed}$ *(watershed-inch)* with no Runoff Reduction (1-year storm, 2-year storm, 10-year storm)**<br>*The post-development runoff volume in watershed-inches for the Drainage Area tab without applying any RR-BMPs. This value is calculated for each target rainfall event entered by the user (1-yr, 2-yr, 10-yr storms) using the D.A. tab composite curve number ($CN_{(D.A.)}$).*<br>*Equation 16* | **E35-G35** |
| **$RV_{Developed}$ *(watershed-inch)* with Runoff Reduction (1-year storm, 2-year storm, 10-year storm)**<br>*The post-development runoff volume in watershed-inches for the Drainage Area tab after applying runoff volume reduction from any utilized RR-BMPs. The runoff volume reduction is subtracted from the post-development runoff volume above ($RV_{Developed}$ no RR) for each target rainfall event and converted to watershed-inches.*<br>*Equation 17* | **E36-G36** |
| **Adjusted CN (1-year storm, 2-year storm, 10-year storm)**<br>*The adjusted curve number for each target rainfall event obtained using a look-up table of curve numbers and corresponding runoff depths (watershed-in). Adjusted CN can also be determined using Fig. 2-1 of TR-55.*<br>*Equation 18* | **E37-G37** |

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## 7.3. INTEGRATING WATER QUALITY TREATMENT WITH CONTROL OF LARGER STORMS

Compliance with the technical criteria of the VESMR regulations requires that stormwater management include provisions for channel protection and flood control. The VESMR regulations require management of the one-inch storm event (approximately equivalent to a 3-month, 24-hour storm). The stormwater BMP Design Specifications allow for additional storage features that go beyond the required quality BMP treatment volumes and beyond the assigned runoff reduction credits. If a BMP is designed with increased storage volume to manage the volume from a 1-, 2-, or 10-year storm event, the VRRM spreadsheet will not recognize this additional storage volume. The designer will need to perform additional computations outside of the VRRM spreadsheet as part of their analysis. BMPs may also include additional discharges from adjacent parcels which run-on to the site; areas outside of the owner and/or operator's legal control cannot be included in the Site tab or Drainage Area tabs for additional quality credit.

Stormwater BMPs that provide a runoff reduction (RR) credit do so by providing a storage component and/or slowing the release of discharge to the nearby receiving stream. These processes attenuate the runoff by encouraging abstraction and infiltration, resulting in a decrease in the computed release volume. The effectiveness of a practice's volume reduction (or ability to reduce the curve number) during larger storms is dependent on the relative volume of storage provided versus the volume of runoff generated. As the runoff depth increases, say from a 1-year frequency rainfall to a 10-year frequency rainfall, the practice's reduction volume remains the same but relative to the increased runoff generated, the practice's proportional runoff reduction decreases.

BMP practices that can be expanded to provide a greater volume of storage for larger storm events may be utilized in accordance with guidance provided in the BMP Design Specifications. The designer may then choose to utilize the total storage volume provided rather than the values used in the VRRM spreadsheet and compute an adjusted curve number directly from TR-55 for the desired storm events. A curve number must be computed for each storm event due to the diminishing effect of storage as rainfall depth increases. It is important to note that the RR credit assigned in the spreadsheet, and not the actual storage, must be used for the water quality calculations. In most cases, use of upland runoff reduction practices will reduce the storage volumes needed to manage the larger storm events associated with channel protection and/or flood control.

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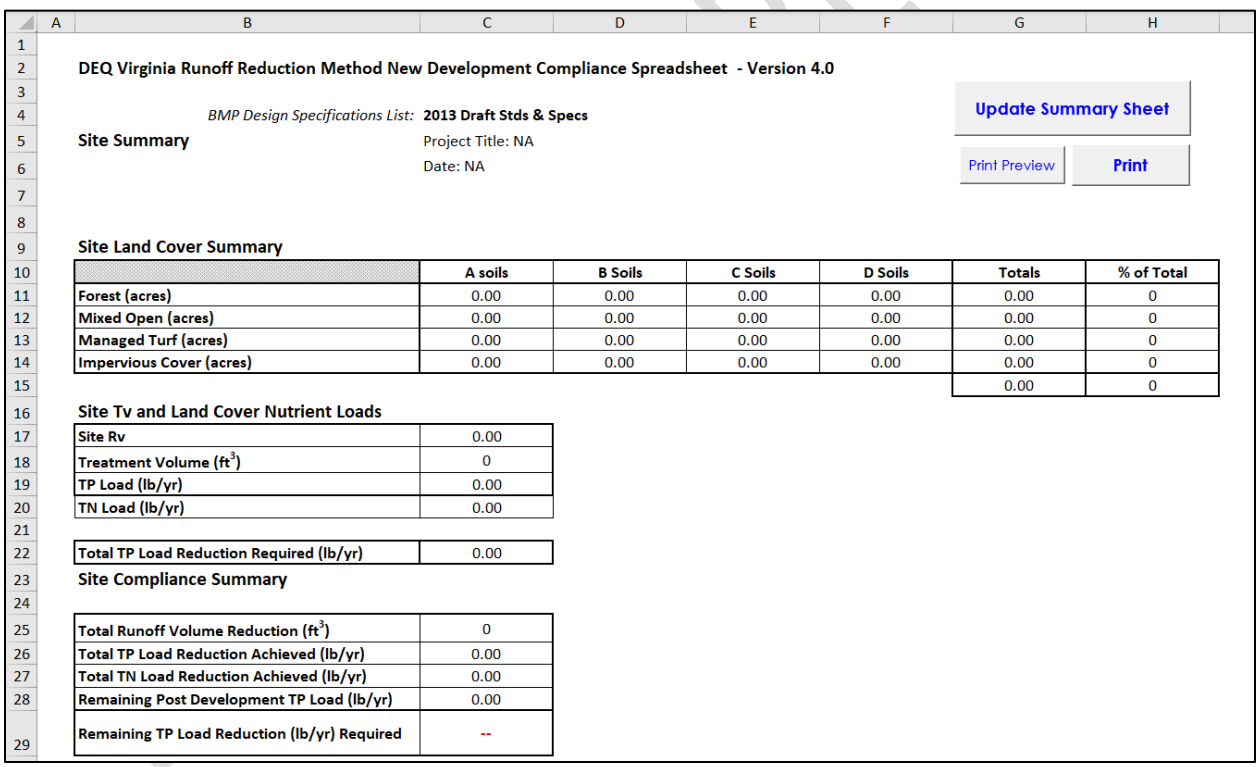
# 8.0 SUMMARY TAB (COMPLIANCE SUMMARY)

**The user must enable macros for full functionality of the Summary tab.**

The **Summary tab** compiles a report style summary of the spreadsheet results and water quality compliance information. All but one section of the **Summary tab** will auto-populate as user entries are made on the **Site tab**, **Drainage Area tabs**, and **Runoff and CN tab**. The individual **Drainage Area tab** summaries, including BMP selection summaries, will only populate and/or update once the user clicks the **Update Summary Sheet** button. The **Print Preview** button was included to remind the user that the printout can be customized to accommodate user needs (e.g., specify 1 page wide by X pages long), and the **Print** button opens the Excel Print Function (see user steps 27-28 below).

The upper section of the **Summary tab** includes site information and water quality compliance information carried forward from the **Site tab** and **Water Quality Compliance tab**, respectively (rows 5-29 for New Development, Fig.20; rows 5-48 for Redevelopment, Fig. 20).



**DEQ Virginia Runoff Reduction Method New Development Compliance Spreadsheet - Version 4.0**

*BMP Design Specifications List:* **2013 Draft Stds & Specs**

**Site Summary**

Project Title: NA

Date: NA

Update Summary Sheet

Print Preview | Print

**Site Land Cover Summary**

| | A soils | B Soils | C Soils | D Soils | Totals | % of Total |
|---|---|---|---|---|---|---|
| Forest (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Mixed Open (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Managed Turf (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Impervious Cover (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| | | | | | 0.00 | 0 |

**Site Tv and Land Cover Nutrient Loads**

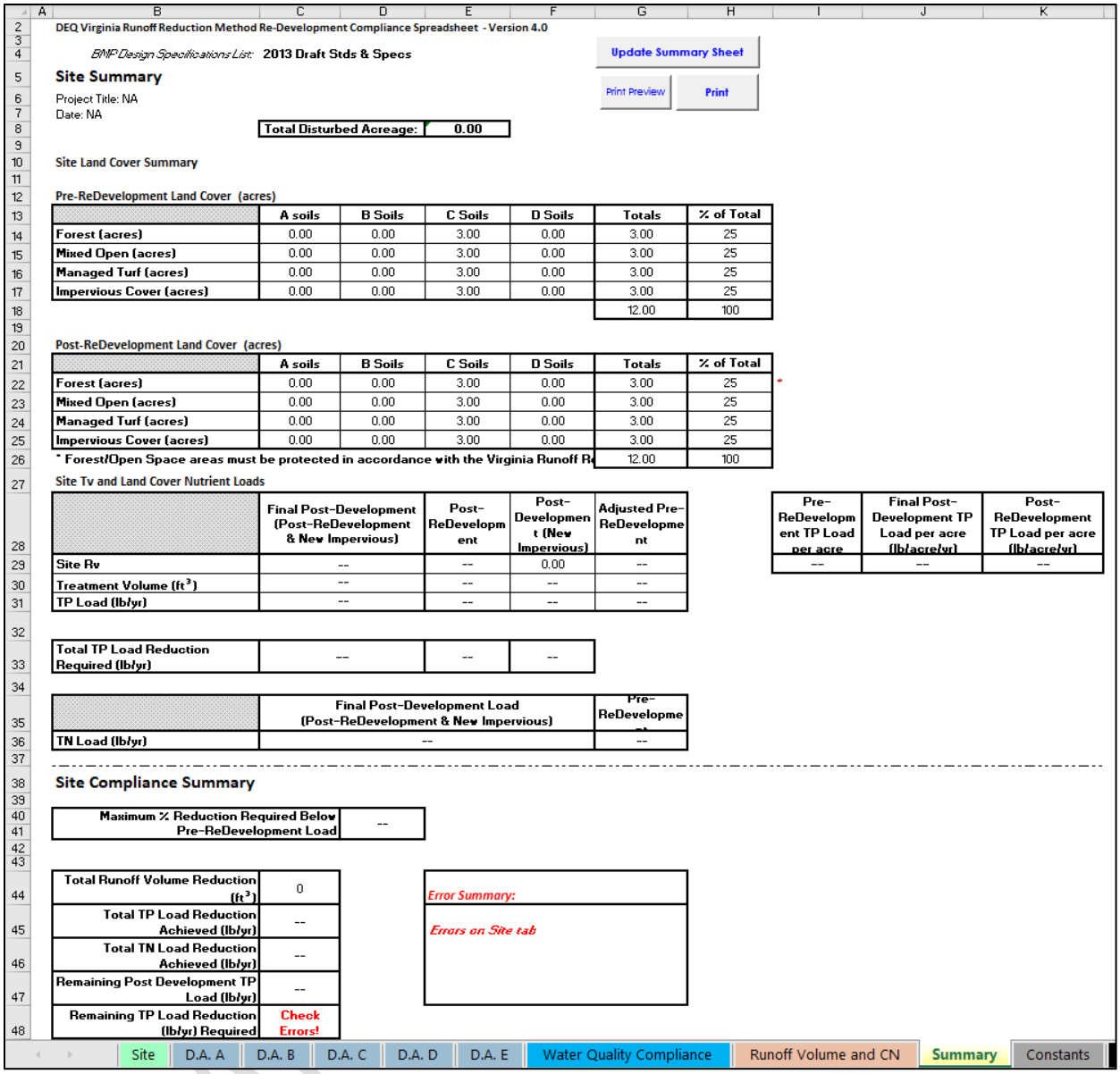
| | |
|---|---|
| Site Rv | 0.00 |
| Treatment Volume ($ft^3$) | 0 |
| TP Load (lb/yr) | 0.00 |
| TN Load (lb/yr) | 0.00 |
| Total TP Load Reduction Required (lb/yr) | 0.00 |

**Site Compliance Summary**

| | |
|---|---|
| Total Runoff Volume Reduction ($ft^3$) | 0 |
| Total TP Load Reduction Achieved (lb/yr) | 0.00 |
| Total TN Load Reduction Achieved (lb/yr) | 0.00 |
| Remaining Post Development TP Load (lb/yr) | 0.00 |
| Remaining TP Load Reduction (lb/yr) Required | -- |

**Figure 20. New Development Summary Tab – Water Quality Compliance, Site Summary Sections.**

PREVIEW



DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 4.0

*BMP Design Specifications List:* 2013 Draft Stds & Specs

Update Summary Sheet

Print Preview | Print

**Site Summary**

Project Title: NA
Date: NA

| Total Disturbed Acreage: | 0.00 |
|---|---|

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

| | A soils | B Soils | C Soils | D Soils | Totals | % of Total |
|---|---|---|---|---|---|---|
| Forest (acres) | 0.00 | 0.00 | 3.00 | 0.00 | 3.00 | 25 |
| Mixed Open (acres) | 0.00 | 0.00 | 3.00 | 0.00 | 3.00 | 25 |
| Managed Turf (acres) | 0.00 | 0.00 | 3.00 | 0.00 | 3.00 | 25 |
| Impervious Cover (acres) | 0.00 | 0.00 | 3.00 | 0.00 | 3.00 | 25 |
| | | | | | 12.00 | 100 |

Post-ReDevelopment Land Cover (acres)

| | A soils | B Soils | C Soils | D Soils | Totals | % of Total |
|---|---|---|---|---|---|---|
| Forest (acres) | 0.00 | 0.00 | 3.00 | 0.00 | 3.00 | 25 * |
| Mixed Open (acres) | 0.00 | 0.00 | 3.00 | 0.00 | 3.00 | 25 |
| Managed Turf (acres) | 0.00 | 0.00 | 3.00 | 0.00 | 3.00 | 25 |
| Impervious Cover (acres) | 0.00 | 0.00 | 3.00 | 0.00 | 3.00 | 25 |
| * Forest/Open Space areas must be protected in accordance with the Virginia Runoff R | | | | | 12.00 | 100 |

Site Tv and Land Cover Nutrient Loads

| | Final Post-Development (Post-ReDevelopment & New Impervious) | Post-ReDevelopment | Post-Development (New Impervious) | Adjusted Pre-ReDevelopment |
|---|---|---|---|---|
| Site Rv | -- | -- | 0.00 | -- |
| Treatment Volume (ft³) | -- | -- | -- | -- |
| TP Load (lb/yr) | -- | -- | -- | -- |

| Pre-ReDevelopment TP Load per acre | Final Post-Development TP Load per acre (lb/acre/yr) | Post-ReDevelopment TP Load per acre (lb/acre/yr) |
|---|---|---|
| -- | -- | -- |

| | | | |
|---|---|---|---|
| Total TP Load Reduction Required (lb/yr) | -- | -- | -- |

| | Final Post-Development Load (Post-ReDevelopment & New Impervious) | Pre-ReDevelopment |
|---|---|---|
| TN Load (lb/yr) | -- | -- |

**Site Compliance Summary**

| | |
|---|---|
| Maximum % Reduction Required Below Pre-ReDevelopment Load | -- |

| | |
|---|---|
| Total Runoff Volume Reduction (ft³) | 0 |
| Total TP Load Reduction Achieved (lb/yr) | -- |
| Total TN Load Reduction Achieved (lb/yr) | -- |
| Remaining Post Development TP Load (lb/yr) | -- |
| Remaining TP Load Reduction (lb/yr) Required | Check Errors! |

*Error Summary:*

*Errors on Site tab*

Site | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Water Quality Compliance | Runoff Volume and CN | Summary | Constants

**Figure 21. Redevelopment Summary Tab – Water Quality Compliance, Site Summary showing errors.**

The next section of the **Summary tab** includes land cover and nutrient loading reductions for all of the **Drainage Area tabs** carried forward from the **Drainage Area tabs** (rows 31-44 for New Development, Fig. 22; rows 50-63 for Redevelopment).

**Drainage Area Summary**

| | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Total |
|---|---|---|---|---|---|---|
| Forest (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mixed Open (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Managed Turf (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Impervious Cover (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total Area (acres) | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** |

**Drainage Area Compliance Summary**

| | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Total |
|---|---|---|---|---|---|---|
| TP Load Reduced (lb/yr) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TN Load Reduced (lb/yr) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Figure 22. New Development Summary Tab – Drainage Area Summary and Drainage Area Compliance Summary.**

The individual **Drainage Area tab** summaries (Fig. 23) populate just below the overall **Drainage Area tab** summary (rows 47+ for New Development Spreadsheet and rows 66+ for Redevelopment Spreadsheet). The **Drainage Area tab** summaries include land cover information and a BMP summary for each **Drainage Area tab** where user inputs have been made (i.e., only utilized **Drainage Area tabs** and selected BMPs will populate in this section of the **Summary tab**).

Drainage Area A Summary

**Land Cover Summary**

| | A Soils | B Soils | C Soils | D Soils | Total | % of Total |
|---|---|---|---|---|---|---|
| Forest (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Mixed Open (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Managed Turf (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Impervious Cover (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| | | | | | **0.00** | |

**BMP Selections**

| Practice | Mixed Open Credit Area (acres) | Managed Turf Credit Area (acres) | Impervious Cover Credit Area (acres) | BMP Treatment Volume ($ft^3$) | TP Load from Upstream Practices (lbs) | Untreated TP Load to Practice (lbs) | TP Removed (lb/yr) | TP Remaining (lb/yr) | Downstream Treatment to be Employed |
|---|---|---|---|---|---|---|---|---|---|

| | |
|---|---|
| Total Impervious Cover Treated (acres) | 0.00 |
| Total Mixed Open Treated (acres) | 0.00 |
| Total Turf Area Treated (acres) | 0.00 |
| Total TP Load Reduction Achieved in D.A. (lb/yr) | 0.00 |
| Total TN Load Reduction Achieved in D.A. (lb/yr) | 0.00 |

**Figure 23. Summary Tab – Drainage Area A Land Cover Summary, BMP Selections, and Water Quality Compliance.**

The bottom section of the **Summary tab** includes a table of composite curve numbers, runoff reductions and adjusted curve numbers from the **Runoff Volume and CN tab** for each drainage area (Fig. 24). The exact location of this section on the tab will depend on the quantity of information compiled for the preceding section of individual Drainage Area tab summaries.

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**Runoff Volume and CN Calculations**

| | 1-year storm | 2-year storm | 10-year storm |
|---|---|---|---|
| Target Rainfall Event (in) | 0.00 | 0.00 | 0.00 |

| Drainage Areas | RV & CN | Drainage Area A | Drainage Area B | Drainage Area C | Drainage Area D | Drainage Area E |
|---|---|---|---|---|---|---|
| CN | | 0 | 0 | 0 | 0 | 0 |
| RR ($ft^3$) | | 0 | 0 | 0 | 0 | 0 |
| 1-year return period | RV wo RR (ws-in) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | RV w RR (ws-in) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | CN adjusted | 0 | 0 | 0 | 0 | 0 |
| 2-year return period | RV wo RR (ws-in) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | RV w RR (ws-in) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | CN adjusted | 0 | 0 | 0 | 0 | 0 |
| 10-year return period | RV wo RR (ws-in) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | RV w RR (ws-in) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | CN adjusted | 0 | 0 | 0 | 0 | 0 |

**Figure 24. Summary Tab – Water Quality Compliance, Runoff Volume and CN Calculations.**

## Using the VRRM spreadsheet *(Summary Tab)*

**24. Remember**: Macros must be enabled for full functionality of the **Summary tab.** Return to **Site tab** and Step 1 in this document.

**25.** Click the **Update Summary Sheet** button in order to populate the individual **Drainage Area tabs** with BMP summaries.

Each time changes are made to individual Drainage Area tabs, the **Summary tab** must be updated by selecting this button.

**26.** Review the summary sheet:

a. If errors are noted, return to the tabs identified in the error notification table (Fig. 25).

b. If there are no errors, proceed to the next step.

**Site Compliance Summary** *New Development Spreadsheet*

| | |
|---|---|
| Total Runoff Volume Reduction ($ft^3$) | 1,707 |
| Total TP Load Reduction Achieved (lb/yr) | 0.39 |
| Total TN Load Reduction Achieved (lb/yr) | 5.44 |
| Remaining Post Development TP Load (lb/yr) | -0.39 |
| Remaining TP Load Reduction (lb/yr) Required | Check Errors! |

*Error Summary:*
*Areas on D.A. tab(s) exceed Site tab areas*

**Drainage Area Summary**

| | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Total | |
|---|---|---|---|---|---|---|---|
| Forest (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Mixed Open (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Managed Turf (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Impervious Cover (acres) | 1.10 | 0.00 | 0.00 | 0.00 | 0.00 | 1.10 | x |
| Total Area (acres) | **1.10** | **0.00** | **0.00** | **0.00** | **0.00** | **1.10** | |

**Site Compliance Summary** *Re-Development Spreadsheet*

| | |
|---|---|
| Maximum % Reduction Required Below Pre-ReDevelopment Load | 10% |

| | |
|---|---|
| Total Runoff Volume Reduction ($ft^3$) | 1,707 |
| Total TP Load Reduction Achieved (lb/yr) | x |
| Total TN Load Reduction Achieved (lb/yr) | 5.44 |
| Remaining Post Development TP Load (lb/yr) | -- |
| Remaining TP Load Reduction (lb/yr) Required | Check Errors! |

*Error Summary:*
*Errors on D.A. tab(s)*

**Drainage Area Summary**

| | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Total |
|---|---|---|---|---|---|---|
| Forest (acres) | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 |
| Mixed Open (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Managed Turf (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Impervious Cover (acres) | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 |
| Total Area (acres) | **2.00** | **0.00** | **0.00** | **0.00** | **0.00** | **2.00** |

D.A. A Errors!

**Figure 25. Summary Tab Error Notifications for New Development (upper) and Redevelopment (lower) Spreadsheets.**

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## Using the VRRM spreadsheet *(Summary Tab)*

**27.** Click the **Print Preview** button. This will open the Excel Print Preview Screen (Fig. 26) and allow the user to:

a. View the report prior to printing, and/or

b. Select the Excel Page Setup function (top bar menu option) in order to customize the report printout.

**28.** At this point, the user can click the **Print** button, select a connected printer, or print to PDF (Fig. 27).

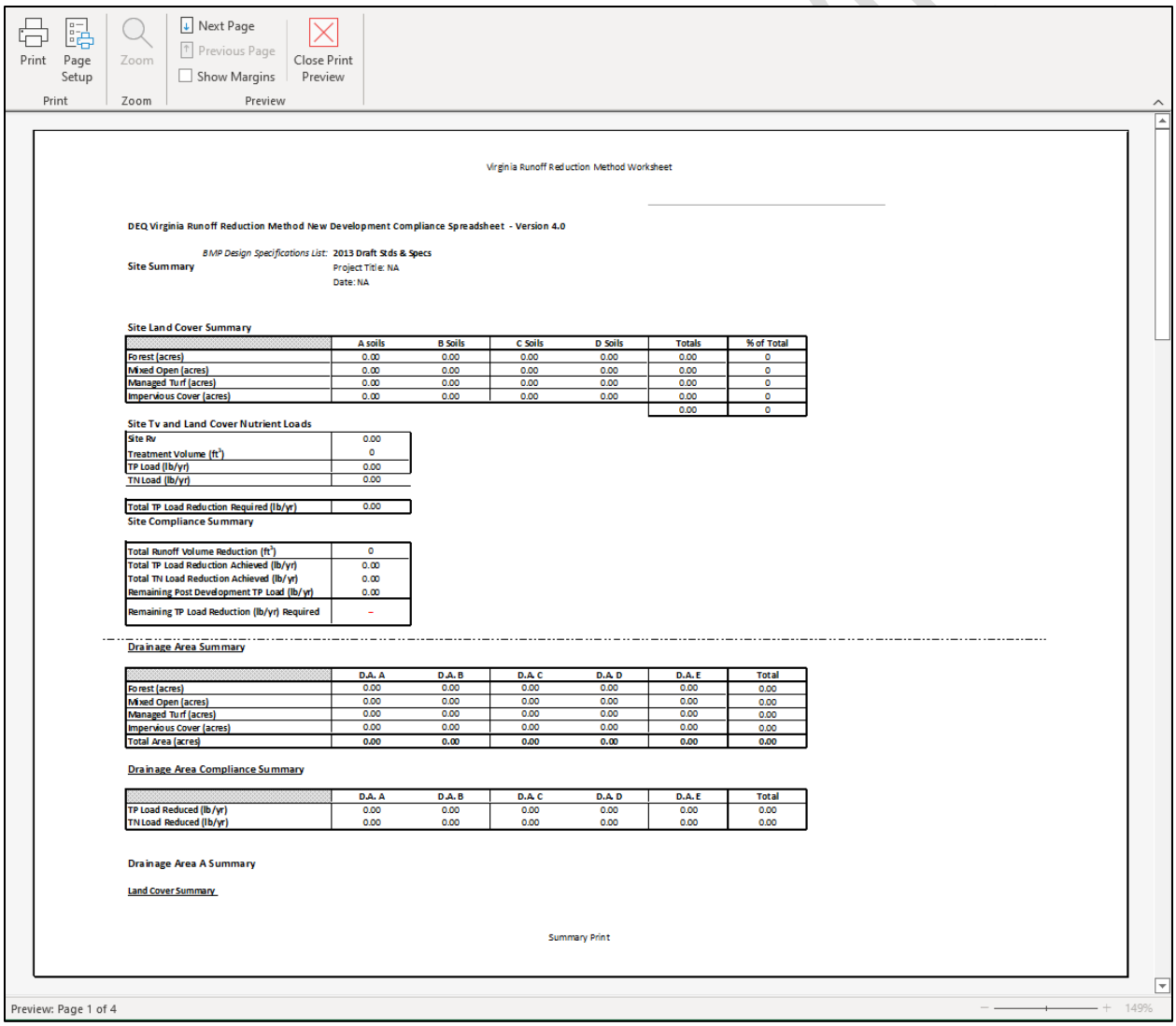
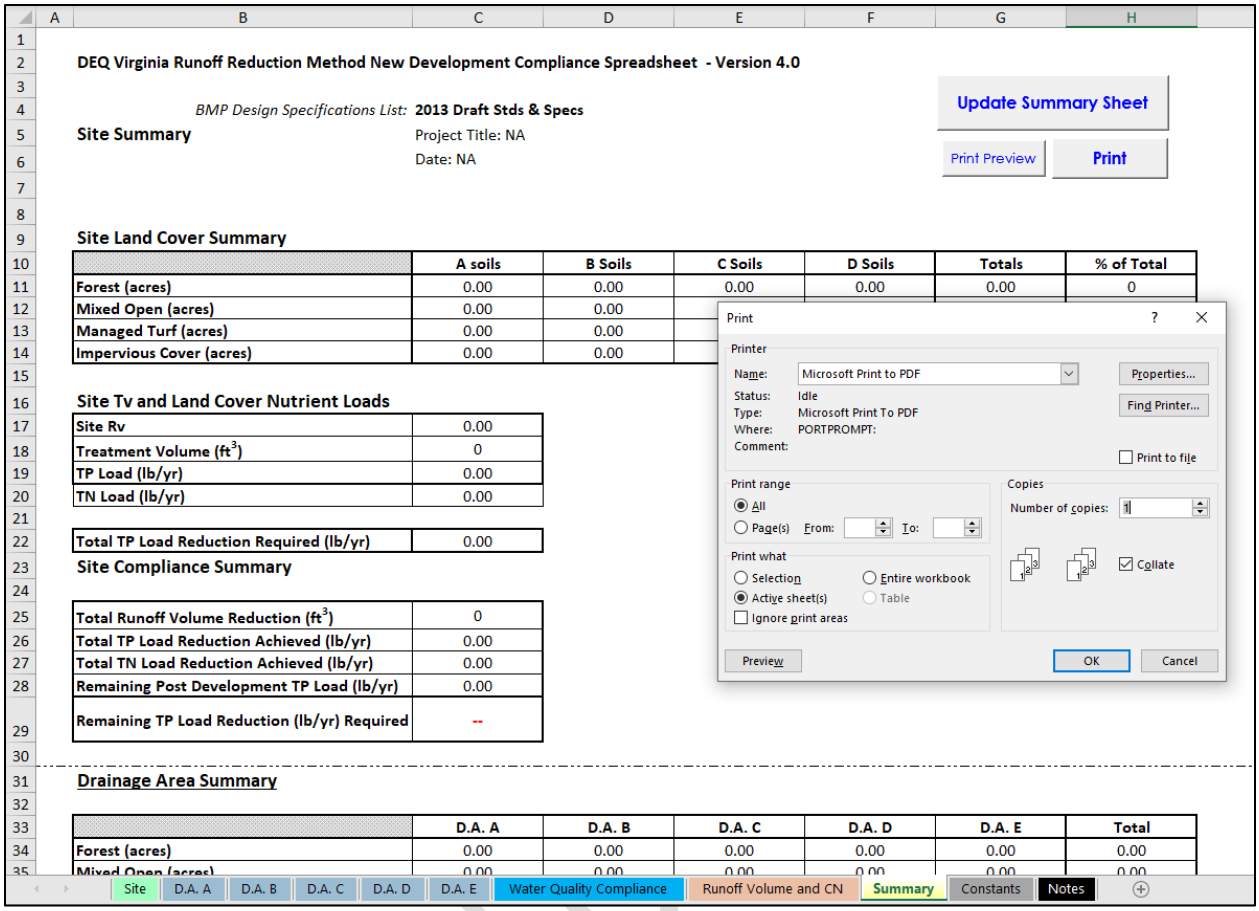



**Figure 26. Summary Tab – Water Quality Compliance Report – Print Preview Screen.**



**DEQ Virginia Runoff Reduction Method New Development Compliance Spreadsheet - Version 4.0**

*BMP Design Specifications List:* **2013 Draft Stds & Specs**

**Site Summary**

Project Title: NA

Date: NA

Update Summary Sheet

Print Preview | Print

**Site Land Cover Summary**

| | A soils | B Soils | C Soils | D Soils | Totals | % of Total |
|---|---|---|---|---|---|---|
| Forest (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Mixed Open (acres) | 0.00 | 0.00 | | | | |
| Managed Turf (acres) | 0.00 | 0.00 | | | | |
| Impervious Cover (acres) | 0.00 | 0.00 | | | | |

**Site Tv and Land Cover Nutrient Loads**

| | |
|---|---|
| Site Rv | 0.00 |
| Treatment Volume ($ft^3$) | 0 |
| TP Load (lb/yr) | 0.00 |
| TN Load (lb/yr) | 0.00 |
| Total TP Load Reduction Required (lb/yr) | 0.00 |

**Site Compliance Summary**

| | |
|---|---|
| Total Runoff Volume Reduction ($ft^3$) | 0 |
| Total TP Load Reduction Achieved (lb/yr) | 0.00 |
| Total TN Load Reduction Achieved (lb/yr) | 0.00 |
| Remaining Post Development TP Load (lb/yr) | 0.00 |
| Remaining TP Load Reduction (lb/yr) Required | -- |

**Drainage Area Summary**

| | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Total |
|---|---|---|---|---|---|---|
| Forest (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mixed Open (acres) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Site | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Water Quality Compliance | Runoff Volume and CN | Summary | Constants | Notes



**Figure 27. Site Summary Tab (Print Button Activated).**

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## 9.0 CONSTANTS TAB

The New Development Spreadsheet and Redevelopment Spreadsheet both use the same constants, stored in the **Constants tab**. All constants are shown in **yellow cells**. All sheets reference these values from this single location. This sheet is locked to prevent accidental modification by the user. It is recommended that this sheet be printed and filed with project records.

**Table 23. Spreadsheet Constants**

| Runoff Volume and CN (Results for D.A. A Tab) | Cell Reference |
|---|---|
| **Target Rainfall Event (inches)** | **B2** |
| **Target TP Load (lb/acre/yr)** | **B3** |
| **Runoff Coefficients (Rv)** | **B7-E7** (F)<br>**B8-E8** (MO)<br>**B9-E9** (MT)<br>**B10-E10** (IC) |
| **Curve Numbers (CN)** | **H7-K7** (F)<br>**H8-K8** (MO)<br>**H9-K9** (MT)<br>**H10-K10** (IC) |
| **Phosphorus Loading Rates (lb/acre/yr)** | **B14-E14** (F)<br>**B15-E15** (MO)<br>**B16-E16** (MT)<br>**B17-E17** (IC) |
| **Nitrogen Loading Rates (lb/acre/yr)** | **B21-E21** (F)<br>**B22-E22** (MO)<br>**B23-E23** (MT)<br>**B24-E24** (IC) |
| **Runoff Reduction Credit (%) – Stormwater BMPs** | **B28-B94** |
| **Phosphorus Removal Efficiency (%) – Stormwater BMPs** | **C28-C94** |
| **Nitrogen Removal Efficiency (%) – Stormwater BMPs** | **D28-D94** |

Note that the runoff reduction credit for ”Rainwater Harvesting” and the nutrient removal credit for ”Manufactured Treatment Devices” must be entered by the user in the appropriate Drainage Area tab.

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## 10.0 REFERENCES

Center for Watershed Protection, 2008, *Technical Memorandum: The Runoff Reduction Method*, April 18, 2008: https://www.deq.virginia.gov/home/showpublisheddocument/15107/637908143151830000

Chesapeake Bay Program (CBP), 2022. *Chesapeake Assessment and Scenario Tool (CAST) Version CAST Phase 6 –7.4.0*. Chesapeake Bay Program Office, Last accessed [October, 2022].

Chesapeake Bay Program, 2023, Chesapeake Bay Land Use and Land Cover (LULC) Database 2022 Edition: U.S. Geological Survey data release, https://doi.org/10.5066/P981GV1L.

NOAA Atlas 14 - NWS-NOAA. 2004. *Precipitation-Frequency Atlas of the United States, NOAA Atlas 14*, Vol 2, Version 3, NOAA, National Weather Service, Silver Spring, MD: Data can be accessed through the internet Precipitation Frequency Data Server (PFDS): https://hdsc.nws.noaa.gov/hdsc/pfds/

NRCS (1986) *Urban Hydrology for Small Watersheds: Technical Release 55 (TR-55)*; Second Edition, June 1986: https://www.deq.virginia.gov/home/showpublisheddocument/15150/637909741480130000

Virginia Stormwater Management Handbook (*Forthcoming 2024*)

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# Appendix A VRRM SPREADSHEET EQUATIONS

## A.1. SITE TAB

***Equation 1.1a. Forest Runoff Coefficient (Weighted for Soil Groups):***

$$Rv_F = \frac{\left[\left(A_{F_A} \times 0.02\right) + \left(A_{F_B} \times 0.03\right) + \left(A_{F_C} \times 0.04\right) + \left(A_{F_D} \times 0.05\right)\right]}{A_F}$$

***Equation 1.1b. Percentage Forest Area:***

$$\%F = \frac{A_{F_A} + A_{F_B} + A_{F_C} + A_{F_D}}{A_{site}} \times 100$$

***Equation 1.2a. Mixed Open Runoff Coefficient (Weighted for Soil Groups):***

$$Rv_{MO} = \frac{\left[\left(A_{MO_A} \times 0.08\right) + \left(A_{MO_B} \times 0.11\right) + \left(A_{MO_C} \times 0.13\right) + \left(A_{MO_D} \times 0.15\right)\right]}{A_{MO}}$$

***Equation 1.2b. Percentage Mixed Open Area:***

$$\%MO = \frac{A_{MO_A} + A_{MO_B} + A_{MO_C} + A_{MO_D}}{A_{site}} \times 100$$

***Equation 1.3a. Managed Turf Runoff Coefficient (Weighted for Soil Groups):***

$$Rv_{MT} = \frac{\left[\left(A_{MT_A} \times 0.15\right) + \left(A_{MT_B} \times 0.20\right) + \left(A_{MT_C} \times 0.22\right) + \left(A_{MT_D} \times 0.25\right)\right]}{A_{MT}}$$

***Equation 1.3b. Percentage Managed Turf Area:***

$$\%MT = \frac{A_{MT_A} + A_{MT_B} + A_{MT_C} + A_{MT_D}}{A_{site}} \times 100$$

***Equation 1.4a. Impervious Cover Runoff Coefficient:***

$$Rv_{IC} = 0.95$$

***Equation 1.4b. Percentage Impervious Cover Area:***

$$\%MT = \frac{A_{MT_A} + A_{MT_B} + A_{MT_C} + A_{MT_D}}{A_{site}} \times 100$$

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*Where:*

$Rv_F$ = *weighted forest runoff coefficient across hydrologic soil groups*
$\%F$ = *percentage of total forest area for the site*
$A_{F_A}$ = *area of post-development forest with A soils (acres)*
$A_{F_B}$ = *area of post-development forest with B soils (acres)*
$A_{F_C}$ = *area of post-development forest with C soils (acres)*
$A_{F_D}$ = *area of post-development forest with D soils (acres)*

$Rv_{MO}$ = *weighted mixed open runoff coefficient across hydrologic soil groups*
$\%MO$ = *percentage of total mixed open area for the site*
$A_{MO_A}$ = *area of post-development mixed open with A soils (acres)*
$A_{MO_B}$ = *area of post-development mixed open with B soils (acres)*
$A_{MO_C}$ = *area of post-development mixed open with C soils (acres)*
$A_{MO_D}$ = *area of post-development mixed open with D soils (acres)*

$Rv_{MT}$ = *weighted managed turf runoff coefficient across hydrologic soil groups*
$\%MT$ = *percentage of total managed turf area for the site*
$A_{MT_A}$ = *area of post-development managed turf with A soils (acres)*
$A_{MT_B}$ = *area of post-development managed turf with B soils (acres)*
$A_{MT_C}$ = *area of post-development managed turf with C soils (acres)*
$A_{MT_D}$ = *area of post-development managed turf with D soils (acres)*

$Rv_{IC}$ = *weighted impervious cover runoff coefficient across hydrologic soil groups*
$\%IC$ = *percentage of total impervious cover area for the site*
$A_{IC_A}$ = *area of post-development impervious cover with A soils (acres)*
$A_{IC_B}$ = *area of post-development impervious cover with B soils (acres)*
$A_{IC_C}$ = *area of post-development impervious cover with C soils (acres)*
$A_{IC_D}$ = *area of post-development impervious cover with D soils (acres)*
$A_{site}$ = *total site area (acres)*

### *Equation 2. Site Composite Runoff Coefficient*

$$Rv_{site} = \frac{[(Rv_F \times \%F) + (Rv_{MO} \times \%MO) + (Rv_{MT} \times \%MT) + (Rv_{IC} \times \%IC)]}{100}$$

*Where:*

$Rv_{site}$ = *unitless composite volumetric runoff coefficient for the site*
$Rv_F$ = *weighted forest/open space runoff coefficient across hydrologic soil groups (Eq. 1.1a)*
$Rv_{MO}$ = *weighted mixed open runoff coefficient across hydrologic soil groups (Eq.1.2a)*
$Rv_{MT}$ = *weighted managed turf runoff coefficient across hydrologic soil groups (Eq.1.3a)*
$Rv_{IC}$ = *impervious cover runoff coefficient across hydrologic soil groups (Eq.1.4a)*
$\%F$ = *percentage of total forest area for the site (Eq.1.1b)*
$\%MO$ = *percentage of total mixed open area for the site (Eq.1.2b)*
$\%MT$ = *percentage of total managed turf area for the site (Eq.1.3b)*
$\%IC$ = *percentage of total impervious cover area for the site (Eq.1.4b)*

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### *Equation 3. Post-Development Site Treatment Volume*

$$Tv_{site} = Rd \times Rv_{site} \times {}^{A_{site}}/_{12} \quad (acre\text{-}ft)$$
$$= Rd \times Rv_{site} \times {}^{A_{site}}/_{12} \times 43{,}560 \quad (ft^3)$$

*Where:*

| | |
|---|---|
| $Tv_{site}$ | *= post-development treatment volume for site (acre-ft)* |
| $Rd$ | *= target rainfall event depth (1 inch for water quality storm)* |
| $Rv_{site}$ | *= runoff coefficient for the site (Eq.2)* |
| $A_{site}$ | *= total site area (acres)* |
| 12 | *= unit adjustment factor, converting inches to feet* |
| 43,560 | *= unit adjustment factor, converting acres to square feet* |

### *Equation 4. Post-Development Site TP Load*

$$L = L_{RSite} \times A_{site}$$

*Where:*

| | |
|---|---|
| $L$ | *= post-development pollutant load for site (pounds/year)* |
| $L_{RSite}$ | *= site composite loading rate (pounds/acre/year)* |
| $A_{site}$ | *= total site area (acres)* |

### *Equation 5. Required Site TP Load Reduction*

$$L_{reduction} = L_{TP} - TP_{target} \times A_{site}$$

*Where:*

| | |
|---|---|
| $L_{reduction}$ | *= required TP Load Reduction (pounds/year)* |
| $L_{TP}$ | *= post-development TP load for site (pounds/year), calculated as in Eq.4* |
| $TP_{target}$ | *= target phosphorus load (pounds/acre/year) = 0.26 lb/ac/yr* |
| $A_{site}$ | *= total site area (acres)* |

## A.2. D.A. TABS

### *Equation 6. Runoff Volume from Entire Drainage Area (Cell N9)*

$$Tv_{DA_} = Rd \times Rv_{DA_MO,MT,IC} \times DA_{MO,MT,IC} \times 3{,}630$$

*Where:*

| | |
|---|---|
| $Tv_{DA_}$ | *= runoff or treatment volume for entire drainage area (DA_) = (mixed open, turf, and impervious areas only, cubic feet)* |
| $Rd$ | *= rainfall depth for target event (1 inch for water quality storm)* |
| $Rv_{DA_MO,MT,IC}$ | *= composite runoff coefficient for mixed open, turf, and impervious areas in DA_* $= \frac{(Rv_{DA_MO} \times DA_{MO}) + (Rv_{DA_MT} \times DA_{MT}) + (Rv_{DA_IC} \times DA_{IC})}{DA_{MO} + DA_{MT} + DA_{IC}}$ |
| $DA_{MO,MT,IC}$ | *= mixed open, turf, and impervious areas in DA_ (acres)* |
| 3,630 | *= unit adjustment factor, converting acre-inches to cubic feet* |

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### *Equation 7. Total Phosphorus Available for Removal From Entire Drainage Area (Cell N8)*

$L_{(TP,DA_)} = [DA] \cdot [PL]$ *(dot product)*

*Where:*

$L_{(TP,DA_)}$ *= post-development TP load for DA_ (pounds/ year)*
$[DA]$ *= The matrix of area for each land cover/hydrologic soil grade pair (acres) (cells B5:E8)*
$[PL]$ *= The matrix of phosphorus loading rates for each land cover/HSG pair (pounds/acre/year) (Constants Tab, cells B14:E17)*

### *Equation 8. Runoff Volume from Contributing Drainage Area*

$$Tv_{CA} = Rd \times Rv_{CA} \times CA \times 3{,}630$$

*Where:*

$Tv_{CA}$ *= treatment volume for contributing drainage area, or Credit area to practice (cubic feet)*
$Rd$ *= rainfall depth for target event (1 inch for water quality storm)*
$Rv_{CA}$ *= composite runoff coefficient for credit area (CA) being treated by credit practice (only MO, MT, and IC areas considered)*

$$= \frac{(Rv_{MO} \times CA_{MO}) + (Rv_{MT} \times CA_{MT}) + (Rv_{IC} \times CA_{IC})}{CA_{MO} + CA_{MT} + CA_{IC}}$$

$CA$ *= credit area applied to practice (acres, columns C through E)*
3,630 *= unit adjustment factor, converting acre-inches to cubic feet*

### *Equation 9. Runoff Reduction Achieved by Practice (Column G)*

$$\begin{aligned} V_{reduction} &= Tv_{BMP} \times RR_{CR} \\ &= \left(Tv_{CA} + V_{upstream}\right) \times RR_{CR} \\ &= \left[(Rd \times Rv_{CA} \times CA \times 3{,}630) + V_{upstream}\right] \times RR_{CR} \ * \end{aligned}$$

**formula used in spreadsheet, substituting in Eqs. 8 and 11*

*Where:*

$V_{reduction}$ *= runoff reduction achieved by practice (cubic feet)*
$Tv_{BMP}$ *= total volume of runoff to practice (cubic feet, Eq.11, column I)*
$RR_{CR}$ *= runoff reduction performance credit for the practice (column B)*
$Tv_{CA}$ *= treatment volume for credit area (cubic feet, Eq.8)*
$V_{upstream}$ *= volume from upstream runoff reduction practice (cubic feet, column F)*
$Rd$ *= rainfall depth for target event (1 inch for water quality storm)*
$Rv_{CA}$ *= composite runoff coefficient for credit area (CA) being treated by credit practice (only MO, MT, and IC areas considered)*
$CA$ *= credit area applied to practice (acres, columns C through E)*
3,630 *= unit adjustment factor, converting acre-inches to cubic feet*

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### *Equation 10. Remaining Runoff Volume Leaving the Practice (Column H)*

$$V_{remaining} = Tv_{BMP} \times (1 - RR_{CR})$$
$$= \left(Tv_{CA} + V_{upstream}\right) \times (1 - RR_{CR})$$
$$= \left[(Rd \times Rv_{CA} \times CA \times 3{,}630) + V_{upstream}\right] \times (1 - RR_{CR})^*$$

**formula used in spreadsheet, substituting in Eqs. 8 and 11*

*Where:*

| | |
|---|---|
| $V_{remaining}$ | *= volume of runoff remaining or discharged from practice after applying practice's runoff reduction credit (cubic feet)* |
| $Tv_{BMP}$ | *= total volume of runoff to practice (cubic feet, Eq.11, column I)* |
| $RR_{CR}$ | *= runoff reduction performance credit for the practice (column B)* |
| $Tv_{CA}$ | *= treatment volume for credit area (cubic feet, Eq.8)* |
| $V_{upstream}$ | *= volume from upstream runoff reduction practice (cubic feet, column F)* |
| $Rd$ | *= rainfall depth for target event (1 inch for water quality storm)* |
| $Rv_{CA}$ | *= composite runoff coefficient for credit area (CA) being treated by credit practice (only MO, MT, and IC areas considered)* |
| $CA$ | *= credit area applied to practice (acres, columns C through E)* |
| 3,630 | *= unit adjustment factor, converting acre-inches to cubic feet* |

***OR***

$$V_{remaining} = Tv_{BMP} - V_{reduction}$$

*Where:*

| | |
|---|---|
| $V_{remaining}$ | *= volume of runoff remaining or discharged from practice after applying practice's runoff reduction credit (cubic feet)* |
| $Tv_{BMP}$ | *= total volume of runoff to practice (cubic feet, Eq.11, column I)* |
| $V_{reduction}$ | *= runoff reduction achieved by practice (cubic feet, Eq. 9, column G)* |

### *Equation 11. BMP Treatment Volume (Total Runoff Volume to Practice, Column I)*

$$Tv_{BMP} = Tv_{CA} + V_{upstream}$$
$$= \left(Tv_{CA} + V_{upstream}\right)(RR_{CR}) + \left(Tv_{CA} + V_{upstream}\right)(1 - RR_{CR})$$
$$= V_{reduction} + V_{remaining}{}^*$$

**formula used in spreadsheet, rearranging and substituting in Eqs. 9 and 10*

*Where:*

| | |
|---|---|
| $Tv_{BMP}$ | *= total volume of runoff to practice (cubic feet)* |
| $Tv_{CA}$ | *= treatment volume for credit area (cubic feet, Eq.8)* |
| $V_{upstream}$ | *= volume from upstream runoff reduction practice (cubic feet, column F)* |
| $V_{reduction}$ | *= runoff reduction achieved by practice (cubic feet)* |
| $V_{remaining}$ | *= volume of runoff remaining or discharged from practice after applying practice's runoff reduction credit (cubic feet)* |

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### *Equation 12. Untreated Pollutant Load to Practice (Phosphorus, Column L; Nitrogen, Column T)*

$$L = L_{R_{MO}} \times A_{MO} + L_{R_{MT}} \times A_{MT} + L_{R_{IC}} \times A_{IC}$$

*Where:*

| | |
|---|---|
| $L$ | *= post-development pollutant load for site (pounds/year)* |
| $L_{R_{MO}}$ | *= MO composite loading rate (pounds/acre/year, cell H6 or R6)* |
| $A_{MO}$ | *= MO area flowing directly into BMP (acres)* |
| $L_{R_{MT}}$ | *= MT composite loading rate (pounds/acre/year, cell H7 or R7)* |
| $A_{MT}$ | *= MT area flowing directly into BMP (acres)* |
| $L_{R_{IC}}$ | *= IC composite loading rate (pounds/acre/year, cell H8 or R8)* |
| $A_{IC}$ | *= IC area flowing directly into BMP (acres)* |

### *Equation 13. Total Load Removal by Practice (Phosphorus, Column M; Nitrogen, Column U)*

$$L_{removed} = \left(L_{upstream} + L_{untreated}\right) \times \left(Tv_{BMP} \times {}^{PR_{CR}}/_{100}\right) / Tv_{BMP}$$

*Derivation:*

$$\left[\left(L_{upstream} + L_{untreated}\right) \times \frac{V_{reduction}}{Tv_{BMP}}\right] + \left[\left(L_{upstream} + L_{untreated}\right) \times \frac{V_{remaining}}{Tv_{BMP}} \times \left({}^{PR_{CR}}/_{100}\right)\right]$$

$$= \left(L_{upstream} + L_{untreated}\right) \times \left[\frac{V_{reduction} + V_{remaining} \times \left({}^{PR_{CR}}/_{100}\right)}{Tv_{BMP}}\right]$$

*Where:*

| | |
|---|---|
| $L_{removed}$ | *= total pollutant load removed by practice (pounds/year)* |
| $L_{upstream}$ | *= pollutant load from upstream treatment practice (pounds/year, TP-column K, TN-column S)* |
| $L_{untreated}$ | *= untreated pollutant load to practice (pounds/year, Eq. 12, TP-column L, TN-column T)* |
| $Tv_{BMP}$ | *= total runoff volume to practice (cubic feet, Eq. 11, column I)* |
| $PR_{CR}$ | *= pollutant removal performance credit (TP-column J, TN-column R)* |
| *100* | *= % conversion factor* |
| $V_{reduction}$ | *= runoff reduction achieved by practice (cubic feet, column G)* |
| $V_{remaining}$ | *= volume of runoff remaining or discharged from practice after applying practice's runoff reduction credit (cubic feet, column H)* |

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## *Equation 14. Remaining Load (Phosphorus, Column N; Nitrogen, Column V)*

$$L_{remaining} = L_{upstream} + L_{untreated} - L_{removed}$$

*Where:*

| | |
|---|---|
| $L_{remaining}$ | *= post-development pollutant load for site (pounds/year) pollutant load leaving practice or remaining after treatment (pounds/year, TP-column N, TN-column V)* |
| $L_{upstream}$ | *= pollutant load from upstream treatment practice (pounds/year, TP-column K, TN-column S)* |
| $L_{untreated}$ | *= untreated pollutant load to practice (pounds/year, Eq.12, TP-column L, TN-column T)* |
| $L_{removed}$ | *= total pollutant load removed by practice (pounds/year, Eq.13, TP-column M, TN-column U)* |

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# A.3. RUNOFF VOLUME AND CN TAB

## *Equation 15. Composite Curve Number (CN)*

$$CN_{D.A.} = \left[\left(A_{F_A} \times 30\right) + \left(A_{F_B} \times 55\right) + \left(A_{F_C} \times 70\right) + \left(A_{F_D} \times 77\right)\right] + \left[\left(A_{MO_A} \times 34\right) + \left(A_{MO_B} \times 59\right) + \left(A_{MO_C} \times 72\right) + \left(A_{MO_D} \times 79\right)\right] + \left[\left(A_{MT_A} \times 39\right) + \left(A_{MT_B} \times 61\right) + \left(A_{MT_C} \times 74\right) + \left(A_{MT_D} \times 80\right)\right] + \left[\left(A_{IC_A} + A_{IC_B} + A_{IC_C} + A_{IC_D}\right) \times 98\right]/DA$$

*Where:*

$CN_{D.A.}$ *= composite curve number for Drainage Area*
$A_{F_A}$ *= area of post-development forest with A soils (acres)*
$A_{F_B}$ *= area of post-development forest in B soils (acres)*
$A_{F_C}$ *= area of post-development forest in C soils (acres)*
$A_{F_D}$ *= area of post-development forest in D soils (acres)*

$A_{MO_A}$ *= area of post-development mixed open in A soils (acres)*
$A_{MO_B}$ *= area of post-development mixed open in B soils (acres)*
$A_{MO_C}$ *= area of post-development mixed open in C soils (acres)*
$A_{MO_D}$ *= area of post-development mixed open in D soils (acres)*

$A_{MT_A}$ *= area of post-development managed turf in A soils (acres)*
$A_{MT_B}$ *= area of post-development managed turf in B soils (acres)*
$A_{MT_C}$ *= area of post-development managed turf in C soils (acres)*
$A_{MT_D}$ *= area of post-development managed turf in D soils (acres)*

$A_{IC_A}$ *= area of post-development impervious cover in A soils (acres)*
$A_{IC_B}$ *= area of post-development impervious cover in B soils (acres)*
$A_{IC_C}$ *= area of post-development impervious cover in C soils (acres)*
$A_{IC_D}$ *= area of post-development impervious cover in D soils (acres)*

*30, 55, 70, 77 = assigned curve numbers for forest space A, B, C, D soils, respectively*
*34, 59, 72, 79 = assigned curve numbers for mixed open A, B, C, D soils, respectively*
*39, 61, 74, 80 = assigned curve numbers for managed turf A, B, C, D soils, respectively*
*98 = assigned curve number for impervious cover irrespective of underlying soil groups*

$DA$ *= Drainage Area (acres)*

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### *Equation 16. Runoff Volume with No Runoff Reduction, Row 35*

$$RV_{no\text{-}RR} = (P - 0.2 \times S)^2/(P + 0.8 \times S)$$

*Where:*

$RV_{no-RR}$ = *post-development runoff volume without runoff reduction practices in drainage area (watershed-inches)*

$P$ = $Rd$, *rainfall depth for target rainfall event (24-hour storm depth, inches)*

$S$ = *potential maximum retention after runoff begins (inches), based on composite curve number for drainage area,* $CN_{D.A.}$ *(Eq. 15)*

$$= \frac{1000}{CN_{D.A.}} - 10$$

### *Equation 17. Runoff Volume with Runoff Reduction, Row 36*

$$RV_{RR} = RV_{no\text{-}RR} - \left(V_{total_red}/3{,}630\right)/DA$$

*Where:*

$RV_{RR}$ = *post-development runoff volume in drainage area with runoff reduction practices, if applicable (watershed-inches)*

$RV_{no-RR}$ = *post-development runoff volume in drainage area without runoff reduction practices (watershed-inches, Eq. 16)*

$V_{total_red}$ = *runoff reduction volume achieved by runoff reduction practices in drainage area (cubic feet, cell K25)*

*3,630* = *unit adjustment factor, cubic feet to acre-inches*

*DA* = *drainage area (acres)*

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## *Equation 18: Adjusted Curve Number*

***Note:*** *The adjusted curve number ($CN_{adjusted}$) is determined using a lookup table of curve number and runoff volumes so that:*

$CN_{adjusted}$ *corresponds to Runoff Volume with runoff reduction,* $RV_{RR}$ *(watershed-in, Eq. 17)*

*such that*

$$RV_{RR} = \left(P - 0.2 \times S_{adjusted}\right)^2 / \left(P + 0.8 \times S_{adjusted}\right)$$

*and*

$$S_{adjusted} = \frac{1000}{CN_{adjusted}} - 10$$

*Where:*

$CN_{adjusted}$ = *adjusted curve number generating a runoff volume (watershed-inches) equal to the drainage area runoff volume with runoff reduction practices ($RV_{RR}$, Eq. 17)*

$RV_{RR}$ = *Runoff reduction volume in drainage area with runoff reduction practices (watershed-inches)*

$P$ = $Rd$, *rainfall depth for target rainfall event (24-hour storm depth, inches)*

$S_{adjusted}$ = *potential maximum retention after runoff begins (inches) based upon adjusted curve number*

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## A.4. REDEVELOPMENT SITE TAB – COMPUTATIONS

This section provides the equations (including logical derivations) for the determination of redevelopment water quality compliance. A graphical representation is given Section 4.2.3.

### *Equation 19. Net Change in Impervious Cover*

$$A_{IC,post} - A_{IC,pre} = X_{IC}$$

*Where:*

$A_{IC,post}$ *= area of post-development impervious cover (acres)*

$A_{IC,pre}$ *= area of pre-redevelopment impervious cover (acres)*

$X_{IC}$ *= the change in pre-redevelopment to post-development impervious acreage*

### *A.4.1 REDEVELOPMENT WITH IMPERVIOUS COVER INCREASE,* $(\boldsymbol{A_{IC,post} - A_{IC,pre}}) > \mathbf{0}$

### *Equation 20. TP Load Reduction Requirement for New Net Impervious Cover*

$$L_{reduction_IC,new.post} = L_{IC,new.post} - TP_{target} \times A_{IC,new.post}$$

*Where:*

$L_{reduction_IC,new.post}$ *= required TP load reduction for post-development new net impervious cover (pounds/year)*

$L_{IC,new.post}$ *= post-development TP load for new net impervious cover (pounds/year), calculated as in Eq. 4*

$TP_{target}$ *= target phosphorous load (pounds/acre/year) = 0.26 lb/ac/yr*

$A_{IC,new.post}$ *= impervious cover net increase from pre-redevelopment to post-development, equal to* $X_{IC}$ *from Eq. 19 when the impervious cover change is a net increase (acres)*

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### *Equation 21. Net Decrease in Pervious Areas*

The net decrease in pervious acreages (forest, mixed open, and/or managed turf) is equivalent to the post-development increase in impervious cover.

$$X_{IC} = -(X_F + X_{MO} + X_{MT})$$

*Where:*

$$X_{FO} = A_{F,post} - A_{F,pre}$$
$$X_{MO} = A_{MO,post} - A_{MO,pre}$$
$$X_{MT} = A_{MT,post} - A_{MT,pre}$$

Given that the pre-development site acreage equals the post-development site acreage:

$A_{site,pre} = A_{site,post}$ *Where:* $A_{site,pre} = A_{F,pre} + A_{MO,pre} + A_{MT,pre} + A_{IC,pre}$

*And:* $A_{site,post} = A_{F,post} + A_{MO,post} + A_{MT,post} + A_{IC,post}$

*Therefore:*

$$A_{F,pre} + A_{MO,pre} + A_{MT,pre} + A_{IC,pre} = A_{F,post} + A_{MO,post} + A_{MT,post} + A_{IC,post}$$

*We can rearrange to:*

$$A_{IC,post} - A_{IC,pre} = \left(A_{F,pre} - A_{F,post}\right) + \left(A_{MO,pre} - A_{MO,post}\right) + \left(A_{MT,pre} - A_{MT,post}\right)$$

*And, by substitution:*

$$X_{IC} = -(X_F + X_{MO} + X_{MT}) \qquad \textbf{(Eq. 21)}$$

*Where:*

$A_{site,pre}$ = *pre-redevelopment site area (acres)*
$A_{site,post}$ = *post-development site area (acres)*
$A_{F,pre}$ = *area of pre-redevelopment forest (acres)*
$A_{MO,pre}$ = *area of pre-redevelopment mixed open (acres)*
$A_{MT,pre}$ = *area of pre-redevelopment managed turf (acres)*
$A_{IC,pre}$ = *area pr pre-redevelopment impervious cover (acres)*
$A_{F,post}$ = *area of post-development forest (acres)*
$A_{MO,post}$ = *area of post-development mixed open (acres)*
$A_{MT,post}$ = *area of post-development managed turf (acres)*
$A_{IC,post}$ = *area of post-development impervious cover (acres)*
$X_{IC}$ = *difference in pre-redevelopment to post-development impervious acreage*
$X_F$ = *difference in pre-redevelopment to post-development forest acreage*
$X_{MO}$ = *difference in pre-redevelopment to post-development mixed open acreage*
$X_{MT}$ = *difference in pre-redevelopment to post-development managed turf acreage*

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When the net impervious cover (IC) increases following redevelopment, there must be a simultaneous decrease in forest (F), mixed open (MO), and/or managed turf (MT). Through a comparison process, the net decrease for the specific pervious land cover type areas must be quantified (F, MO, and/or MT) in order to exclude those acreages from the pre-redevelopment F, MO, and MT areas and establish the pre-redevelopment adjusted areas. This computation is performed in the ***Redevelopment spreadsheet Site tab (hidden columns N through Z)*** as follows in Fig. 28:

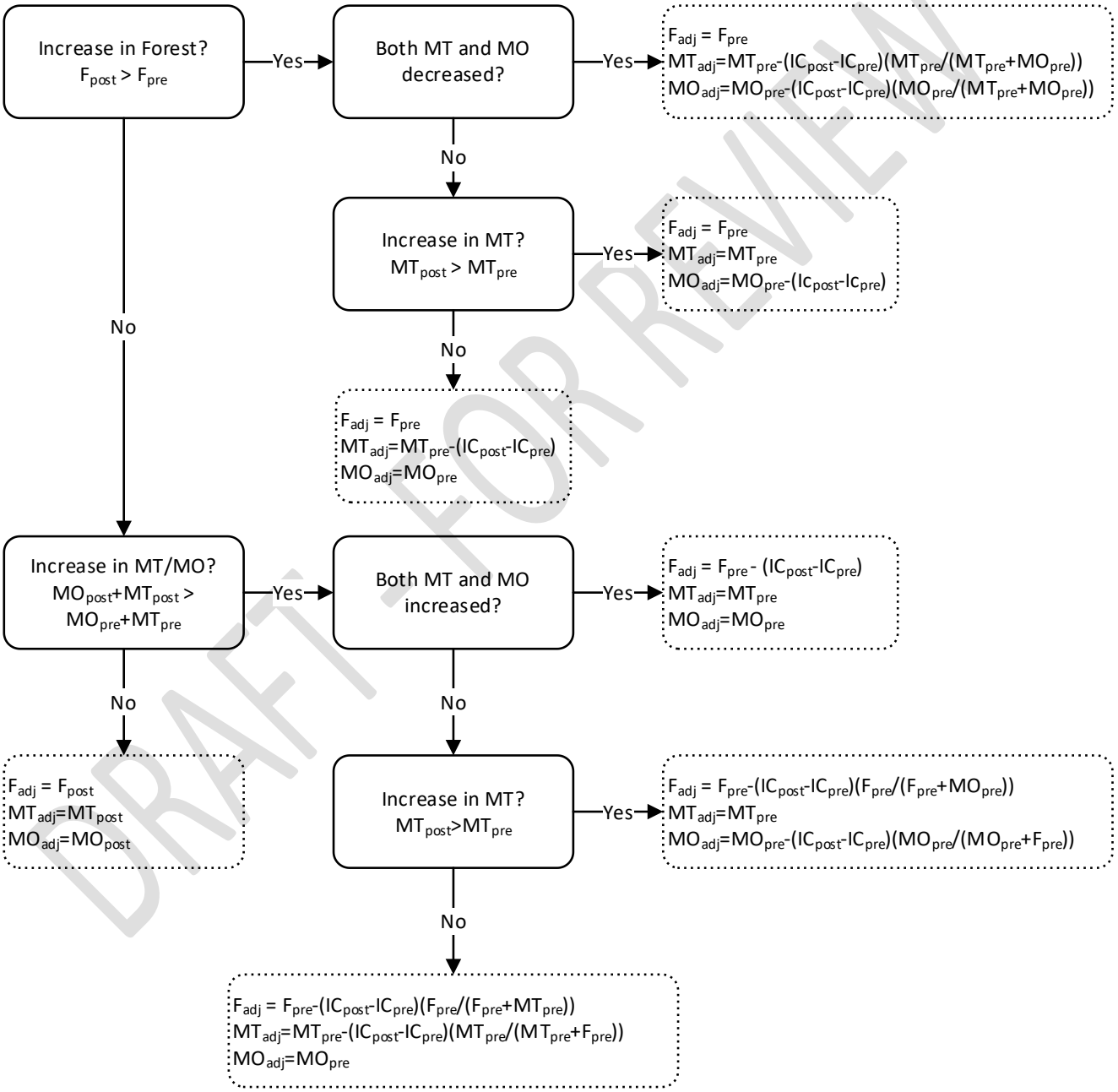


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**Figure 28. Decision flowchart for determination of pervious area converted to new net impervious cover in redevelopment spreadsheet.**

The required reduction for the pre-redevelopment area is the post-redevelopment load for the site (excluding new net impervious cover) minus [the pre-redevelopment load for the adjusted site areas (excluding pervious areas proposed for new net impervious cover) after reduction by the maximum percentage reduction requirement] or [the TP baseline load], whichever is greatest. The required TP reduction is limited to the TP baseline load of 0.26 lb TP/acre/year applied to the adjusted pre-redevelopment site areas, as explained in Section 4.2.3.

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***Equation 22a. TP Load Reduction Requirement for Post-Redevelopment Area (when target TP baseline less than or equal to target TP load, $L_{TP\ Baseline} \leq L_{target,preReDev}$)***

$$L_{reduction_postReDev} = L_{postReDev} - L_{target,preReDev}$$
$$= \left(L_{F,post} + L_{MO,post} + L_{MT,post} + L_{IC,post.ReD}\right) - (1 - \%MaxR) \times \left(L_{F,pre_adj} + L_{MO,pre_adj} + L_{MT,pre_adj} + L_{IC,pre_adj}\right)$$

*Where:*

| | |
|---|---|
| $L_{TP\ Baseline}$ | *= $0.26\ lb/acre/yr \times A_{site,pre_adj}$ = baseline TP load (lb/yr)* |
| $L_{target,preReDev}$ | *= the target pre-redevelopment TP load (lb/yr)* <br> *= $(1 - \%MaxR) \times \left(L_{F,pre_adj} + L_{MO,pre_adj} + L_{MT,pre_adj} + L_{IC,pre_adj}\right)$* |
| $L_{reduction_postReDev}$ | *= required TP load reduction for the post-development area not including any new net impervious cover (pounds/year)* |
| $L_{postReDev}$ | *= the post-redevelopment TP load (excluding new net impervious cover)* <br> *= $\left(L_{F,post} + L_{MO,post} + L_{MT,post} + L_{IC,post.ReD}\right)$* |
| $A_{site,pre_adj}$ | *= adjusted pre-redevelopment total site area that excludes pervious areas proposed for new net impervious cover (acres)* |
| $L_{F,post}$ | *= TP load calculated for post-development forest areas (pounds/year)* |
| $L_{MO,post}$ | *= TP load calculated for post-development mixed open areas (pounds/year)* |
| $L_{MT,post}$ | *= TP load calculated for post-development managed turf areas (pounds/year)* |
| $L_{IC,post.ReD}$ | *= TP load calculated for post-development impervious cover areas that do not include any new net impervious cover (pounds/year)* |
| $\%MaxR$ | *= the maximum percentage reduction required below the pre-redevelopment load (10 or 20% expressed as 0.1 or 0.2, respectively)* |
| $L_{FO,pre_adj}$ | *= TP Load calculated for pre-redevelopment forest space areas that do not include forest space areas converted to post-development new net impervious cover (pounds/year)* |
| $L_{MO,pre_adj}$ | *= TP Load calculated for pre-redevelopment mixed open areas that do not include mixed open areas converted to post-development new net impervious cover (pounds/year)* |
| $L_{MT,pre_adj}$ | *= TP Load calculated for pre-redevelopment managed turf areas that do not include managed turf areas converted to post-development new net impervious cover (pounds/year)* |
| $L_{IC,pre_adj}$ | *= TP Load calculated for pre-redevelopment impervious cover areas (pounds/year)* |

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### *Equation 22b. TP Load Reduction Requirement for Post-Redevelopment Area (when target TP load less than TP baseline, $L_{target,preReDev} < L_{TP\ Baseline}$)*

$$L_{reduction_{postReDev}} = L_{postReDev} - L_{TP\ Baseline} = \left(L_{F,post} + L_{MO,post} + L_{MT,post} + L_{IC,post.ReD}\right) \times A_{site,pre_adj} - 0.26\ lb/acre/yr$$

*Where:*

$L_{target,preReDev}$ = *the target pre-redevelopment TP load (pounds/year)*

$$= (1 - \%MaxR) \times \left(L_{F,pre_adj} + L_{MO,pre_adj} + L_{MT,pre_adj} + L_{IC,pre_adj}\right)$$

$L_{TP\ Baseline}$ = $0.26\ lb/acre/yr \times A_{site,pre_adj}$ = *baseline TP load*

$L_{reduction_postReDev}$ = *required TP load reduction for the post-development area excluding any new net impervious cover (pounds/year)*

$L_{postReDev}$ = *the post-redevelopment TP load (excludes new net impervious cover)*

$$= \left(L_{F,post} + L_{MO,post} + L_{MT,post} + L_{IC,post.ReD}\right)$$

$\%MaxR$ = *the maximum percentage reduction required below the pre-redevelopment load (10 or 20%, expressed as 0.1 or 0.2, respectively)*

$L_{F,pre_adj}$ = *TP Load calculated for pre-redevelopment forest areas that do not include forest areas converted to post-development new net impervious cover (pounds/year)*

$L_{MO,pre_adj}$ = *TP Load calculated for pre-redevelopment mixed open areas that do not include mixed open areas converted to post-development new net impervious cover (pounds/year)*

$L_{MT,pre_adj}$ = *TP Load calculated for pre-redevelopment managed turf areas that do not include managed turf areas converted to post-development new net impervious cover (pounds/year)*

$L_{IC,pre_adj}$ = *TP Load calculated for pre-redevelopment impervious cover areas (pounds/year)*

$A_{site,pre_adj}$ = *adjusted pre-redevelopment total site area that excludes pervious areas proposed for new net impervious cover (acres)*

$L_{F,post}$ = *TP load calculated for post-development forest areas (pounds/year)*

$L_{MO,post}$ = *TP load calculated for post-development mixed open areas (pounds/year)*

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$L_{MT,post}$ = *TP load calculated for post-development managed turf areas (pounds/year)*

$L_{IC,post.ReD}$ = *TP load calculated for post-development impervious cover areas that do not include any new net impervious cover (pounds/year)*

## A.4.2. REDEVELOPMENT WITH NO IMPERVIOUS COVER INCREASE, $(A_{IC,post} - A_{IC,pre}) \leq 0$

In the situations where a redevelopment project does not include a net change in impervious cover acreage (i.e., no new net impervious cover), the post-development site total phosphorus load must meet the pre-redevelopment total phosphorus load after the 10 or 20% reduction, depending on the project's total disturbed acreage, up to the pre-redevelopment project's baseline load at 0.26 lb TP/acre/yr. This situation is illustrated above in Section 4.2.3.

*Using Equations 19 and 20:*

$A_{IC,new.post} = 0$
*And*
$L_{reduction_IC,new.post} = 0$

## A.4.3. FINAL POST-DEVELOPMENT SITE REQUIREMENT

### Equation 23. Final TP Load Reduction Requirement for Redevelopment

$$L_{reduction_FinalPost} = L_{reduction_IC,new.post} + L_{reduction_postReDev}$$

*Where:*

$L_{reduction_FinalPost}$ = *required TP load reduction for the post-development site consisting of all land cover areas (pounds/year)*

$L_{reduction_IC,new.post}$ = *required TP load reduction for post-development new net impervious cover (pounds/year)*

$L_{reduction_postReDev}$ = *required TP load reduction for the post-development area not including any new net impervious cover (pounds/year)*

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# Appendix B ACRONYMS AND DEFINITIONS

**BMP:** Best Management Practice

**BMP Clearinghouse:** Virginia Stormwater BMP Clearinghouse

**CAST:** Chesapeake Assessment and Scenario Tool

**CN**: Curve Number

**DA**: Drainage Area

**DEQ:** Virginia Department of Environmental Quality

**F:** Forest

**HSG:** Hydrologic Soil Group

**IC:** Impervious Cover

**LOD:** Limits of disturbance

**MO:** Mixed Open

**MT:** Managed Turf

**MTD:** Manufactured Treatment Device

**NRCS:** Natural Resources Conservation Service

**Permanent BMP:** Permanent best management practice or stormwater management facilities as defined in 9VAC25-875-10

**Regulated Land Disturbing Activity (LDA):** Land-disturbing activity of one acre or more, 2,500 square feet in all areas of jurisdictions designated as subject to the Chesapeake Bay Preservation Act, part of a larger common plan of development or sale that is one acre or more, or a more stringent area as established in local ordinance, that must follow the provisions of the VESMR Regulations and obtain state permit coverage, where applicable, and VESMR authority permit coverage.

**RRM**: Runoff Reduction Method

**RR**: Runoff Reduction

**RV**: Runoff Volume

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**SWM:** Stormwater management

**TN**: Total Nitrogen

**TP**: Total Phosphorus

**TV**: Treatment Volume

**VRRM**: Virginia Runoff Reduction Method

**VESMR:** Virginia Erosion and Stormwater Management Regulation

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# Appendix C SEPARATION OF FOREST/OPEN SPACE INTO FOREST AND MIXED OPEN

## C.1 VRRM Land Cover Categories

Version 4.0 of the VRRM Spreadsheets introduces a new land cover category. The forest/open space land cover from Version 3.0 and previous spreadsheets have been split into two categories: forest and mixed open. The forest category will retain the properties (CN and Rvs) of the previous forest/open space category. The new mixed open category is intended to capture minimally maintained spaces such as utility easements, rights of ways, or other areas surrounding development or utilities that are maintained on an infrequent basis. To integrate the proposed mixed open land cover into the VRRM methodology, curve numbers (CNs) and volumetric runoff coefficients (Rvs) were developed as outlined below.

## C.2 Mixed Open Curve Numbers

The curve numbers included within the VRRM historically have been directly aligned with similar category descriptions found in the National Engineering Handbook (NEH) or the National Resource Conservation Service (NRCS) Technical Report 55 (TR55), Urban Hydrology for Small Watersheds. The mixed open category follows suit in using NEH/TR55 categories to establish curve numbers; however, since this category is a mixture of several categories found in those documents, an average of those individual category values is established for use. These particular categories were chosen since the land cover for the mixed open category is envisioned to be predominantly a mixture of grasses and small shrubs. It is expected that infrequent clearing will prevent establishing a predominant cover condition of brush or small trees. Values in Table 24 are created by averaging the values found in the NEH and rounding to the nearest whole number.

**Table 24: Table of 3 NEH/TR55 land covers averaged to compute Mixed Open CNs**

| Category | A | B | C | D |
|---|---|---|---|---|
| **Meadow** | 30 | 58 | 71 | 78 |
| **Pastureland** | 39 | 61 | 74 | 80 |
| **Woods/Grass** | 32 | 58 | 72 | 79 |
| **Avg Mixed Open** | **34** | **59** | **72** | **79** |

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## C.3 Mixed Open Rv Coefficients

Rv coefficients for the forest and managed turf categories were originally developed using several studies that were outlined in Battiata [2010]. Values for those two land covers will remain as reported in VRRM 3.0. Because the Mixed Open cover is intended to share some of the characteristics of each of the forest and managed turf areas, the Rvs and CNs of these two existing categories were used to derive new Rv coefficients for the mixed open category.

Values of the Rv coefficients for the A soils were created using a slope-averaging method using both the CN coefficients and the existing Rv coefficients for the forest and managed turf categories.

The equation used is:

$$MO_{R_v} = F_{R_v} + \left(MT_{R_v} - F_{R_v}\right)/(MT_{CN} - F_{CN}) \times (MO_{CN} - F_{CN})$$

*Where:*

| | |
|---|---|
| $MO_{R_v}$ | *= Mixed open Rv Coefficient* |
| $MO_{CN}$ | *= Mixed Open curve number* |
| $F_{R_v}$ | *= Forest Rv Coefficient* |
| $F_{CN}$ | *= Forest curve number* |
| $MT_{R_v}$ | *= Managed Turf Rv Coefficient* |
| $MT_{CN}$ | *= Managed Turf curve number* |

Substituting using values for A soils, the mixed open Rv coefficients for this hydrologic soil classifications are:

$$MO_{R_{v-A\,soil}} = 0.02 + \frac{(0.15 - 0.02)}{(39 - 30)} \times (34 - 30) = \underline{\mathbf{0.08}}$$

Rv coefficients for the remaining soil groups were determined by performing a comparative analysis of the CN coefficients and Rv coefficients between soil groups. First, the difference between soil types is computed for the Forest, Mixed Open, and Managed Turf land covers. For instance, for the Forest category, the difference between A and B soils CN values is 25, for B-C it is 15, and for C-D it is 7. Table 25a shows these differences for each.

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**Table 25a: Curve number differences between soil types**

| Category | B-A | C-B | D-C |
|---|---|---|---|
| Forest | 25 | 15 | 7 |
| Mixed Open | 25 | 13 | 7 |
| Managed Turf | 22 | 13 | 6 |

Similarly, the difference in the Rv coefficients for the Forest and Managed Turf categories can be computed.

**Table 25b: Rv differences between soil types**

| Category | B-A | C-B | D-C |
|---|---|---|---|
| Forest | 0.01 | 0.01 | 0.01 |
| Mixed Open | -- | -- | -- |
| Managed Turf | 0.05 | 0.02 | 0.03 |

From Tables 25a and 25b, the ratio of the change in Rv to the change in CN can be computed. These values are then averaged to establish the ratios for the Mixed Open category.

**Table 25c: Ratio of difference in Rv to difference in CN**

| Category | B-A | C-B | D-C |
|---|---|---|---|
| Forest | 0.0004 | 0.0007 | 0.0014 |
| Mixed Open | 0.0013 | 0.0011 | 0.0032 |
| Managed Turf | 0.0023 | 0.0015 | 0.0050 |

Now, the Rv coefficients for the Mixed Open category which draws components from both the Forest and the Managed Turf categories is computed as follows:

A = 0.08, as established above
B = 0.08 +0.0013*25 = 0.113
C = 0.113 + 0.0011*13 = 0.126
D = 0.126 + 0.0032*7 = 0.148

**Table 25d: Rv Coefficients used in the VRRM 4.0 Spreadsheets**

| Category | A | B | C | D |
|---|---|---|---|---|
| Forest | 0.02 | 0.03 | 0.04 | 0.05 |
| Mixed Open | 0.08 | 0.11 | 0.13 | 0.15 |
| Managed Turf | 0.15 | 0.20 | 0.22 | 0.25 |
| Impervious | 0.95 | 0.95 | 0.95 | 0.95 |

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# Appendix D ASSIGNING CAST LAND COVERS TO VRRM LAND USE CATEGORIES

## D.1 CAST LAND COVERS

The Chesapeake Assessment Scenario Tool (CAST) has 49 total land covers, broken into five sectors (Agriculture, Septic, Wastewater, Developed and Natural). A complete CAST land cover list is provided in **Table 26**. Land cover definitions can be found on CAST's source data page (https://cast.chesapeakebay.net/Home/SourceData) [CBP 2022]. Three of CAST's five sectors are not consistent with typical post-development VRRM land covers. These include agriculture, septic and wastewater. Agriculture includes 17 different types of agricultural land, ranging from agricultural open space (unmanaged agricultural land that receives no nutrient applications) to specific crop types (e.g., Leguminous hay, which includes nitrogen fixing species such as alfalfa). Septic includes two land covers (septic and rapid infiltration basin), which collectively refer to terrestrial, infiltration-based disposal systems for treated wastewater and the nutrient loads they deliver to streams. Wastewater includes three land covers (combined sewer overflow, industrial wastewater treatment plant and municipal wastewater treatment plant), which capture the nutrient loads delivered to streams by wastewater treatment infrastructure.

The remaining two CAST land cover sectors (developed and natural) are generally consistent with post-development VRRM land covers. Developed includes 17 land cover categories, encompassing both pervious and impervious cover, within and outside MS4 areas. This includes categories such as MS4, CSS and non-regulated turf grass (e.g., herbaceous and barren lands that have been altered through compaction, removal of organic material, or fertilization, and are located in areas with municipal separate storm sewer systems, combined sewer overflow systems, or neither, respectively), as well as MS4, CSS, and non-regulated roads (e.g., paved and unpaved roads and bridges within MS4, CSS, or non-regulated areas, respectively). The developed sector also includes a variety of "cover over" categories of land cover, where tree canopy is present above other types of land such as imperviousness or turf grass.

The final CAST sector is natural, which includes 10 land cover categories. These categories range from mixed open (e.g., shrubby, herbaceous and barren lands that are minimally disturbed) to true forest (e.g., patches of trees ≥ 30-80 feet from non-road impervious surfaces that cover more than 1-acre). Natural also includes aquatic land covers (water) and interfacial (soil-water) land covers (e.g., nontidal floodplain wetland, headwater or isolated wetland, streambed and bank, shoreline).

## D.2 LAND COVER ASSIGNMENTS (FROM CAST TO VRRM)

Because CAST's agriculture, septic and wastewater land cover sectors do not represent typical post-development VRMM land covers, they were not assigned to VRMM land cover categories;

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however, 14 land covers from CAST's developed and natural sectors were assigned. Ten of these were developed land covers (five for MS4 areas, five for non-regulated areas), including buildings and other, roads, tree canopy over imperviousness, tree canopy over turf grass, and turf grass. The remaining four were natural land covers, including true forest, mixed open, headwater or isolated wetland, and non-tidal floodplain wetland (green symbols, **Table 26**). Thirteen developed or natural land covers were not assigned to VRRM categories either because they represented a mixture of cover types, and there was no feasible way to break them into their components (e.g., shoreline, streambed and bank, regulated construction), because they did not effectively represent developed land cover loadings (e.g., water and harvested forest), or because nutrient loading information was not reported for them by CAST, precluding their inclusion (e.g., CSS forest, CSS mixed open, CSS buildings and other, CSS construction, CSS roads, CSS tree canopy over imperviousness, CSS tree canopy over turf grass, CSS turf grass; grey symbols, **Table 26**).

**Table 26: CAST land covers organized by sector. Green (grey) symbols indicate developed or natural land covers included (not included) in VRRM land cover classifications.**

| Agriculture | Septic | | Developed | |
|---|---|---|---|---|
| Ag open space | Septic | | CSS buildings and other | ● |
| Double cropped land | Rapid Infiltration Basin | | CSS construction | ● |
| Full season soybeans | **Wastewater** | | CSS roads | ● |
| Grain with manure | Combined sewer overflow | | CSS tree canopy over impervious | ● |
| Grain without manure | Industrial wastewater treatment plant | | CSS tree canopy over turf grass | ● |
| Leguminous hay | Municipal wastewater treatment plant | | CSS turf grass | ● |
| Non-permitted feeding space | **Natural** | | MS4 buildings and other | ● |
| Other agronomic crops | CSS forest | ● | MS4 roads | ● |
| Other hay | CSS mixed open | ● | MS4 tree canopy over impervious | ● |
| Pasture | Harvested forest | ● | MS4 tree canopy over turf grass | ● |
| Permitted feeding space | Headwater or isolated wetland | ● | MS4 turf grass | ● |
| Riparian pasture deposition | Mixed open | ● | Non-regulated buildings and other | ● |
| Silage with manure | Non-tidal floodplain wetland | ● | Non-regulated roads | ● |
| Silage without manure | Shoreline | ● | Non-regulated tree canopy over impervious | ● |
| Small grains and grains | Streambed and bank | ● | Non-regulated tree canopy over turf grass | ● |
| Specialty crop high | True forest | ● | Non-regulated turf grass | ● |
| Specialty crop low | Water | ● | Regulated construction | ● |

Of the 14 land covers assigned to VRRM categories, six became part of the category "Impervious" (**Table 27**). This includes MS4 buildings and other, non-regulated buildings and other, MS4 roads, non-regulated roads; MS4 tree canopy over imperviousness; and non-regulated tree canopy over imperviousness. Because canopy cover varies by season, "cover over" CAST land covers, such as tree canopy over impervious, were assigned to VRRM categories based on their substory (i.e., in late fall to early spring tree canopy over impervious simplifies to impervious, making the latter the more appropriate classifier) [CBP 2022].

Table 27: CAST land covers assigned to VRRM categories

| VRRM | CAST Land Cover | CAST Land Cover Definition *(abbreviated)* |
|---|---|---|
| Forest | True forest | Trees farther than 30'-80' from non-road impervious surfaces and forming contiguous patches greater than 1-acre in extent |
| | Headwater or isolated wetland | Transitional land between terrestrial & aquatic systems. Includes small, shallow open water ponds or potholes, often called swamps, marshes, potholes, bogs, or fens. |
| | Non-tidal floodplain wetland | Transitional land between terrestrial & aquatic systems. Includes lacustrine, palustrine and riverine wetland systems. |
| Turf | MS4 turf grass | Herbaceous and barren lands that have been altered through compaction, removal of organic material, and/or fertilization. These include all herbaceous and barren lands within road rights-of-way and residential, commercial, recreational, and other turf-dominated land uses (e.g., cemeteries, shopping centers) and a portion of herbaceous and barren lands within federal facilities, parks, institutional campuses, and large developed parcels. They are located within MS4 areas. |
| | Non-regulated turf grass | Same as above except located outside MS4 and CSS areas |
| | MS4 tree canopy over turf grass | Trees within 30'-80' of non-road impervious surfaces where the understory is assumed to be turf grass or otherwise altered through compaction, removal of surface organic material, and/or fertilization within MS4 areas |
| | Non-regulated tree canopy over turf grass | Same as above except located outside MS4 and CSS areas |
| Mixed Open | Mixed open | All scrub-shrub and herbaceous and barren lands that have been minimally disturbed (e.g., periodically bush hogged, meadows, etc.), reclaimed, or that have internal and/or regulated drainage. These include active, abandoned and reclaimed mines, landfills, beaches, waterbody margins, natural grasslands, utility rights-of-way and a portion of herbaceous lands within industrial, transitional (early stages of construction), and warehousing land uses. |
| Impervious | MS4 buildings and other | Buildings, driveways, sidewalks, parking lots, runways, some private roads, railroads and rail rights-of-way, and barren lands within industrial, transitional (early stages of construction), and warehousing within MS4 areas |
| | Non-regulated buildings and other | Same as above except located outside MS4 and CSS areas |
| | MS4 roads | Paved and unpaved roads and bridges on land within MS4 areas |
| | Non-regulated roads | Same as above except located outside MS4 and CSS areas |
| | MS4 tree canopy over impervious | Trees over roads and non-road impervious surfaces within MS4 areas |
| | Non-regulated tree canopy over impervious | Same as above except located outside MS4 and CSS areas |

Three CAST land covers were assigned to the VRRM category "Forest", including true forest (trees that form contiguous patches exceeding 1-acre and that are greater than 30-80 ft from non-road impervious surfaces), headwater or isolated wetlands (small, shallow open water ponds or potholes, often called swamps, marshes, potholes, bogs, or fens), and non-tidal floodplain wetlands (lacustrine, palustrine and riverine wetland systems) (**Table 27**). Four land covers were assigned to the VRRM category "Turf", including MS4 turf grass, non-regulated turf-grass, MS4 tree canopy over turf-grass, and non-regulated tree canopy over turf grass (**Table 27**). Finally, one CAST land cover, mixed open, was assigned to a new VRRM land cover category of the same name "Mixed Open". This new category captures shrubby, herbaceous or barren lands that are minimally disturbed (for instance, periodically bush hogged), and includes active, abandoned and reclaimed mines, landfills, beaches, waterbody margins, natural grasslands, utility rights-of-way and a portion of herbaceous lands within industrial, transitional, and warehousing land uses (**Table 27**).

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# Appendix E ESTABLISHING NUTRIENT LOADING RATES

## E.1 OBJECTIVES

The Chesapeake Assessment Scenario Tool (CAST) provides nutrient loads and areas that can be used to establish loading rates for phosphorus and nitrogen (lbs/acre/year) across various land use categories. This section describes the methodology employed to map these nutrient loading rates across the four land cover conditions and the four hydrologic soil groups (HSG) depicted within the Virginia Runoff Reduction Method (VRRM). The analyses described in the following sections are based on a customized run of CAST Phase 6 – v. 7.4.0 employing an adjusted fertilizer application rate of 1.06 lbs/acre/year.

## E.2 CAST LOADING RATES

CAST nutrient loading rates are shown in Table 28. Note that this summary table does not include all 49 land cover conditions depicted in the CAST model; rather, only the 14 identified as relevant for inclusion in the VRRM.

**Table 28: CAST nutrient loading rates (lbs/acre/yr)**

| CAST Land Cover | Phosphorus Loading Rate | Nitrogen Loading Rate |
|---|---|---|
| Headwater or Isolated Wetland | 0.056 | 1.211 |
| Non-tidal Floodplain Wetland | 0.061 | 1.091 |
| True Forest | 0.071 | 1.197 |
| MS4 Buildings and Other | 0.711 | 10.343 |
| MS4 Roads | 0.862 | 12.686 |
| MS4 Tree Canopy over Impervious | 0.768 | 12.413 |
| Non-Regulated Buildings and Other | 0.740 | 10.607 |
| Non-Regulated Roads | 0.921 | 13.827 |
| Non-Regulated Tree Canopy over Impervious | 0.773 | 13.234 |
| Mixed Open | 0.355 | 1.623 |
| MS4 Tree Canopy over Turf Grass | 0.452 | 5.461 |
| MS4 Turf Grass | 0.598 | 7.093 |
| Non-Regulated Tree Canopy over Turf Grass | 0.537 | 6.007 |
| Non-Regulated Turf Grass | 0.749 | 7.828 |

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To establish cumulative runoff loads resulting from the CAST loading rates shown in Table 28, model scenarios were conducted for the portion of the Commonwealth of Virginia that flows into the Chesapeake Bay. The CAST model allows users to conduct runoff/loading scenarios with or without the inclusion of water quality BMPs in the modeled drainage area. The model runs used to assign loading rates to the VRRM were conducted under a "No BMP" scenario as the VRRM should compute loading rates that are "pre-treatment." Further, CAST reports cumulative loads at both "Edge of Stream" (EOS) and "Edge of Tide" (EOT) locations. The analysis described in the following sections was performed using CAST loads computed at EOS locations, such that any attenuation/mitigation of nutrient loads occurring from EOS to EOT is omitted (i.e., nutrient loads more accurately reflect "site scale" runoff values as intended in the VRRM).

## E.3 CAST LOADING RATE ASSIGNMENT PROCEDURE

The VRRM considers four distinct land use categories: Forest, Impervious, Mixed Open, and Managed Turf. Of the 49 land use categories depicted in the CAST, 14 were identified for inclusion in the VRRM. The 14 CAST land use categories considered in the VRRM are presented in Table 27, grouped by the respective VRRM land use categories.

To establish a single, consolidated loading rate for each VRRM land use category, area weighting was performed using the individual CAST loading rates and their respective land areas. As noted earlier, land areas reflect only those portions of the Commonwealth that flow into the Chesapeake Bay.

***Equation 24. Area Weighting to determine a single, consolidated nutrient loading rate for each VRRM land use category.***

$$Wr = \frac{(C_r)(A_i)}{A_{total}}$$

*Where:*
$W_r$ *= Area-weighted CAST loading rate for VRRM land use category (lbs/acre/yr)*
$C_r$ *= CAST loading rate corresponding each of 16 individual CAST land use categories (lbs/acre/yr)*
$A_i$ *= CAST land use areas (acres)*
$A_{total}$ *= Cumulative area of each VRRM land use category (acres)*

Table 29 presents a summary of this calculation for phosphorus for the VRRM land use category designated as "Managed Turf."

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**Table 29: Area-Weighting Summary – VRRM "Managed Turf" Land Use Category**

| | | Cast Loading Rate (Cr) | Acres (A) | Weighted Loading Rate (Wr) |
|---|---|---|---|---|
| Managed Turf | MS4 Tree Canopy over Turf Grass | 0.452 | 112,230.49 | 0.042 |
| | MS4 Turf Grass | 0.598 | 199,773.93 | 0.100 |
| | Non-Regulated Tree Canopy over Turf Grass | 0.537 | 218,772.37 | 0.098 |
| | Non-Regulated Turf Grass | 0.749 | 664,044.91 | 0.416 |
| | | **Totals** | **1,194,821.71** | **0.657** |

Table 30 presents the consolidated nutrient loading rates computed for each VRRM land use category, obtained by this area-weighting procedure.

**Table 30: Consolidated Nutrient Loading Rates – All VRRM Land Use Categories**

| VRRM Land Use Category | Phosphorus Consolidated Loading Rate (lbs/acre/yr) | Nitrogen Consolidated Loading Rate (lbs/acre/yr) |
|---|---|---|
| Forest | 0.071 | 1.194 |
| Impervious | 0.794 | 11.796 |
| Mixed Open | 0.355 | 1.623 |
| Turf | 0.657 | 7.150 |

It is reasonably assumed that nutrient loading rates will increase with increasing runoff volume (i.e. with increasing HSG classification, A→D). Therefore, the results presented in Table 30 potentially overestimate the nutrient loads coming from HSG A while potentially underestimating the loads coming from HSG C and D.

The following section describes the methodology for considering the different runoff (load) potential across the four hydrologic soil groups.

## E.4 LOADING RATES ACROSS HYDROLOGIC SOIL GROUPS

The variable runoff (load) potential across the differing HSGs must be considered, and an assumption made regarding the breakdown of loading rates across the four HSG categories. The runoff coefficient ($R_v$) percentages across the HSG categories align very closely with the loading rate percentages presented in the 2017 VRRM spreadsheet. Note that for the "Impervious" land cover category in the VRRM it is assumed that the runoff (load) potential is equivalent across the four HSGs. Tables 31 and 32 present the percentage of total loading rates per HSG category and the percentage of Total $R_v$ per category, respectively, from the 2017 VRRM spreadsheet.

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**Table 31: Percentage of Total Loading Rates (per HSG Category) 2017 VRRM**

| Category | A | B | C | D |
|---|---|---|---|---|
| **Forest** | 16% | 22% | 28% | 34% |
| **Managed Turf** | 18% | 25% | 27% | 30% |
| **Impervious** | 25% | 25% | 25% | 25% |

**Table 32: Percentage of Total Rv (per HSG Category) 2017 VRRM**

| Category | A | B | C | D |
|---|---|---|---|---|
| **Forest** | 14% | 21% | 29% | 36% |
| **Managed Turf** | 18% | 24% | 27% | 30% |
| **Impervious** | 25% | 25% | 25% | 25% |

Because the percentage $R_V$ components align so closely with the percentage of total loading rates, the Rv component percentages can be reasonably used to estimate the load contribution from each HSG category. Table 33 presents the updated $R_V$ values which also include the new Mixed Open land use category.

**Table 33: Percentage of Total Rv (per HSG Category) Updated VRRM Values**

| Category | A | B | C | D |
|---|---|---|---|---|
| **Forest** | 14% | 21% | 29% | 36% |
| **Mixed Open** | 17% | 24% | 27% | 32% |
| **Managed Turf** | 18% | 24% | 27% | 30% |
| **Impervious** | 25% | 25% | 25% | 25% |

The following sections describe how the Rv percentages from Table 33 were used, along with the percentage of total drainage area depicted by each HSG category, to compute individual loading rates.

## E.5 DISTRIBUTION OF HYDROLOGIC SOIL GROUPS ACROSS THE COMMONWEALTH

An assumption regarding the distribution (percentage) of the various HSG categories across the total drainage area must be made. In doing so, only the portion of the Commonwealth draining to the Chesapeake Bay was considered. This was because the metrics from the CAST model only include areas within the Bay Watershed. It is assumed that this breakdown is similar for the remaining portion of the Commonwealth. For soils having a dual classification (i.e. A/D, B/D, and C/D), a 50/50 area split between the two HSG categories was assumed. Table 34 presents the respective land areas (and corresponding percentages) for each HSG category, as shown on the map titled "Hydrologic Soil Group Map Commonwealth of Virginia" prepared by Wetland Studies and Solutions, Inc., dated April 7, 2021.

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**Table 34: Percentage of Total Drainage Area by HSG Category**

| HSG | Acres | Adjusted | Percentage |
|---|---|---|---|
| A | 1,785,145 | 1,839,829.0 | 14% |
| A/D | 109,368 | | |
| B | 6,205,088 | 6,635,353.0 | 50% |
| B/D | 860,530 | | |
| C | 2,141,879 | 2,371,927.5 | 18% |
| C/D | 460,097 | | |
| D | 1,669,429 | 3,384,426.5 | 18% |
| **Totals** | **13,231,536** | **13,231,536.0** | **100%** |

## E.6 SOLVING FOR LOADING RATES

This section describes the computational methodology employed to integrate the $R_V$ and land area percentages to establish nutrient loading rates across the four land cover conditions and the four HSG categories depicted within the VRRM.

First, a matrix is constructed with cell entries computed as the product of the $R_V$ percentages presented in Table 33 and a user-specified row "sum." The units of these entries are lbs/acre/year. Initial row sum values are set to 1.0; they will be manually modified as described in the following steps. Table 35 presents this matrix for Phosphorus, based on the 2021 CAST loading rates.

**Table 35: Intermediate Computational Matrix 1 – Phosphorus (lbs/acre/yr)**

| Category | *A* | *B* | *C* | *D* | *SUM* |
|---|---|---|---|---|---|
| **Forest** | 0.143 | 0.214 | 0.286 | 0.357 | 1.000 |
| **Mixed Open** | 0.168 | 0.240 | 0.271 | 0.320 | 1.000 |
| **Managed Turf** | 0.183 | 0.244 | 0.268 | 0.305 | 1.000 |

Second, a new matrix is constructed with cell entries computed as the product of the land area percentages presented in Table 34 and the cell entries (preliminary loading rates) from the first computational matrix (Table 35). Note that the cell entries from the first matrix are a function of the user-specified row sum. The resulting row values in the second matrix are mathematically summed and titled "Total Rate" in units of lbs/acre/yr. Table 36 presents this matrix.

**Table 36: Intermediate Computational Matrix 2 – Phosphorus (lbs/acre/yr)**

| *Area %* | *14%* | *50%* | *18%* | *18%* | |
|---|---|---|---|---|---|
| **Category** | *A* | *B* | *C* | *D* | *Total Rate* |
| **Forest** | 0.020 | 0.107 | 0.051 | 0.064 | 0.243 |
| **Mixed Open** | 0.023 | 0.121 | 0.049 | 0.058 | 0.250 |
| **Managed Turf** | 0.025 | 0.122 | 0.048 | 0.055 | 0.251 |

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Third, the row sum entries in the first matrix are manually adjusted in a "trial and error" manner until the total loading rates (row sums) depicted in the second matrix (Table 36) converge to match the consolidated CAST loading rates shown in Table 30. This process can be expedited by the use of a solver, such as the Microsoft Excel "Goal Seek" function. The cell entries depicted in the first matrix are a function of the user-specified row sum, and as that sum is modified, these cell entries change. When the total loading rates (row sums) from the second matrix equal the consolidated CAST loading rates, the cell entries in the first matrix represent the final VRRM loading rates for the varying land cover conditions and HSG categories. Tables 37 and 38 present the final matrices resulting from this procedure for Phosphorus, based on the 2021 CAST loading rates. Note that this analysis is not required for the Impervious land use category, as runoff rates and resulting loads are considered independent of HSG classification.

**Table 37: Final Computational Matrix 1 – Phosphorus (lbs/acre/yr)**

| *Category* | *A* | *B* | *C* | *D* | *Adj. Rate* |
|---|---|---|---|---|---|
| **Forest** | 0.042 | 0.062 | 0.083 | 0.104 | 0.291 |
| **Mixed Open** | 0.239 | 0.341 | 0.385 | 0.454 | 1.420 |
| **Managed Turf** | 0.479 | 0.639 | 0.703 | 0.799 | 2.621 |

**Table 38: Final Computational Matrix 2 – Phosphorus (lbs/acre/yr)**

| *Area %* | *14%* | *50%* | *18%* | *18%* | | |
|---|---|---|---|---|---|---|
| | *A* | *B* | *C* | *D* | *Total Rate* | *CAST Value* |
| **Forest** | 0.006 | 0.031 | 0.015 | 0.019 | 0.071 | 0.071 |
| **Mixed Open** | 0.033 | 0.171 | 0.069 | 0.082 | 0.355 | 0.355 |
| **Managed Turf** | 0.067 | 0.321 | 0.126 | 0.144 | 0.657 | 0.657* |

*Note that in the publicly available version of CAST, a cumulative area-weighted loading rate of 1.443 lbs/acre/yr was computed across all of the CAST land use categories considered for the managed turf land cover. In the preceding section, and as shown in Table 38, a total phosphorus loading rate of 0.657 lbs/acre/yr was applied to determine final VRRM loading rates (rather than the previously presented value of 1.443 lb/acre/yr). The following section explains this discrepancy.

On December 31, 2013, a Virginia law went into effect that prohibited the sale of lawn maintenance fertilizer containing more than zero percent phosphorus or other compounds containing phosphorus, such as phosphate. Data obtained from the Association of American Plant Food Control Officials (AAPFCO) and the Virginia Department of Agriculture and Consumer Services (VDACS) show that the effects of this ban have been significant in reducing the sale of phosphorus for "non-farm" applications in the Commonwealth. The 2021 CAST model used to establish VRRM phosphorus loading rates, as previously described, does not consider the impact of the phosphorus sales ban; therefore, it is believed to overestimate the

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phosphorus load originating from non-farm uses (to include the VRRM "Managed Turf" category). Between the period 2013 and 2021, the CAST model applied a phosphorus fertilizer application rate of 3.93 lb/acre/yr to non-farmland uses within the Chesapeake Bay. An analysis of AAPFCO phosphorus sales data over this period of time suggests that the loading rate is more accurately defined as 2.42 lb/acre/yr for non-farmland uses in Virginia. Because phosphorus in fertilizer data is reported in terms of phosphorus pentoxide ($P_2O_5$), the 2.42 lbs/acre/yr value must be converted to $P_2O_5$-P, particulate phosphorus. This conversion is made by multiplying 2.42 lb/ac/yr by 0.4365, yielding 1.056 lb/ac/yr. EPA authorized a special CAST run for purposes of computing loading rates for the VRRM spreadsheets that adjusted the phosphorus application rate to turf land covers from 3.93 lbs/acre/yr to 1.06 lbs/acre/yr. The resulting adjustment yields a final, cumulative loading rate of 0.657 lb/acre/yr when proportionally allocated across all hydrologic soil groups for the VRRM "Managed Turf" category.

## E.7 RESULTS

The final VRRM nutrient loading rates computed from the 2021 CAST loading rates and employing the previously described methodology are presented in Tables 39 and 40.

**Table 39: VRRM Loading Rates – Phosphorus (lbs/acre/yr)**

| *Category* | *A* | *B* | *C* | *D* |
|---|---|---|---|---|
| **Forest** | 0.042 | 0.062 | 0.083 | 0.104 |
| **Mixed Open** | 0.239 | 0.341 | 0.385 | 0.454 |
| **Managed Turf** | 0.479 | 0.639 | 0.703 | 0.799 |
| **Impervious** | 0.794 | 0.794 | 0.794 | 0.794 |

**Table 40: VRRM Loading Rates – Nitrogen (lbs/acre/yr)**

| *Category* | *A* | *B* | *C* | *D* |
|---|---|---|---|---|
| **Forest** | 0.702 | 1.054 | 1.405 | 1.756 |
| **Natural** | 1.091 | 1.559 | 1.760 | 2.075 |
| **Managed Turf** | 5.215 | 6.953 | 7.649 | 8.692 |
| **Impervious** | 11.797 | 11.797 | 11.797 | 11.797 |

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# Appendix F ESTABLISHING NUTRIENT TARGET VALUE

## F.1 Introduction

In 2011, the Virginia Soil and Water Conservation Board adopted amendments to 4VAC50-60-63, providing that the total phosphorous load for new development projects shall not exceed 0.41 pounds per acre per year. The Department of Conservation and Recreation's (DCR) summary published in the Virginia Register described this as "[a] scientifically based 0.41 lbs/acre/year phosphorous standard for new development activities statewide" and noted that the prior adopted standard was 0.45 pounds per acre per year. At the same time, the Virginia Soil and Water Conservation Board adopted language providing: "Upon completion of the 2017 Chesapeake Bay Phase III Watershed Implementation Plan, the department shall review the water quality design criteria standards."

In 2013, because of Chapters 756 and 793 of the 2013 Acts of Assembly, the Commonwealth's stormwater management, erosion and sediment control, and Chesapeake Bay Preservation Act programs were transferred from the Virginia Soil and Water Conservation Board and DCR to the State Water Control Board and the Department of Environmental Quality (DEQ). As a result of this, the Commonwealth's stormwater regulations were transferred to the State Water Control Board. The design criteria requirement for the total phosphorous load of new development projects was renumbered as 9VAC25-870-63 A 1 but did not otherwise change. Similarly, the requirement to review water quality design criteria standards upon completion of the 2017 Chesapeake Bay Phase III Watershed Implementation Plan was renumbered as 9VAC25-870-63 C but did not otherwise change.

Initiative 48 in the Commonwealth of Virginia Chesapeake Bay TMDL Phase III Watershed Implementation Plan (WIP) requires DEQ to "initiate a review of the post-development water quality design criteria requirements established under the Virginia Erosion and Stormwater Management Regulation (VESMR) Regulation, 9VAC25-870-63." Initiative 48 further specifies that "The Commonwealth's review will determine if the criteria continue to satisfy the offset requirement of the TMDL. Subsequent amendments to the VESMR Regulation may be necessary if the criteria are no longer consistent with the TMDL."

Pursuant to Initiative 48, the Commonwealth has reviewed the latest outputs from the Chesapeake Bay Model, compared with the Chesapeake Bay Phase III Watershed Implementation Plan (Phase 3 WIP) to determine if use of the 0.41 lbs/ac/yr post-construction target should continue. This review included evaluating the latest loading rates from the Chesapeake Bay Model and making necessary modifications to the Virginia Runoff Reduction Model (VRRM) Version 3.0 spreadsheets. The evaluation utilized scenario data from the most recent model runs of the Chesapeake Bay Model, accessed using the Chesapeake Assessment and Scenario Tool (CAST) Version 2019, using both 2021 and 2025 (the Phase 3 WIP) data.

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Note that the 2021 data was used to establish concentrations for this analysis and the 2025 data was only used to verify that significant concentration variations are not currently expected between the datasets. The full methodology used to determine compliance with the offset requirement is described in detail below.

## F.2 Computation of Updated Phosphorus Target Standard

The phosphorus standard is computed through an analysis of the most recent completed CAST dataset (2021) for nutrient loadings and expected current land use (natural or agricultural) conversion to developed land use percentages for natural (81%) and agricultural (19%) areas from recently analyzed and published data (Chesapeake Bay Program, 2023). Land conversion percentages as shown herein are expected to be implemented in the upcoming Phase 7 of the Chesapeake Bay model.

As development occurs, predevelopment land uses with lower average loading rates are slowly replaced with developed land cover having higher average loading rates. Knowing the predicted conversion rate from undeveloped to developed land based on analysis of land cover data changes across several years allows computation of a nutrient target, an average theoretical loading rate that can be discharged without increasing loadings beyond what would be expected if the average land condition remained unchanged (i.e., undeveloped). The intent is to provide a threshold value that must be maintained to mitigate increases in phosphorus loading due to development of undeveloped land uses in the future. This must be evaluated on a periodic basis to verify that the assumptions concerning the natural and agricultural breakdowns remain consistent—major changes will require an adjustment to the computed nutrient target.

To perform this loading rate analysis, the 42 applicable CAST land uses (sewage treatment related, shoreline, and stream types were not used) were divided into three categories: 1) Agriculture, 2) Developed (including agricultural production areas), and 3) Natural/Forest, as shown in Table 41.

**Table 41: Categorization of CAST land covers into three major categories for analysis.**

| Agriculture | Developed | Natural/Forest |
|---|---|---|
| • Ag Open Space<br>• Double Cropped Land<br>• Full Season Soybeans<br>• Grain with Manure<br>• Grain without Manure<br>• Leguminous Hay<br>• Other Agronomic Crops<br>• Other Hay<br>• Pasture<br>• Riparian Pasture Deposition | • CSS Buildings and Other<br>• CSS Construction<br>• CSS Roads<br>• CSS Tree Canopy over Impervious<br>• CSS Tree Canopy over Turf Grass<br>• CSS Turf Grass<br>• MS4 Buildings and Other<br>• MS4 Roads | • CSS Forest<br>• Harvested Forest<br>• Headwater or Isolated Wetland<br>• Non-tidal Floodplain Wetland<br>• True Forest<br>• Water<br>• CSS Mixed Open<br>• Mixed Open |

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| | | |
|---|---|---|
| • Silage with Manure<br>• Silage without Manure<br>• Small Grains and Grains<br>• Specialty Crop High<br>• Specialty Crop Low | • MS4 Tree Canopy over Impervious<br>• MS4 Tree Canopy over Turf Grass<br>• MS4 Turf Grass<br>• Non-Regulated Buildings and Other<br>• Non-Regulated Roads<br>• Non-Regulated Tree Canopy over Impervious<br>• Non-Regulated Tree Canopy over Turf Grass<br>• Non-Regulated Turf Grass<br>• Regulated Construction<br>• Non-Permitted Feeding Space<br>• Permitted Feeding Space | |

The total land area belonging to each of these three land cover categories were estimated for both the 2021 and 2025 CAST runs (see Table 42). Initially, a comparison between the 2025 and 2021 datasets was planned to be used for the nutrient target conversion comparison. However, during the project, more accurate updated land cover data (Chesapeake Bay Program, 2023) was published and downloaded for use in this effort.

The fifth column in Table 42 indicates proportions (i.e., in what cover category) of the land conversion between 2021 and 2025 is expected to occur according to current CAST model land cover assumptions. Note that these values were replaced with 81% (natural) and 19% (agricultural) for the final analysis, based on the more recent land cover conversion data reference above that will be implemented in Phase 7 of the Chesapeake Bay Model. These values (percent land cover conversion) will be used as weighting metrics later in the analysis. Both sets of percentages are shown for comparison.

**Table 42: Comparison of Aggregated Land Use Data for 2021/2025**

| Category | 2025 Area (acres) | 2021 Area (acres) | Difference | % of Total Deviation in CAST | Updated Land Cover Conversion Used |
|---|---|---|---|---|---|
| **Natural/Forest** | 9,424,007.68 | 9,446,636.97 | 22,629.28 | 49% | 81% |
| **Agriculture** | 2,317,967.62 | 2,341,688.33 | 23,720.71 | 51% | 19% |
| **Developed** | 1,967,149.61 | 1,920,799.62 | 46,349.99 | | |

Next, average phosphorus loads are aggregated for the 2021 CAST run at the Edge of Stream (EOS) location for each category (natural/forest, agriculture, and developed). The EOS location was used since it is closer to the site evaluation location, and matches the assumptions used during computation of the VRRM land cover loading rates, which also used the EOS data for nutrient loading computations. Therefore, the comparison of remaining site loading to the

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nutrient target are being compared on the same basis. Loading rates are computed by dividing the P load by the area (see Table 43).

**Table 43: Computation of Average Loading Rates**

| Category | 2021 P-Load (lbs) | 2021 Area (acres) | Average Category Loading Rate (lb/ac/yr) |
|---|---|---|---|
| **Natural/Forest** | 864,805.61 | 9,446,636.97 | 0.092 |
| **Agriculture** | 2,335,314.65 | 2,341,688.33 | 0.997 |
| **Developed** | 2,400,074.29 | 1,920,799.62 | 1.250 |

The final target is calculated by weighting each category based on its percent of the total expected conversion and summing the result across categories. This is accomplished by multiplying the appropriate assumed conversion percentages and summing (Table 44).

**Table 44: Computation of Unadjusted Nutrient Target**

| Category | % of Total | Combined Loading Rate (lb/ac/yr) | Adjusted Loading Rate (lb/ac/yr) |
|---|---|---|---|
| **Natural/Forest** | 81% | 0.092 | 0.074 |
| **Agriculture** | 19% | 0.997 | 0.189 |
| | | **Nutrient Target** | **0.264** |

Although a factor of safety was initially considered for application to the nutrient target value due to potential model errors and limitations in estimating the natural/forest and agricultural conversions rates in CAST, no adjustment was ultimately made to the computed value. Based on the quality of the land conversion dataset, predictions for conversion appear to be much more accurate than data used in the current Phase 6 model. Therefore, the final proposed phosphorus nutrient target is the value computed above, **0.26 lbs/ac/yr**.

## F.3 Alternative Methods Explored

During the original development of the previous nutrient target (0.41 lbs TP/ac/year) an alternative method to the "no net increase of TP runoff method" based on expected land cover of lands projected to be developed in the future (discussed in F.2) was considered. This methodology utilized expected land cover types for development that was not expected to be detrimental to downstream water bodies using non-structural (i.e., land use density) BMPs. Three scenarios were assessed and one of them (10% impervious, 30% turf, and 60% forest) matched the selected previous nutrient target (0.41 lbs/ac/year) at that time using then current Bay Model runoff data. All three land use scenarios were explored to provide supplemental information for evaluation of the methodology outlined in the previous section. This method

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employs loadings for impervious cover, turf, and forest cover to several assumed target land cover conditions. The CAST loading rates as outlined in Appendix E for impervious cover (0.794 lbs/ac/yr), turf (0.657 lbs/ac/yr), and forest (0.071 lbs/ac/yr) are appropriate for use in this analysis since these values match the target rates used for computing loading rates for the VRRM 4.0 spreadsheets.

The three scenarios suggested during the previous nutrient target evaluation were as follows:

1) 5% impervious, 30% turf, 65% forest
2) 7.5% impervious, 30% turf, 62.5% forest;
3) 10% impervious, 30% turf, 60% forest; and

Using these metrics, the derived rates are:

0.28 lbs/ac/yr; 2) 0.30 lbs/ac/yr; and 3) 0.32 lbs/ac/yr

The lower threshold of these values is similar in magnitude to the values computed via the method in F.2 (0.26 lbs/ac/yr). The consistency of values between the two methods is notable. Because the method discussed in F.2 is more rigorous and based on the latest available data, the proposed value of 0.26 lbs/ac/yr has been selected for the phosphorus nutrient target.

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