

## *Chapter 12*

# VIRGINIA RUNOFF REDUCTION METHOD Compliance Spreadsheet User's Guide & Documentation (Version 2.7, April 2013)

## *Table of Contents*

### CHAPTER SECTION HEADINGS

<b>12.0</b>	<b>INTRODUCTION</b>	12-3
<b>12.1</b>	<b>VRRM COMPLIANCE SPREADSHEET BASICS</b>	12-4
	12.1.1 Site Data Tab	12-4
	12.1.2 Drainage Area Tabs	12-9
	12.1.3 Water Quality Compliance Tab	12-12
	12.1.4 Channel and Flood Protection Tab	12-12
	12.1.5 Summary Tab	12-15
<b>12.2</b>	<b>USING THE VRRM SPREADSHEET</b>	12-16
	12.2.1 Getting Started	12-16
	12.2.2 Site Data	12-16
	12.2.3 Drainage Areas	12-17
	12.2.4 Water Quality Compliance	12-21
	12.2.5 Channel and Flood Protection	12-22
	12.2.6 Summary	12-23
<b>12.3</b>	<b>VRRM COMPLIANCE SPREADSHEET FOR DEVELOPMENT ON PRIOR DEVELOPED LAND (REDEVELOPMENT)</b>	12-24
	12.3.1 VRRM Redevelopment Compliance Spreadsheet Site Data Tab Basics	12-24
	12.3.2 Using the VRRM Redevelopment Compliance Spreadsheet	12-27
	12.3.2.1 Site Data	12-28
	12.3.2.2 Load Reduction Requirement	12-30
<b>12.4</b>	<b>THE VRRM COMPLIANCE SPREADSHEET DOCUMENTATION</b>	12-32
	12.4.1 Site Data Tab	12-32
	12.4.2 D.A. Tabs	12-34
<b>12.5</b>	<b>REFERENCES</b>	12-38

**FIGURES**

Figure 12.1	Site Data Tab	12-5
Figure 12.2	Top Portion of Drainage Area Tab – Volume Reduction Practices	12-7
Figure 12.3	Lower portion of Drainage Area Tab	12-8
Figure 12.4	Water Quality Compliance Tab	12-13
Figure 12.5	Channel and Flood Protection Tab	12-15
Figure 12.6	VRRM Redevelopment Compliance Spreadsheet Site Data Tab (upper cells)	12-25
Figure 12.7	VRRM Redevelopment Compliance Spreadsheet Site Data Tab (lower cells)	12-26

**TABLES**

Table 12.1.	Land Cover Guidance	12-18
-------------	---------------------	-------

**EQUATIONS**

Equation 12.1	Composite Land Cover (Rv)	12-32
Equation 12.2	Site Rv	12-33
Equation 12.3	Post-Development Site Treatment Volume	12-33
Equation 12.4	Post-Development Site TP Load	12-33
Equation 12.5	Required Site TP Load Reduction	12-34
Equation 12.6	Runoff Volume from Contributing Drainage Area	12-34
Equation 12.7	Total Runoff Volume to Practice	12-34
Equation 12.8	Runoff Reduction Achieved by Practice (column I)	12-35
Equation 12.9	Remaining Runoff Volume Leaving the Practice (column J)	12-35
Equation 12.10	Untreated Pollutant Load to Practice (Phosphorus, column M; Nitrogen, column N)	12-35
Equation 12.11	Total Load Reduction by Practice (Column N)	12-36
Equation 12.12	Remaining Phosphorus Load (Column O)	12-36
Equation 12.13	Composite Curve Number (CN)	12-36
Equation 12.14	Potential Maximum Retention After Runoff Begins (S, cell H35)	12-37
Equation 12.15	Runoff Volume with no Runoff Reduction (row 37)	12-37
Equation 12.16	Runoff Volume with Runoff Reduction (row 38)	12-37
Equation 12.17	Adjusted Curve Number (row39)	12-38

## 12.0 INTRODUCTION

Virginia's Stormwater Management Program (VSMP) Regulations (9 VAC 25-870) include water quality and quantity requirements based, in part, on the "Virginia Runoff Reduction Method" (VRRM). This method is supported by recent stormwater research findings on the combined runoff volume reduction and pollutant removal performance of various stormwater best management practices (BMPs). More information and documentation on the development and the basis of the VRRM can be found in the Technical Memorandum, dated April 18, 2008 (CWP 2008) prepared by the Center for Watershed Protection and the Chesapeake Stormwater Network. The memorandum can be downloaded from the DCR Stormwater Program website.

The VRRM is accompanied by two compliance spreadsheets. The first is applicable to new development and is referred to as the **VRRM Compliance Spreadsheet**. The second is applicable to development on prior developed lands and is referred to simply as the **VRRM Redevelopment Compliance Spreadsheet**. The spreadsheets are designed to help designers and plan reviewers to quickly evaluate the implementation of BMPs on a given site and verify compliance with the local and/or State stormwater requirements. The spreadsheets:

- Provide a summary of land cover for the entire site in its developed condition, the pollutant load (Total Phosphorus and Total Nitrogen), and the corresponding design Treatment Volume.
- The Redevelopment spreadsheet provides a summary of the pre- and postdevelopment (or pre- and post-redevelopment) land cover, pollutant load, and corresponding design Treatment Volume.
- Allow the designer to quickly evaluate the effectiveness of different BMPs and BMP combinations in up to five different drainage areas.
- Provide a summary for each drainage area that includes the land cover, runoff volume and pollutant load generated in the drainage area, the BMPs selected, and the runoff volume and pollutant load reduced by the selected BMPs.
- Calculate the volume reduction credited towards compliance with quantity control requirements in each drainage area (i.e., channel and flood protection requirements).
- Provide an overall compliance summary report that itemizes BMP implementation in each drainage area as well as overall site compliance.

***NOTE:** The RRM compliance spreadsheets are not BMP design tools. When a BMP is selected in a spreadsheet, it is assumed that the designer will locate and design the BMP according to the design criteria provided in the Virginia BMP Design Specifications. Please refer to the Virginia BMP Clearinghouse website, found online at <http://vwrrc.vt.edu/swc/PostConstructionBMPs.html>, for the latest BMP design criteria.*

**Using this Guidance:** The Department recommends that the user review this information with the spreadsheet open on a computer. The VRRM Compliance Spreadsheet Basics (**Section 12.1**) and Using the VRRM Compliance Spreadsheet (**Section 12.2**) are generally focused on the new development compliance. The VRRM Redevelopment Compliance Spreadsheet incorporates

different computations on the Site Data tab in order to compute the water quality pollutant load reduction requirements for redevelopment projects (9 VAC 25-870-63 A 2) and is discussed in **Section 12.3**. Once the load reduction requirements are determined, the procedures for evaluating the implementation of BMPs and verifying compliance are generally the same as those for new development. This guidance applies to (an updated) version 2.7 of the Spreadsheet, dated April 2013. This version provides corrections of several errors found in the earlier Spreadsheet versions and adds ease-of-use features.

## 12.1 VRRM COMPLIANCE SPREADSHEET BASICS

The VRRM Compliance Spreadsheets include several terms that may or may not be exactly consistent with definitions in the regulations. The following provides a listing of important terms by spreadsheet tab, and a basic definition of how the term is applied in the VRRM compliance spreadsheet.

### 12.1.1 Site Data Tab

**Figure 12.1** below provides a screen shot of the Site Data tab.

**Annual Rainfall** is a user defined value that may vary across Virginia. (Refer to the Virginia Stormwater Management Handbook (VSMH) for appropriate values).

**Target Rainfall Event** is defined as the one-inch rainfall depth (as determined to be the 90<sup>th</sup> percentile annual rainfall depth).

**Phosphorus EMC** (mg/l) and **Nitrogen EMC** are the Event Mean Concentrations of Total Phosphorus and Total Nitrogen, respectively, in urban runoff. This value is based on an extensive review of monitoring data in Virginia. (CWP 2008)

**Target Phosphorus Load** (lb/ac/yr) is the load limit established by the VSMP Regulations.

**Land Cover** (acres) includes the three basic categories of developed land: *Forest/Open Space*, *Managed Turf*, or *Impervious cover*. Definitions of the three categories of land cover and the basic qualifications for each is provided in **Section 12.2.2**, **Table 12.1** of this Guide). The acreages of each land cover are entered by the user *for the entire site* on the Site Data Tab.

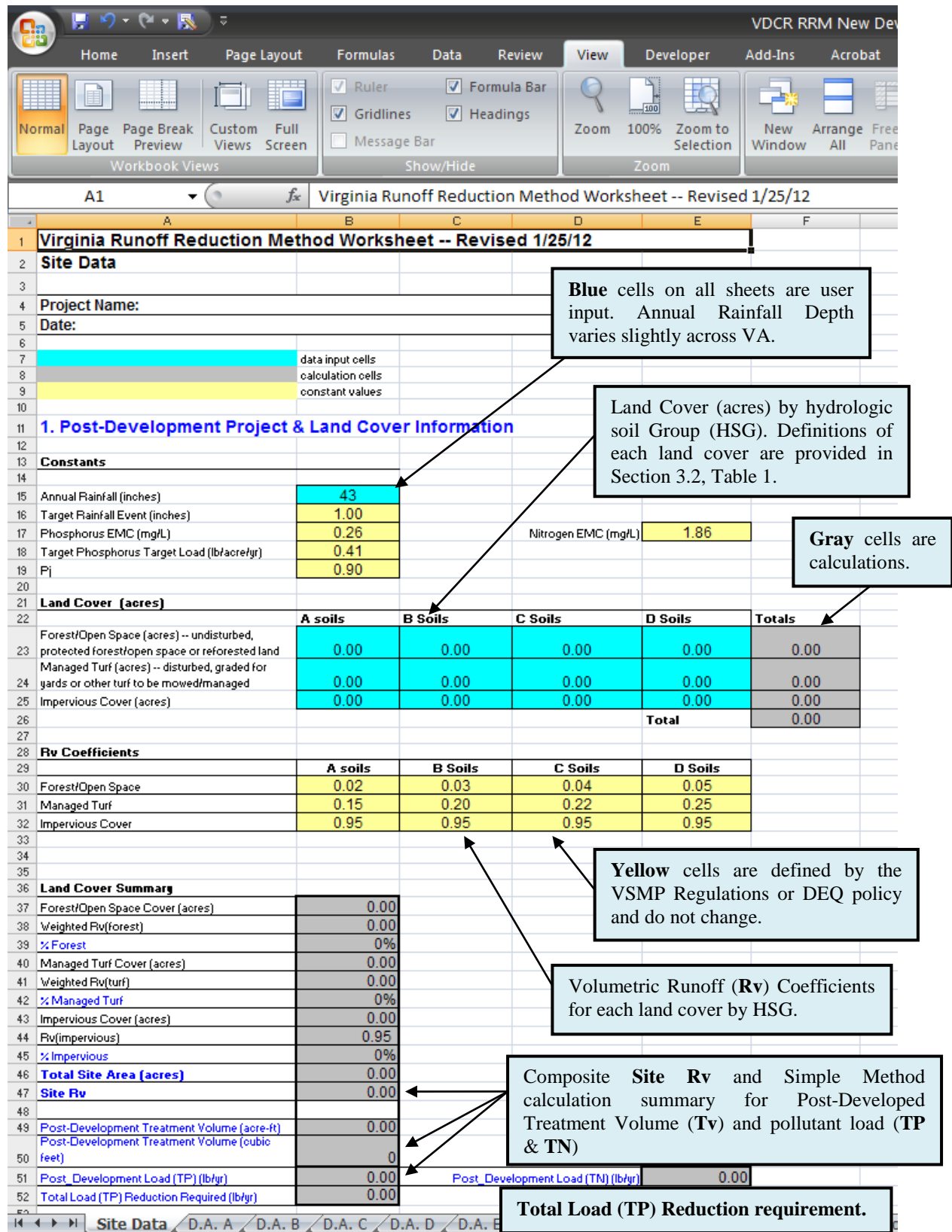


Figure 12.1. Site Data Tab

***NOTE:** The preservation of existing natural features such as highly permeable soils, wooded areas, natural flow paths, etc., are generally considered self crediting in terms of generating the developed condition hydrology, treatment volume, and runoff peak flow rates. However, some of these same features can also be utilized as runoff reduction BMPs to either reduce the runoff volume that would otherwise be generated by disturbing or converting the land, or by directing runoff from developed areas to the undisturbed open space to achieve runoff volume reduction. Refer to **Table 12.1** below for the definitions of the three land cover categories. It is important that the appropriate land cover be entered on the Site Data Tab as well as the individual drainage area tabs to ensure accurate computation of runoff volume and pollutant load.*

**Rv Coefficients** are the unit less volumetric runoff coefficients that represent the runoff potential of the different land cover and soil types (Hydrologic Soil Groups A, B, C, and D).

**Land Cover Summary** cells represent the summary of the calculations to determine the composite land cover Rv. The composite Rv is provided for each land cover based on soil type (**Equation 12.1** below).

**Site Rv** is the composite Rv Coefficient for the entire site based on the area entered for each land cover and each soil type (**Equation 12.2** below).

**Post Development Treatment Volume** is the design volume of runoff in acre-feet and cubic feet resulting from the *Target Rainfall Event*. (**Equation 12.3** below).

**Post Development Load (TP & TN)(lb/yr)** is the calculated load of Total Phosphorus and Total Nitrogen for the entire site calculated using the Simple Method. (**Equation 12.4** below).

**Total Load (TP) Reduction Required (lb/yr)** is the difference between the site's calculated TP and TN load and that represented by the load limit of 0.41 lb/ac/yr. Only the TP load reduction is calculated since TP is the regulatory requirement.

***NOTE:** The VRRM Compliance Spreadsheet for Development on Prior Developed Land includes data input cells for **Pre-Redevelopment Land Cover** and **Post-Redevelopment Land Cover** in order to calculate the corresponding **Site Rv**, **Treatment Volume**, **pollutant Load**, and required load reductions. **Section 12.3** provides a detailed description and guidance on using the VRRM Compliance Spreadsheet for Development on Prior Developed Land.*

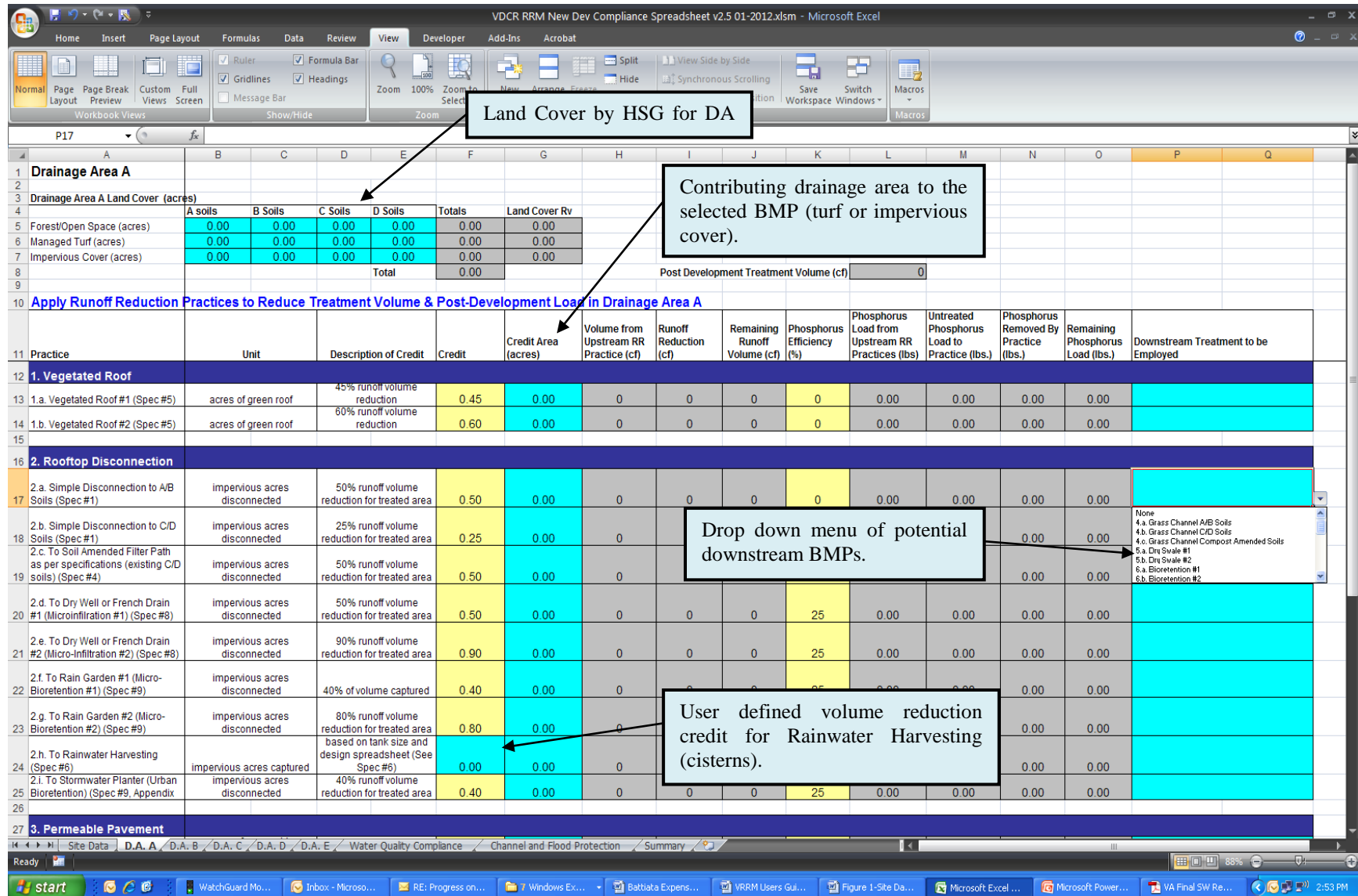


Figure 12.2. Top Portion of Drainage Area Tab – Volume Reduction Practices

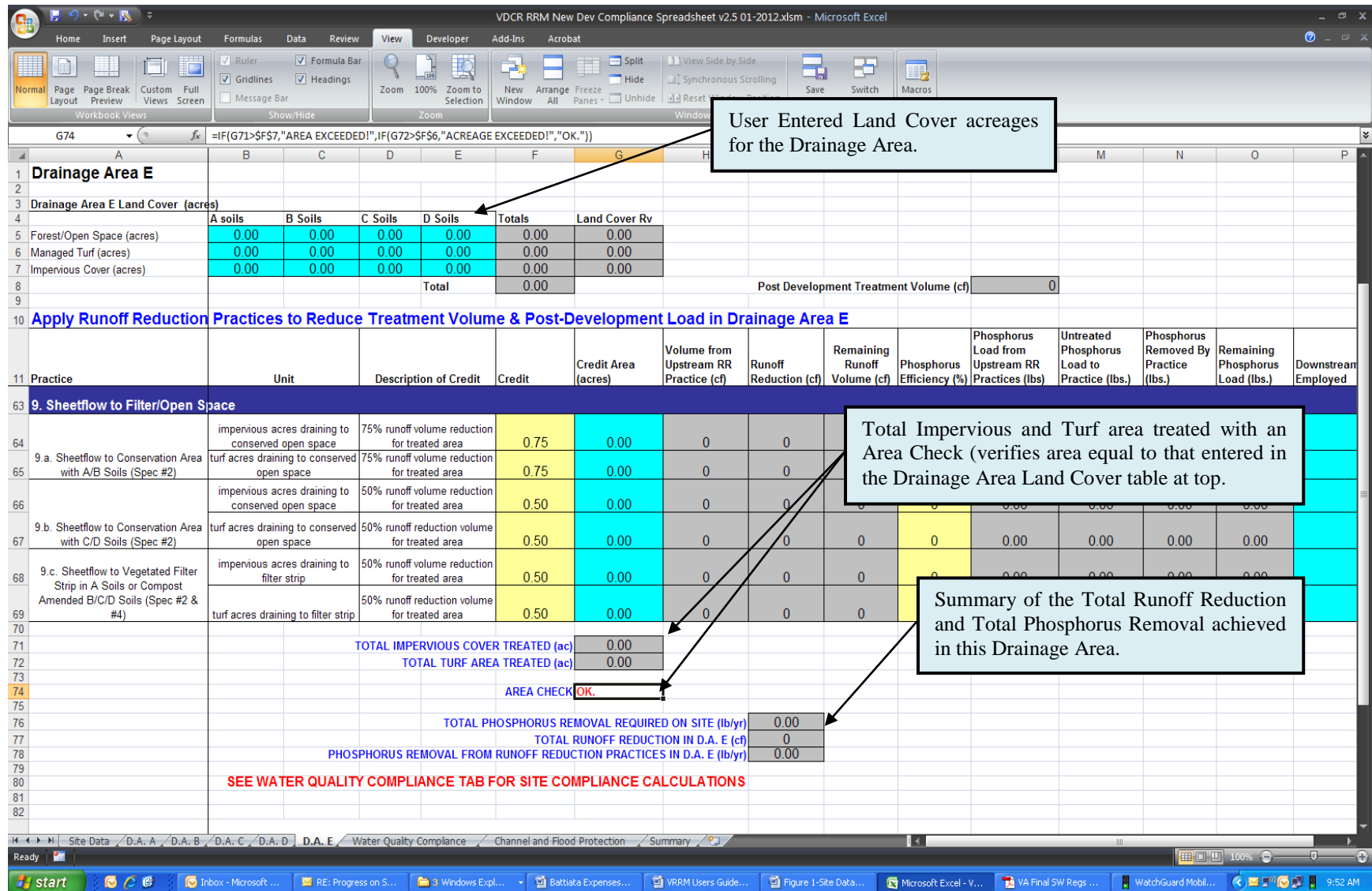


Figure 12.3. Lower portion of Drainage Area Tab



### 12.1.2 Drainage Area (D.A.) Tabs

**Figure 12.2** above shows a screen shot of the top portion of the Drainage Area tab, and **Figure 12.3** above shows a lower portion with the Area Check and the pollutant and volume reductions achieved in the drainage area.

The VRRM compliance spreadsheet Drainage Area tabs A through E are identical. Each provides a table near the top of the sheet for the user to enter the specific **Land Cover** acreage by soil type for the specific drainage area. This table computes a composite drainage area land cover  $R_v$ , and the Post-Development Treatment Volume ( $T_v$ ) for the drainage area.

An important feature of the Drainage Area tabs is the segregation of the BMPs into two groups:

- **Runoff Reduction Practices to Reduce Treatment Volume & Post-Development Load;** and
- **Practices that Remove Pollutants but Do Not Reduce Runoff Volume.**

As documented in the VRRM Technical Memorandum (CWP 2008), certain BMPs are effective at reducing both runoff volume and the pollutant concentration in the remaining runoff. Since the most cost-effective application of BMPs is to use these dual function BMPs, the VRRM compliance spreadsheet displays the table of these *Runoff Reduction (RR)* BMPs first.

The Runoff Reduction BMPs listed on the website in the order they appear on the spreadsheet, are:

1. Vegetated Roof (BMP Design Specification No. 5)
  - a. Vegetated roof # 1
  - b. Vegetated roof # 2
2. Rooftop Disconnection (BMP Design Specification No. 1)
  - a. Simple Disconnection to A/B soils
  - b. Simple Disconnection to C/D soils
  - c. Alternative Practice Disconnection to C/D soils with Soil Amended Filter Path
  - d. Alternative Practice Disconnection to Dry Well #1
  - e. Alternative Practice Disconnection to Dry Well #2
  - f. Alternative Practice Disconnection to Rain Garden #1
  - g. Alternative Practice Disconnection to Rain Garden #2
  - h. Alternative Practice Disconnection to Rainwater Harvesting
  - i. Alternative Practice Disconnection to Stormwater Planter
3. Permeable pavement (BMP Design Specification No. 7)
  - a. Permeable pavement #1
  - b. Permeable pavement #2
4. Grass channel (BMP Design Specification No. 3)
  - a. Grass Channel A/B Soils

- b. Grass Channel C/D Soils
  - c. Grass Channel with Compost Amended Soils
5. Dry swale (BMP Design Specification No. 10)
    - a. Dry swale #1
    - b. Dry swale #2
  6. Bioretention (BMP Design Specification No. 9)
    - a. Bioretention #1
    - b. Bioretention #2
  7. Infiltration (BMP Design Specification No. 8)
    - a. Infiltration #1
    - b. Infiltration #2
  8. Extended detention pond (BMP Design Specification No. 15)
    - a. ED #1
    - b. ED #2
  9. Sheetflow to Filter/Open Space (BMP Design Specification No. 2)
    - a. Sheetflow to Conservation Area with A/B Soils
    - b. Sheetflow to Conservation Area with C/D Soils
    - c. Sheetflow to Vegetated Filter Strip in A Soils or Compost Amended B/C/D Soils

The #1 and #2 label added to the BMP name indicates use of the Level 1 or Level 2 BMP design standard. The Level 2 design standard is credited with a greater volume reduction or a greater pollutant removal, or both, as compared to Level 1. The corresponding annual runoff volume reduction credit is provided in column F, the corresponding annual Phosphorus removal efficiency is provided in column K, and the corresponding annual Nitrogen removal efficiency is provided in Column S. The designer should be familiar with the Level 1 and Level 2 design criteria in order to select the appropriate BMPs for the site.

***NOTE:** It is important to understand the design criteria associated with the Level 1 and Level 2 designations. While the Level 2 practices will provide greater load reductions, they may also require a larger footprint, specific soil conditions, or other factors that may limit their use. BMP selection and design guidance, including designated Level 1 and Level 2 criteria, can be found on the Virginia Stormwater BMP Clearinghouse website.*

At the bottom of this table of BMPs is a summary of the total impervious area and turf area treated by the volume reduction practices, along with an Area Check. The Area Check is to ensure that the total area entered as being treated by various BMPs doesn't exceed the total area of that drainage area, as entered into the Land Cover table at the top of the Drainage Area tab.

***NOTE:** A summary of the total runoff volume reduction (cell I77) and phosphorus removal achieved by the runoff reduction practices (cell I78) in the drainage area*

*is provided. The total runoff volume reduction achieved is an important value, as it will be used in the Channel and Flood Protection tab to compute the credit towards quantity control requirements.*

The next table includes pollutant reduction (or “Treatment”) BMPs that remove pollutants but do not reduce runoff volume:

1. Wet Swale (Coastal Plain) (BMP Design Specification No. 11)
  - a. Wet Swale #1
  - b. Wet Swale #2
2. Filtering Practices (BMP Design Specification No. 12)
  - a. Filtering Practice #1
  - b. Filtering Practice #2
3. Constructed Wetland (BMP Design Specification No. 13)
  - a. Constructed Wetland #1
  - b. Constructed Wetland #2
4. Wet Ponds (BMP Design Specification No. 14)
  - a. Wet Pond #1
  - b. Wet Pond #1 (Coastal Plain)
  - c. Wet Pond #2
  - d. Wet Pond #2 (Coastal Plain)
5. Manufactured BMPs

**NOTE:** *Rainwater Harvesting (BMP Design Specification No. 6) requires user input to define the credit. Rainwater Harvesting systems are sized according to a water budget developed using the Virginia Rainwater Harvesting Spreadsheet, which calculates the annual volume reduction credit*

*There are no manufactured BMPs currently incorporated into the spreadsheet. The User should check the BMP Clearinghouse website to verify the pollutant removal credit and associated design guidance for any manufactured BMP.*

A summary of the impervious and turf area treated by the pollutant removal (Treatment) BMPs, and an Area Check is provided below this table of BMPs as well. This Area Check includes the total acreage entered for treatment, including the volume reduction BMPs. A summary of the total pollutant load reduction achieved in the drainage area is also provided. This load reduction summary represents the load reduced by both the volume reduction BMPs and the treatment BMPs. (There is no additional volume reduction achieved by these practices).

**NOTE:** *The Total Phosphorus removal provided in the summary noted above is only that which was achieved in the specific drainage area characterized on that DA tab. The user must proceed to the Water Quality Compliance tab in order to*

*verify whether the selected BMP implementation through multiple drainage areas has met overall compliance.*

### 12.1.3 Water Quality Compliance Tab

The Water Quality Compliance tab summarizes the acreages of impervious cover and turf, and the corresponding acreages treated by BMPs for each Drainage Area. This also serves as an automatic **AREA CHECK**.

***NOTE:** The Area Check on the Water Quality Compliance tab compares the total acreages entered in each drainage area tab with the total land area entered on the Site Data tab. The Area Check on each drainage area tab compares the total acreage treated by BMPs within the drainage area with the total acreage entered for that drainage area. The Water Quality Compliance tab Area Check is important because it is possible that a user may inadvertently enter additional acreage into one or more of the DA Tabs, thereby exceeding the total acreage and resulting in increased load and/or volume reductions, or both. The Water Quality Compliance tab Area Check signals the user to verify that the Land Cover for each Drainage Area was entered into the spreadsheet accurately.*

The Water Quality Compliance tab also summarizes the Runoff Volume and Total Phosphorus load reductions achieved on the entire site, and indicates whether the BMP implementation in Drainage Areas A through E has met the target reductions. **Figure 12.4** below shows the Water Quality Compliance Tab.

### 12.1.4 Channel and Flood Protection Tab

The Channel and Flood Protection Tab calculates the benefit of the runoff volume reduction when considering the larger storms required for channel and flood protection requirements. The benefit is expressed in terms of a Curve Number adjustment that can be used when calculating the storage volume requirements and/or the peak flow rate requirements of the VSMP regulations.

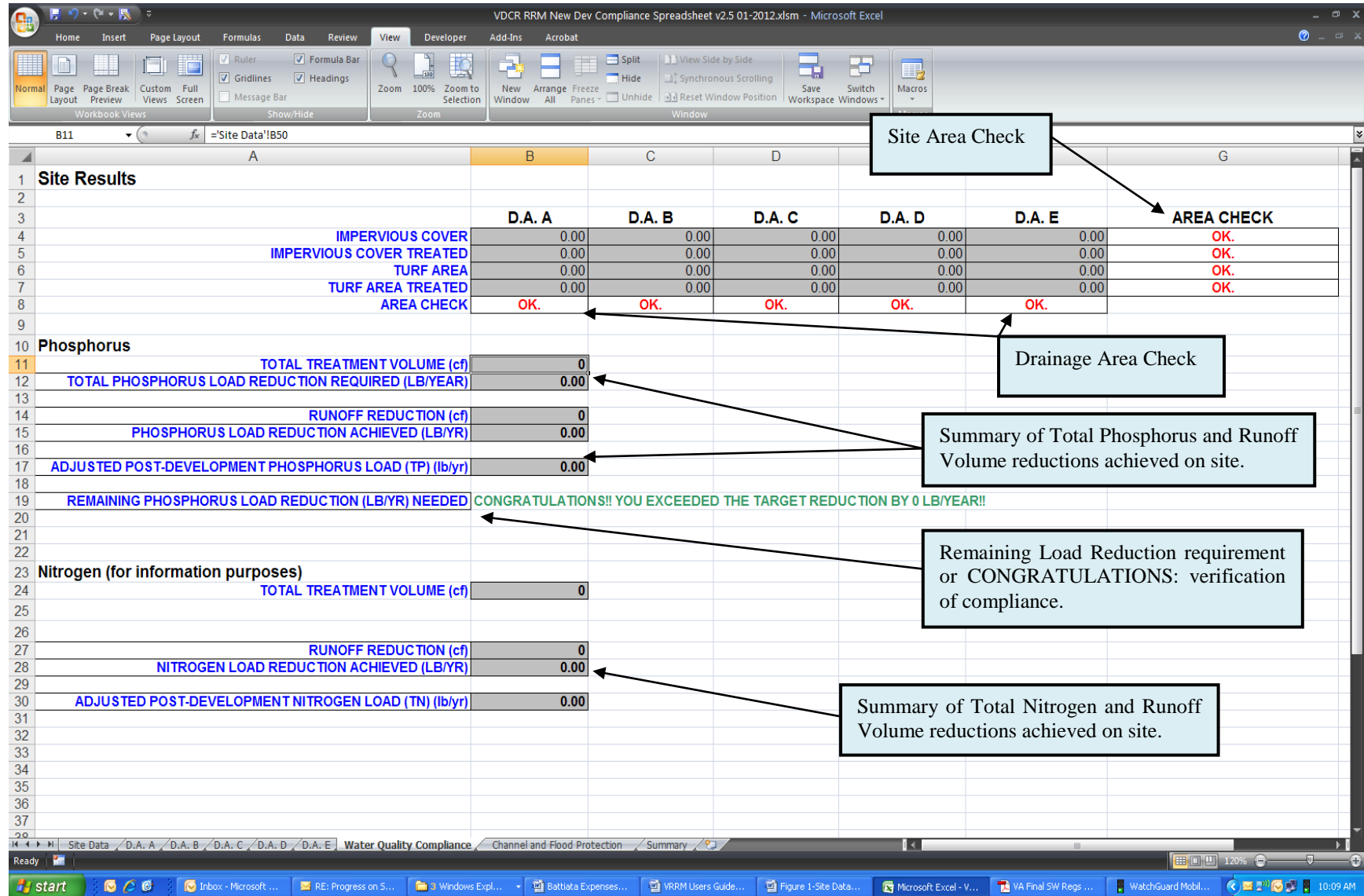


Figure 12.4. Water Quality Compliance Tab

The Curve Number Adjustment is based on the NRCS Runoff Equations to back-calculate a new curve number for each target rainfall event based on the reduced runoff depth resulting from the retention storage. A detailed description of the method is provided in **Chapter 11** of this Handbook.

This is a relatively conservative computation, given that the volume reduction is considered an “annual” reduction while the Curve Number is used in “single event” modeling applications. The Curve Number adjustment is not intended to necessarily replace more rigorous single event hydrologic and hydraulic analyses of distributed practices, if those are preferred by the site designer. However, given the complexities of such analyses, the spreadsheet’s Curve Number adjustment is considered an acceptable method for representing the annual reduction credit when designing downstream channel or flood protection structures, as may be required by runoff quantity control criteria of the VSMP Regulations.

**NOTE:** *The reduced Curve Number is generally not acceptable for the design of downstream conveyance infrastructure such as roadway culverts, bridges, floodplain determinations, etc. The user should consult with the Department or the local plan approving authority for verification of acceptable design criteria.*

Once the user has entered the appropriate **Target Rainfall Event** rainfall depth for the one-year, two-year, and/or 10-year frequency 24-hour rainfall events, the Channel and Flood Protection tab provides a summary table of the drainage area land cover acreages and the calculated composite Curve Number (without considering the volume reduction). Next, a table displays the Runoff Volume, **RV**, measured in watershed inches, with *no* runoff volume reduction, and the **RV** with runoff volume reduction.

**NOTE:** *The value for **Rv** (unit less volumetric runoff coefficient from the Site Data tab) is different than the value for **RV** (runoff volume measured in watershed-inches).*

**In the Site Data tab:**

***Rv** x Target Rainfall Event x Drainage Area = design Treatment Volume, **Tv**, in cubic feet or acre-feet for designing water quality runoff reduction BMPs.*

**In the Channel and Flood Protection tab:**

***RV** x Target Rainfall Event = runoff depth (in watershed-inches) with which to back-calculate the Adjusted Curve Number.*

*This can be confusing since common units of runoff volume are cubic inches, cubic feet, or acre-feet; however in the nomenclature of the VRRM and certain NRCS calculations, runoff is often expressed in units of watershed-inches.*

The Adjusted Curve Number is calculated for each drainage area based on the selected Target Rainfall Event and the runoff volume reduction achieved within the drainage area. **Figure 12.5** below shows the Channel and Flood Protection Tab.

### 12.1.5 Summary Tab

The Summary tab provides the user with a full summary of the Site Data and Drainage Area values for the purpose of generating a summary report. The user must make sure that the spreadsheet settings have been set to allow macro programs to run. The macro programs check each Drainage Area tab to identify the BMPs and BMP combinations used in each drainage area<sup>1</sup>.

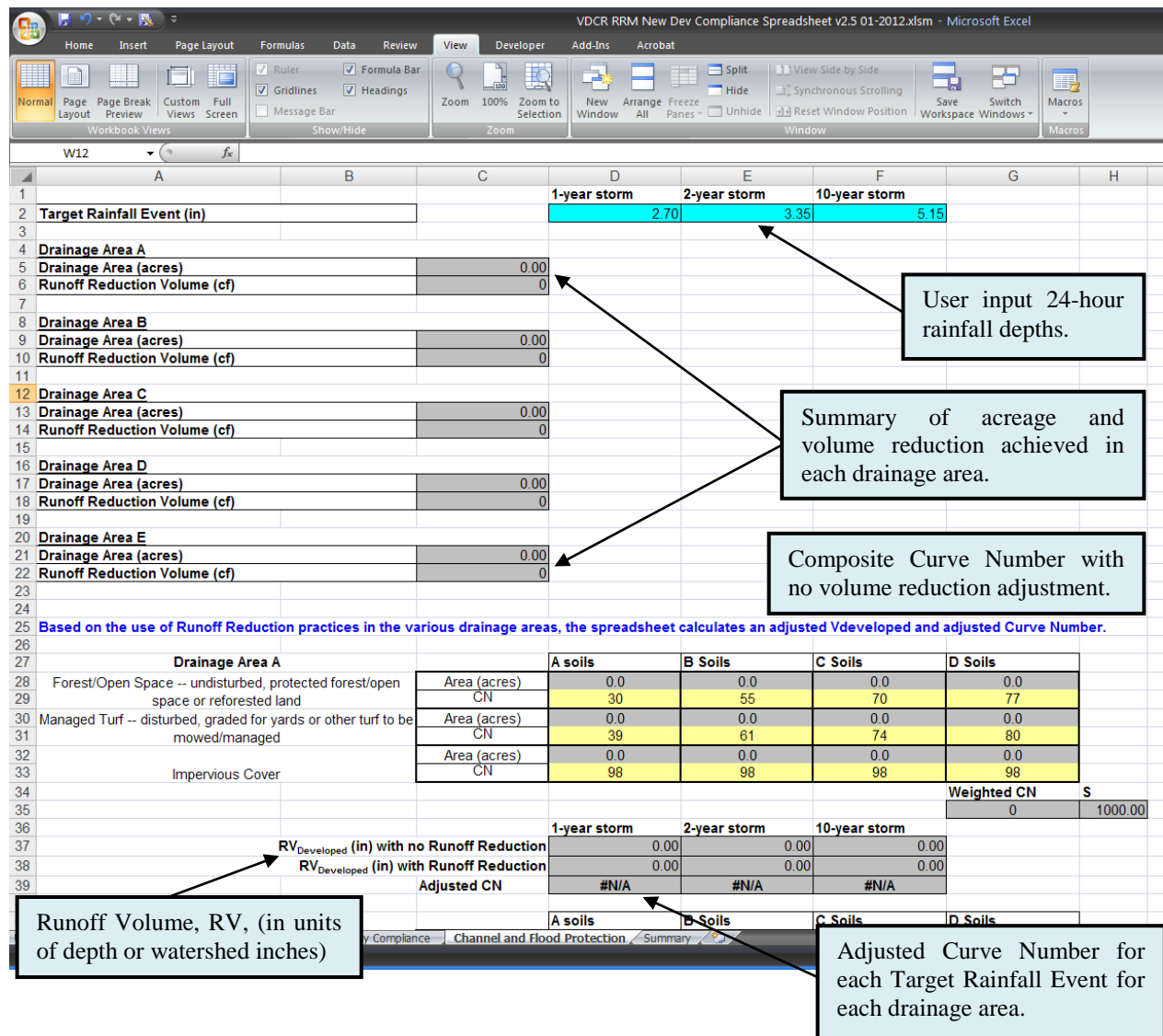


Figure 12.5. Channel and Flood Protection Tab

<sup>1</sup> Special thanks to Michael Baker Engineering’s Henry Manguerra and Sabu Paul for their work in developing the Summary Report Tab.

## 12.2. USING THE VRRM SPREADSHEET

### 12.2.1 Getting Started

These instructions generally follow the idealized process for the planning and design of a stormwater management strategy on a proposed land development project. What is not included in the spreadsheet is an emphasis on the benefit of planning the stormwater strategy early in the development process. This typically starts with the preliminary plan or other planning document that establishes the basic development footprint on the site. A designer who is familiar with the site topography, soils, vegetation, and basic hydrologic features will be able to effectively maximize runoff reduction benefits of nonstructural (and low cost) stormwater practices by using Environmental Site Design (ESD) techniques (see **Chapter 6** of this Handbook).

The first step in using the VRRM Compliance Spreadsheet is to **enable macros**. This will allow the Site Data Summary to reference the Drainage Area tabs and update the summary when the design is complete.

The second important step is to be sure to **“zero out” the spreadsheet**. There may be values entered into miscellaneous user input cells from previous projects or trial designs that can create errors.

### 12.2.2 Site Data

1. Enter the Annual Rainfall (cell B15). The accepted value of central Virginia is 43 inches.
2. The Target Rainfall Event, Phosphorus EMC, Target Phosphorus Load, and Pj (the fraction of annual rainfall less than 0.1 inch) in cells B16 through B19 are constant values.
3. Enter the Land Cover values (in acres) for Forest/Open Space, Managed Turf, and Impervious Cover. Refer to **Table 12.1** below for the Land Cover definitions. The total in cell F26 should be equal to the total site area.
4. The Land Cover Summary (cells B37 through B47) provides the summary values for the composite  $R_v$  calculation for each land cover using **Equation 12.1a** through **12.1c**.
5. The Site  $R_v$  (cell B47) is the unitless composite volumetric runoff coefficient representing the entire site. This is computed using **Equation 12.2**.
6. The Post-Development Treatment Volume (cell B49, in acre-feet) is calculated using **Equation 12.3**. This value multiplied by 43,560 ft<sup>2</sup>/acre is the treatment volume in cubic feet.
7. The Post-Development Total Phosphorus (TP) load (cell B51, in lb/yr) is the load generated by the site in its developed condition. This value is computed using the Simple Method and is based on the site's Post-Development Treatment Volume, annual rainfall, and the TP EMC of 0.26 mg/l (**Equation 12.4**). A Total Nitrogen (TN) load will also be calculated (cell E51)



based on the TN EMC of 1.86 mg/l. This is done only for informational purposes and, perhaps, TMDL accounting. However, VSMP compliance is based on the TP load limit only.

8. The Total TP Load Reduction Required (lb/yr, in cell B52) is the difference between the Post- Development TP Load and the site-based Load Limit of 0.41 lb/ac/yr established by the VSMP Regulations (**Equation 12.5**).

### 12.2.3 Drainage Areas

If the site has multiple discharge points, or complex treatment sequences, it may be beneficial to divide the site into more than one drainage area. Compliance with the site-based water quality pollutant load limit is based on the entire site, meaning the sum of the treatment achieved in each drainage area must meet the total load reduction requirement noted on the site data tab. This also means that additional treatment in one drainage area may compensate for less treatment in the adjacent drainage area, with the total load reduction meeting the site requirement. On the other hand, even a large development site can be addressed through a single BMP treatment train and may only need one drainage area tab to document the BMP strategy.

***NOTE:** The site-based water quality requirements can be met with varying degrees of load reduction achieved in the different drainage areas. However, the quantity control requirements (channel and flood protection) must be met at each stormwater discharge or outfall from the site.*

The following discussion of the Drainage Area tab can be applied to each of the five drainage area tabs.

1. Enter the post-development forest/open space, managed turf, and impervious area acreages based on hydrologic soil groups (rows 5, 6, and 7) in the drainage area. The calculation cells provide the total acreage of each land type, and the composite Land Cover  $R_v$  (**Equation 12.1**).
2. Apply Runoff Reduction (RR) BMPs to the drainage area to reduce post-development treatment volume and load by indicating the Credit Area (acres) in column G to be treated by a selected RR BMP.
3. The user should select the practices that will be appropriate for the given site conditions (soils, drainage area, etc.) and that provide the greatest volume reduction. Column F displays the constant values for the volume reduction credit.
4. The user applies practices by entering the contributing drainage area to the BMP, referred to as Credit Area (acres), in column G. This acreage input corresponds to the land cover unit as described in column B as either *impervious acres* or *turf acres*. Impervious Disconnection and Permeable Pavement only allow one option (impervious acres) due to specific design guidance that intends the practice to only treat runoff from impervious areas.

**Table 12.1. Land Cover Guidance for VRRM Compliance Spreadsheet**

<b>IMPERVIOUS COVER</b>
<ul style="list-style-type: none"> <li>• Roadways, driveways, rooftops, parking lots, sidewalks, and other areas of impervious cover.</li> <li>• 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).<sup>1</sup></li> </ul>
<b>MANAGED TURF</b>
<p>Land disturbed and/or graded for eventual use as managed turf:</p> <ul style="list-style-type: none"> <li>• Portions of residential yards that are graded or disturbed, including yard areas, septic fields, residential utility connections</li> <li>• Roadway rights-of-way that will be mowed and maintained as turf</li> <li>• Turf areas intended to be mowed and maintained as turf within residential, commercial, industrial, and institutional settings</li> </ul>
<b>FOREST &amp; OPEN SPACE</b>
<p>Land that will remain undisturbed OR that will be restored to a hydrologically functional state:</p> <ul style="list-style-type: none"> <li>• Portions of residential lots that will NOT be disturbed during construction</li> <li>• 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 the design specifications</li> <li>• Community open space areas that will not be mowed routinely, but left in a natural vegetated state (can include areas that will be bush hogged no more than four times per year)</li> <li>• Utility rights-of-way that will be left in a natural vegetated state (can include areas that will be bush hogged no more than four times per year)</li> <li>• 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. BMPs in this category include bioretention, dry swale, grass channel, ED pond that is not mowed routinely, stormwater wetland, soil amended areas that are vegetated, and infiltration practices that have a vegetated cover.</li> <li>• Other areas of existing forest and/or open space that will be protected during construction and that will remain undisturbed. These include wetlands.</li> </ul> <p><u>Operational &amp; Management Conditions for Land Cover in Forest &amp; Open Space Category:</u></p> <ul style="list-style-type: none"> <li>• Undisturbed portions of yards, community open space, and other areas that will be considered as forest/open space must be shown outside the LOD on approved E&amp;S plans AND demarcated in the field (e.g., fencing) prior to commencement of construction.</li> <li>• Portions of roadway rights-of-way that will count as forest/open space are assumed to be disturbed during construction, and must follow the most recent design specifications for soil restoration and, if applicable, site reforestation, as well as other relevant specifications if the area will be used as a filter strip, grass channel, bioretention, or other BMP</li> <li>• All areas that will be considered forest/open space for stormwater purposes must have documentation that prescribes that the area will remain in a natural, vegetated state. 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</li> <li>• While the goal is to have forest/open space areas remain undisturbed, some activities may be prescribed in the appropriate documentation, as approved by the local program authority: forest management, control of invasive species, replanting and revegetating, passive recreation (e.g., trails), limited bush hogging to maintain desired vegetative community, etc.</li> </ul>
<p><sup>1</sup> 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).</p>

5. As the user enters acreage into the BMP Credit Area column, the spreadsheet calculates the total volume of runoff generated by the contributing drainage area (**Equation 12.7**). Though the value is not displayed, it is the sum of column I and column J. The next group of columns reflects data related to the runoff volume reduction as follows:
  - a. Column H displays the volume contributed from upstream practices if a treatment train is being used. (This is the remaining runoff volume, column J, from any upstream BMP(s); if no upstream BMP is used, this value is zero. More discussion on treatment trains is provided below in Step 7.
  - b. Column I displays the total volume of Runoff Reduction achieved by the BMP (**Equation 12.8**). This includes the reduction as applied to the volume from the contributing drainage area, as well as a reduction in the volume coming from an upstream BMP.  
  
*NOTE: The runoff volume generated by the contributing drainage area to the practice (or the credit area – column G) is calculated using a **drainage area composite land cover Rv for Turf (cell G6)** rather than a soil type composite Rv for the contributing area to the BMP. The composite Rv for Impervious Cover is 0.95, regardless of soil type.*
  - c. Column J displays the remaining runoff volume that will exit the practice (**Equation 12.9**). If the user chooses to use multiple BMPs in series by designating a downstream BMP (column P), this value will be carried over to the volume from the upstream BMP (column H).
6. The next series of columns provides information on the pollutant removal efficiency and calculated load reduction achieved by the BMP.
  - a. Column K provides the constant value for the Phosphorus Removal Efficiency (measured as a percent reduction of the incoming load).
  - b. Column L displays the TP load contributed from an upstream BMP if a treatment train is being used. [This is the remaining TP load (column O) from any upstream BMP(s); if no upstream BMP is used, this value is zero.] More discussion on treatment trains is provided in the next step.
  - c. Column M is the Untreated Phosphorus Load to the BMP. This is the calculated load generated by the contributing drainage area (or credit area) using the Simple Method (**Equation 12.10**), plus the untreated load from any upstream BMP in a treatment train.
  - d. Column N is the total Phosphorus Load Removed by the BMP. This removal is the combined load reduction resulting from the volume reduction and the pollutant removal (Treatment) BMPs (**Equation 12.11**).

- e. Column O is the Remaining Phosphorus Load. (**Equation 12.12**). If the user chooses to use multiple BMPs in series by designating a downstream practice (column P), this value will be carried over to the load contributed from the upstream BMP (column L).

***NOTE:** The corresponding Nitrogen pollutant load and load reductions are calculated using the same equations, based on the Nitrogen EMC of 1.86 mg/l. The Nitrogen reduction performance credit constant is column S, the Nitrogen load from upstream BMPs is column T, the untreated load generated by the contributing drainage area is column U, and the Nitrogen removed by the BMP is column W.*

7. The user can select multiple BMPs in a treatment train. Column P provides a pull-down menu of BMPs that are acceptable as a downstream practice. The spreadsheet automatically passes the remaining runoff volume and pollutant load to the selected downstream BMP in the treatment train.

When selecting downstream BMPs in a treatment train, the entire discharge must go to the downstream BMP; the outflow cannot be divided and directed to different downstream BMPs. The downstream BMP may include a flow diversion to bypass large storms; however the entire discharge must go to one BMP.

For example, if multiple rooftop downspouts for a building are consolidated into one spreadsheet entry as practice 2.b. *Simple Rooftop Disconnection to C/D Soils*, and the downstream BMP for half the building is practice 6.a. *Bioretention #1*, and the downstream BMP for the other half is practice 8.a. *Extended Detention Pond #1*, then the user must use two different drainage area tabs, one for each half of the roof. Additional areas and BMPs can be represented on the same drainage area tab, as long as the discharge from each practice is being directed to a single BMP.

***NOTE:** If the user elects to reforest a buffer as a conservation area, designate an area as a vegetated filter strip, or create some other land cover conversion that may transition from managed turf to forest/open space as defined in **Table 12.1**, then the acreage should be changed accordingly in the Land Cover table on the Site Data tab, as well as on the individual Drainage Area tabs. This will influence the runoff volume and load calculations, since the Rv for Forest/Open Space is significantly lower than that of managed turf.*

8. The total impervious cover treated and total turf area treated (acres) in the drainage area is summed at the end of the table of volume reduction BMPs. This serves as a check to ensure that the total area of turf and the total area of impervious cover listed as the Credit Area (column G) does not exceed the total entered in the land cover table (column F).

***NOTE:** The Area Check of the total impervious (cell G71) and total turf (cell G72) area treated in the drainage area is only a check against the totals listed in the land cover table of the drainage area (cells F5 through F7). The Water Quality Compliance tab provides an additional Area Check that ensures the area*

*listed in the Drainage Area Land Cover tables does not exceed the total Land Cover entered into the Site Data tab.*

9. The second table of BMPs includes the pollutant reduction (Treatment) practices that remove pollutants but do not remove runoff volume. The same equations are used to calculate the load removed and the load remaining with each practice.

***NOTE:** The column for calculating the volume reduction is provided for these practices in order to maintain the columns and allow for easier scrolling up and down the sheet. However, since these practices do not reduce runoff volume, the runoff reduction column (column I) does not contain a formula and will remain zero.*

10. A second Area Check is provided at the end of the Drainage Area tab that ensures the total area of Turf and Impervious Cover entered as credit area to the volume reduction and pollutant removal BMPs in the drainage area does not exceed the total area of the particular drainage area.

#### **12.2.4 Water Quality Compliance**

The Water Quality Compliance tab does not require any user input. All the cells are calculations that include:

- A check to ensure that the total area listed in the land cover table of each drainage area does not exceed the total area listed in land cover table of the Site Data tab.
- A check to ensure that the total acreage of impervious and turf cover listed as Credit Area to be treated by the BMPs does not exceed the area listed in the land cover table at the top of the Drainage Area tab.
- The total design runoff Treatment Volume (cu. ft.) generated on the site by the target rainfall event (cell B11).
- The Total Phosphorus load reduction (lb/yr) required to meet the site based load limit of 0.41 lb/ac/yr (cell B12).
- The total runoff volume reduction achieved on the site (cell B14)
- The Total Phosphorus load reduction achieved (lb/yr) on the site (cell B15).
- The resulting Phosphorus load after applying the BMPs (cell B17)
- The remaining Phosphorus load reduction (lb/yr) needed to meet the requirement if the selected BMPs have not yet met the load limit (cell B19).

This last value represents compliance with the stormwater regulations. If the BMP strategy has met the requirements, a congratulatory message appears. If not, this value provides the user with the amount of phosphorus reduction that should be pursued through the implementation of additional on-site BMPs or any available offsite or offset fee compliance options.

Lines 24 through 30 summarize the Nitrogen reduction achieved by the BMP strategy. This is for informational purposes or as may be needed for TMDL compliance accounting.

### 12.2.5 Channel and Flood Protection

The Channel and Flood Protection tab calculates the runoff volume reduction benefit in terms that can be applied to the quantity control requirements of the VSMP regulations. These requirements include provisions that include the volume of runoff for the post-development condition:

- The channel protection requirements include a one-year 24-hour storm peak flow rate reduction based (in part) on the ratio of the post-development runoff volume to the pre-development volume.
- The flood protection requirements include ten-year 24-hour storm peak flow rate reductions, as needed, to stay within the conveyance capacity of the downstream receiving system.
- Increased volumes of runoff in the form of sheet flow must be evaluated for impacts to downstream properties.

(The user should carefully review the quantity control requirements found in section 9 VAC 25-870-66 of the VSMP Regulations.)

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 quantity control requirements. This credit is applied in the form of a curve number reduction based on the Natural Resource Conservation Service (NRCS) runoff equations provided in *Urban Hydrology for Small Watersheds* (USDA 1986).

Once again, it is important to note that the calculated runoff volume reduction credit is an annual volume reduction credit based on the long term monitored performance of the practice, and not a modeled single event volume reduction. It is also important to note that the spreadsheet calculates the annual reduction credit assuming that the BMP is designed and sized according to minimum requirements of the BMP Design Specifications posted on the Virginia Stormwater BMP Clearinghouse website.

This means that if the user has oversized a practice for whatever reason, the spreadsheet will not reflect additional water quality credit. This also means that the spreadsheet will not reflect additional channel and flood protection credit. However, the designer may choose to analyze the BMP strategy using more rigorous hydraulic analyses, such as individual practice stage-storage-discharge computations and storage indication routing techniques to demonstrate the peak rate reduction. Routing of BMPs can be a difficult and complex task given all the hydrologic and hydraulic variables associated with volume reduction, such as the influence on the time of concentration, and the effect of evapo-transpiration and slow release storage within the soil media (extended filtration) etc.

The following provides a brief explanation of the computational procedure provided by the spreadsheet. A more detailed derivation of the curve number adjustment can be found in the **Chapter 11** of this Handbook.

1. As a first step, the user should enter the rainfall depth for the Target Rainfall Event, in inches, for the required storms. This will likely be the 1-year, 2-year, and/or 10-year frequency storm events. Refer to the **Appendix 11-B** of **Chapter 11** of this Handbook for regional rainfall depths.
2. The spreadsheet calculation cells in rows 4 through 22 of column C provide the drainage area (acres) and the runoff reduction volume achieved in each of the drainage areas. This runoff reduction volume represents the total volume reduction achieved in each drainage area (as provided in cell I77 of each Drainage Area tab). These values are used to calculate the adjusted curve number for each of the drainage areas as follows (in simple terms):
  - a. The first computation is the determination of the drainage area composite Curve Number (CN) with no runoff reduction. This is based on the standard land cover CNs for each soil group (**Equation 12.13**). The composite CN for the Drainage Area A is provided in cell G35.
  - b. The composite curve number is used to calculate the value of S (the potential maximum retention after runoff begins) in cell H35. This is a function of the composite curve number (**Equation 12.14**).
  - c. The spreadsheet now calculates the runoff volume ( $RV_{Developed}$ ) in watershed-inches, with *no* runoff reduction (line 37, **Equation 12.15**) and *with* runoff reduction (line 38, **Equation 12.16**) for each storm event.
  - d. The spreadsheet determines the adjusted CN for each target rainfall event by referring to a lookup table of Curve Numbers and corresponding runoff depth (watershed-inches) for each target rainfall depth (row 39). The look-up table generally solves **Equation 12.17**. The Adjusted CN can also be determined using Figure 2-2 of TR-55.

The designer should consult **Chapter 11** of this Handbook for details on this computational procedure.

### 12.2.6 Compliance Summary

**The user must enable macros for full functionality of the Summary tab.** This tab compiles a report style summary of all the BMPs in each drainage area. The site data summary will update Site Data Summary tables as the user enters data into the Site Data tab and the Drainage Area tabs. However, the user must click on the “Update Summary Sheet” for the individual drainage area summaries to populate.

The user will notice the screen flickering as the macros check each cell in each drainage area tab to identify the BMPs selected, the downstream BMPs (if any), the credit area to each, and the corresponding volume and pollutant load reductions. The summary will also provide a report of the adjusted curve numbers for channel and flood protection for each drainage area. The user must click on the “print” button and the printer command window will appear.

### 12.3 VRRM COMPLIANCE SPREADSHEET FOR DEVELOPMENT ON PRIOR DEVELOPED LAND (REDEVELOPMENT)

The VRRM Compliance Spreadsheet for Development on Prior Developed Land – referred to hereafter as the **VRRM Redevelopment Compliance Spreadsheet** – has a very different Site Data tab in order to compute the water quality load reduction requirements in accordance with the criteria for development on prior developed lands (9 VAC 25-870-63 A 2). Once the load reduction requirements are determined, the procedures for evaluating the implementation of BMPs and verifying compliance are the same as those for new development.

#### 12.3.1 VRRM Redevelopment Compliance Spreadsheet Site Data Tab Basics

The basic structure of the VRRM Redevelopment Compliance Spreadsheet is similar to the new development compliance spreadsheet with the exception of the Site Data tab. The Site Data tab includes a computation that provides the user with the load reduction requirement that is variable depending on the pre-development conditions (percent reduction) and whether the redevelopment site results in a net increase in impervious cover. Once the load reduction requirement for the redevelopment site has been determined, the procedures for using the spreadsheet Drainage Area, Water Quality Compliance, Channel and Flood Protection, and Summary tabs are the same as those of the new development spreadsheet described in **Section 12.2**.

**Figures 12.6** and **12.7** provide screen shots of the upper and lower portions of VRRM Redevelopment Compliance Spreadsheet's Site Data tab. The same cell coloring scheme governs the designation of user input cells (blue), calculation cells (gray), and data (or VSMP regulation constant) cells, i.e., Total Phosphorus EMC,  $R_v$  coefficients, etc. (yellow).

The following terms are defined and used the same way as in the new development spreadsheet, as described in **Section 12.2.1**:

- **Annual Rainfall**
- **Target Rainfall Event**
- **Phosphorus and Nitrogen EMC**
- **$R_v$  Coefficients**

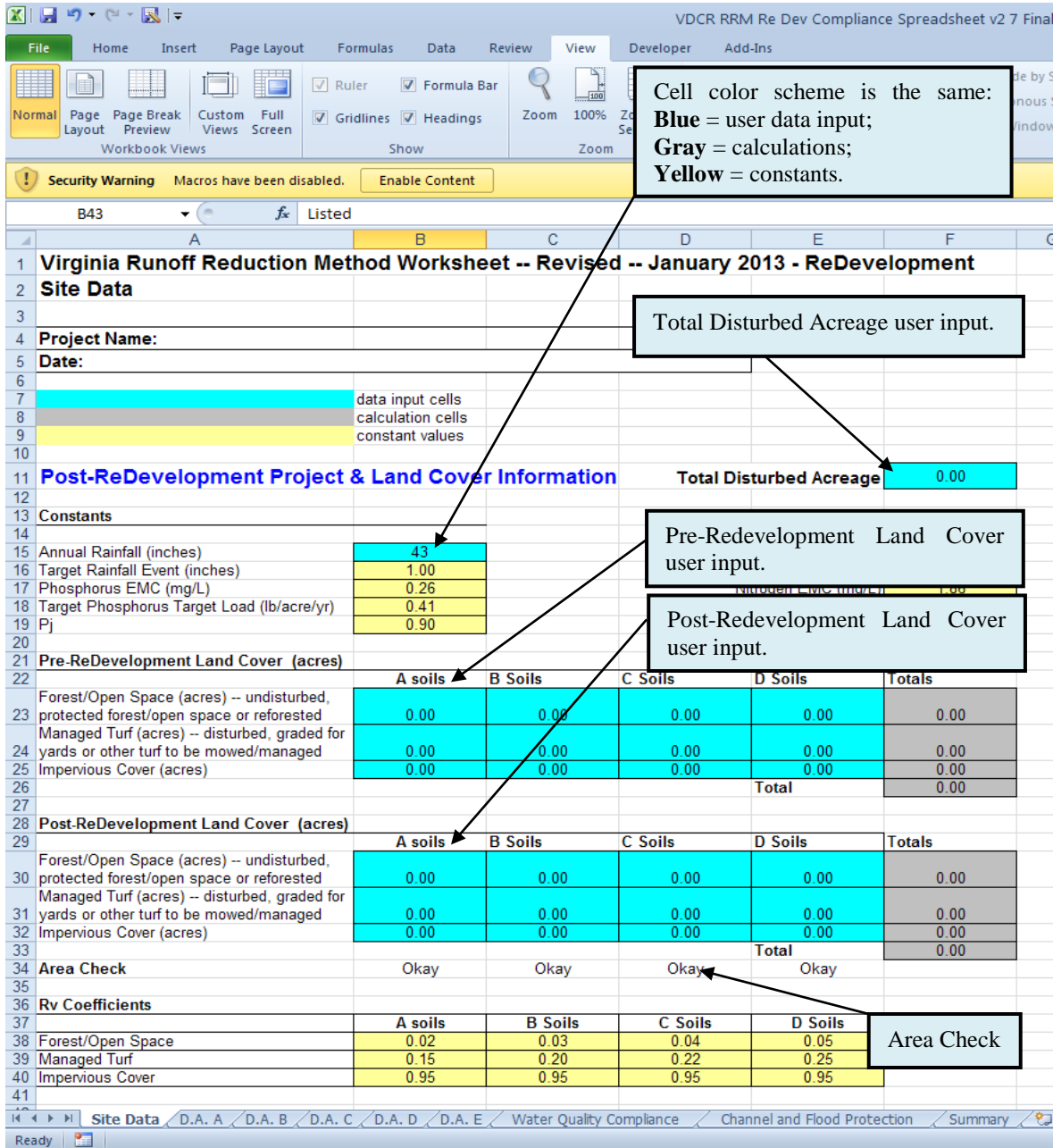
The following terms have slightly different definitions or are used within the computations differently:

**Target Phosphorus Load** (0.41 lb/ac/yr) is the load limit for new development and is applied to the acreage of new impervious cover on the redevelopment site that results in a net increase in impervious cover (9 VAC 25-870-63 A 2 c). The **Target Phosphorus Load** for redevelopment projects that do not result in an increase in impervious cover is based on a percent reduction from the pre-development (or pre-redevelopment) load.

**Land Cover** (acres) is broken into two conditions: the **Pre-Redevelopment** and **Post-Redevelopment** conditions. The land cover categories of *Forest/Open Space*, *Managed Turf*, and



*Impervious Cover* and the corresponding definitions are the same as those for the new development computations, and are defined in **Table 12.1** above.



**Figure 12.6. VRRM Redevelopment Compliance Spreadsheet Site Data Tab (upper cells)**

**Area Check** verifies that the total acreages entered for the Pre-Redevelopment and Post-Redevelopment conditions are the same (row 34).

The **Land Cover Summary** table computes the following site data: the Composite *R<sub>v</sub>* for each land cover type (**Equation 12.1**), and the **Site *R<sub>v</sub>*** (**Equation 12.2**), the **Treatment Volume (*T<sub>v</sub>*)**

(Equation 12.3), and the Pollutant Load (TP) (Equation 12.4) for each of the following categories of land:

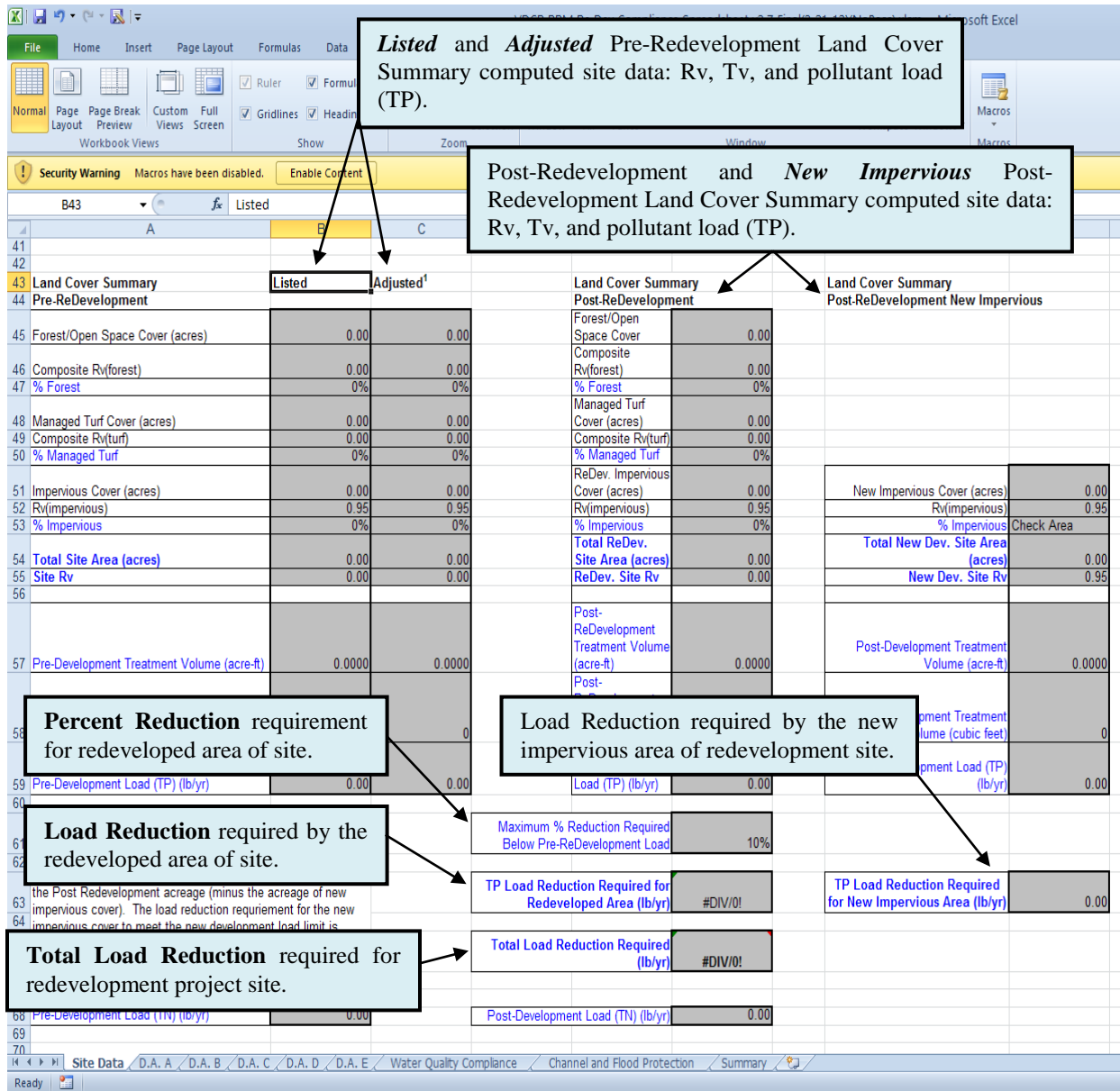


Figure 12.7. VRRM Redevelopment Compliance Spreadsheet Site Data Tab lower cells

- **Listed Pre-Redevelopment Land Cover Summary** (Site Data tab column B) represents the computed site data of the existing (Pre-Redevelopment) Land Cover, as entered by the user.
- **Adjusted Pre-Redevelopment Land Cover Summary** (Site Data tab column C) represents the computed site data of the existing (Pre-Redevelopment) Land Cover **minus** the pervious acreage proposed for new impervious cover (**where redevelopment results in a net increase in impervious cover**). For redevelopment that does *not* result in a net increase in impervious cover, the Adjusted Land Cover Summary is the same as that of the Listed Land Cover Summary

- **Post-Redevelopment Land Cover Summary** (Site Data tab column E) represents the computed site data of the Post- Redevelopment Land Cover **minus the acreage of new impervious cover**. If the redevelopment does not result in a net increase in impervious cover, the values are computed using the Post-Redevelopment Land Cover entered by the user.
- **Post-Redevelopment New Impervious Land Cover Summary** (Site Data tab column I) represents the computed site data for the net acreage of new impervious cover.

The **Listed** and **Adjusted** Pre-Redevelopment computed site data in the Land Cover Summary is needed to facilitate the computation of the load reduction required by the dual standards using only one spreadsheet:

- The percent reduction from the pre-development condition when there is *no* net increase in impervious cover; or
- When there *is* a net increase in impervious cover:
  - The percent reduction requirement for the redeveloped area of the site; **plus**
  - The reduction required for new impervious cover to meet the new development standard of 0.41 lb/ac.

The 10 or 20 percent load reduction from the Pre-Redevelopment load requires that the Pre- and Post-Redevelopment acreage be the same. If there is *no* increase in impervious cover, this percent reduction calculation is based on the Pre- and Post-Redevelopment Land Cover acreage entered by the user.

If there *is* a net increase in impervious cover, the spreadsheet will create the Adjusted Pre-Redevelopment and the Post-Redevelopment Land Cover Summary data (with the new impervious cover removed) in order to compute the load reduction required by the appropriate percent reduction from the existing or pre-development condition. The New Impervious Land Cover Summary data is created in order to compute the load reduction required to meet the new development standard of 0.41 lb/ac.

Cell F65 of the Site Data tab provides the total load reduction requirement of the redevelopment project.

Once again, the basics of the VRRM Redevelopment Compliance Spreadsheet Drainage Area tabs, the Water Quality Compliance tab, the Channel and Flood Protection tab, and the Summary tab are the same as those of the New Development spreadsheet discussed in **Section 12.2**.

### 12.3.2 Using the VRRM Redevelopment Compliance Spreadsheet

The first step in using the VRRM Compliance Spreadsheet is to **enable macros**. This will allow the Site Data Summary to reference the Drainage Area tabs and update the summary when the design is complete.

The second important step is to be sure to “zero out” the spreadsheet. There may be values entered into miscellaneous user input cells from previous projects or trial designs that can create errors.

Similar to the New Development Spreadsheet, the instructions for the Redevelopment Spreadsheet follow a process that emphasizes early planning of the stormwater management strategy in order to establish the redevelopment project “site”. The designer can implement stormwater practices to achieve the load reduction requirement by treating the new, redeveloped, or existing site areas within the limits of the project (as defined by the project site).

The project site should incorporate all of the disturbed area and proposed improvements (including existing buildings when being renovated), and any additional area of the site needed for vehicle access, material and equipment staging, and the construction of the stormwater BMPs. Therefore, the redevelopment project “site” and the disturbed area may not be the same.

### 12.3.2.1 Site Data

1. Enter the Total Disturbed Acreage (cell F11). This determines the redeveloped area pollutant reduction requirement (10 or 20% below the existing or Pre-Redeveloped condition load).
2. Enter the Annual Rainfall (cell B15). The accepted value of central VA is 43 inches.
3. The Target Rainfall Event, Phosphorus EMC, Target Phosphorus Load, and Pj (the fraction of annual rainfall less than 0.1”) in cells B16 through B19 are constant values.
4. Enter the Pre-Redevelopment Land Cover in acres for Forest/Open Space, Managed Turf, and Impervious Cover. Refer to **Table 12.1** above for the Land Cover definitions. The total in cell F26 should be equal to total area of the redevelopment project site.
5. Enter the Post-Redevelopment Land Cover in acres for Forest/Open Space, Managed Turf, and Impervious Cover. Once again, refer to **Table 12.1** above for the Land Cover definitions. The total in cell F33 should be equal to the Pre-Redevelopment total (cell F26).
6. An Area Check will verify that the total Pre-Redevelopment (cell F26) and Post-Redevelopment (cell F33) acreage is equal.

### *Listed Pre-Redevelopment Land Cover Summary Data*

- The *Listed* Pre-Redevelopment Land Cover acreages (cell B45, B48, and B51) reflect the Pre-Redevelopment project site acreage entered by the user.
- The *Listed* Pre-Redevelopment Rv composite for each land cover type (cells B46, B49, and B51) is calculated using **Equations 12.1a** through **12.1c**.
- The *Listed* Pre-Redevelopment Site Rv (cell B55) is the unitless composite volumetric runoff coefficient representing the entire redevelopment project site and is calculated using **Equation 12.2**.

- The *Listed* Pre-Redevelopment Treatment Volume ( $T_v$ , cell B57) in acre feet is calculated using **Equation 12.3**. This value multiplied by 43,560 ft<sup>2</sup>/acre equals the treatment volume in cubic feet.
- The *Listed* Pre-Redevelopment Total Phosphorus (TP) Load (cell B59) in lb/yr is the load generated by the site in its existing (Pre-Redevelopment) condition. This value is computed using the Simple Method and is based on the *Listed* Pre-Redevelopment Treatment Volume, annual rainfall, and the TP EMC of 0.26 mg/l (**Equation 12.4**). A Total Nitrogen (TN) is also calculated (cell B68) for informational purposes and TMDL accounting only, based on the TN EMC of 1.86 mg/l (**Remember:** regulatory compliance is based on the TP load limit only).

### **Adjusted Pre-Redevelopment Land Cover Summary Data**

- The *Adjusted* Pre-Redevelopment Land Cover Summary acreages of Forest/Open Space (cell C45) and Managed Turf (cell C48) are the *Listed* values reduced by the acreages (by soil type) proposed to be converted to new impervious cover as entered by the user.
  - If no net increase in impervious cover is reflected in the Pre- and Post-Development Land Cover entered by the user, then the acreage of the *Listed* and *Adjusted* Land Cover will be the same.)
  - The *Adjusted* and the *Listed* Impervious Cover are the same.
- The *Adjusted* Pre-Redevelopment composite  $R_v$  for each land cover type (cells C46, C49, and C51) is calculated using **Equation 12.1a** through **12.1c** using the Adjusted Land Cover acreage values referenced above.
- The *Adjusted* Pre-Redevelopment Site  $R_v$  (cell C55) is the unitless composite volumetric runoff coefficient representing the entire *Adjusted* redevelopment project site. It is calculated using **Equation 12.2**.
- The *Adjusted* Pre-Redevelopment Treatment Volume ( $T_v$ , cell C57) in acre feet is calculated using the *Adjusted* Land Cover values and Site  $R_v$  (cell C55) in **Equation 12.3**. This value multiplied by 43,560 ft<sup>2</sup>/acre equals the treatment volume in cubic feet.
- The *Adjusted* Pre-Redevelopment Total Phosphorus (TP) Load (cell C59) in lb/yr is the load generated by the *Adjusted* Pre-Redevelopment condition. This value is computed using the Simple Method and is based on the *Adjusted* Pre-Redevelopment Treatment Volume ( $T_v$ ), annual rainfall, and the TP EMC of 0.26 mg/l (**Equation 12.4**).

### **Post-Redevelopment Land Cover Summary Data**

- The Post-Redevelopment Land Cover Summary acreages of Forest/Open Space (cell E45) and Managed Turf (cell E48) reflect Post-Redevelopment Land Cover acreage entered by the user.
  - The Post-Redevelopment Impervious Cover (cell E51) is reduced by the net increase in impervious cover (the difference in the Pre- and Post-Redevelopment user-entered land cover) and is equal to the *Adjusted* Impervious Cover.
  - If *no* net increase in impervious cover is reflected in the Pre- and Post-Development Land Cover entered by the user, then the Post-Redevelopment acreage of impervious cover is the same as the *Listed* impervious cover.

- The Post-Redevelopment  $R_v$  composite for each land cover type (cells E46, E49, and E51) is calculated using **Equation 12.1a** through **12.1c** using the Post-Redevelopment Land Cover acreage values referenced above.
- The Post-Redevelopment Site  $R_v$  (cell E55) is the unitless composite volumetric runoff coefficient representing the entire Post-Redevelopment project site, and is calculated using **Equation 12.2**.
- The Post-Redevelopment Treatment Volume ( $T_v$ , cell E57) in acre feet is calculated using the Post-Redevelopment Land Cover values and Site  $R_v$  (cell E55) in **Equation 12.3**. This value multiplied by 43,560 ft<sup>2</sup>/acre equals the treatment volume in cubic feet.
- The Post-Redevelopment Total Phosphorus (TP) Load (cell E59) in lb/yr is the load generated by the Post-Redevelopment condition. This value is computed using the Simple Method and is based on the Post-Redevelopment Treatment Volume, annual rainfall, and the TP EMC of 0.26 mg/l (**Equation 12.4**).

### ***New Impervious Post-Redevelopment Land Cover Summary Data***

- The *New Impervious Cover* acreage (cell I51) and Total New Dev. Site Area (cell I54) under the *New Impervious Post-Redevelopment Land Cover Summary* is the *net* increase in impervious cover (the difference between the Pre- and Post-Redevelopment acreage entered by the user).
- The *New Impervious Post-Redevelopment  $R_v$*  (cell I52) is 0.95 (regardless of soil type).
- The *New Impervious Post-Redevelopment New Dev. Site  $R_v$*  (cell I55) is the unitless composite volumetric runoff coefficient representing the new impervious cover, and its value is 0.95.
- The *New Impervious Post-Redevelopment Treatment Volume ( $T_v$ , cell I57)* in acre feet is calculated using the *New Impervious Post-Redevelopment Land Cover* values and Site  $R_v$  in **Equation 12.3**. This value multiplied by 43,560 ft<sup>2</sup>/acre equals the treatment volume in cubic feet.
- The *New Impervious Post-Redevelopment Total Phosphorus (TP) Load* (cell I59) in lb/yr is the load generated by the *New Impervious Post-Redevelopment* condition. This value is computed using the Simple Method and is based on the *New Impervious Post-Redevelopment Treatment Volume*, annual rainfall, and the TP EMC of 0.26 mg/l (**Equation 12.4**).

### **12.3.2.2 Load Reduction Requirement**

#### **Maximum Percent (%) Reduction Required Below Pre-Redevelopment Load (cell F61)**

The Post-Redevelopment Land Cover Summary Data is calculated using the Post-Redevelopment Land Cover entered by the user after the acreage is adjusted, as follows:

- The maximum percent reduction below the Pre-Redevelopment pollutant load is either 10 or 20 percent, depending on the acreage of land disturbance on the redevelopment site, entered in cell F11:
  - 10% reduction required when land disturbance is limited to less than one acre; and
  - 20% reduction required when land disturbance is one acre or greater.

**NOTE:** The load reduction computations incorporate compound spreadsheet equations that include “IF” statements in order to (1) evaluate the different options related to the dual requirements of percent load reduction for the redevelopment area of the site (cell F63) and the reduction to meet the load limit of new development on the new impervious cover of the site (cell I63); and (2) display the single total load reduction requirement (F65) for the site conditions as entered into the spreadsheet. The information presented here reflects the computational logic and base equations, while the spreadsheet cell contents display the compound spreadsheet equations.

### TP Load Reduction Required for Redeveloped Area (cell F63)

The TP load reduction calculation procedure for the redeveloped area of the site calculates the load reduction required to be either 10 or 20 percent below the load of the Pre-Redeveloped site condition, depending on the total acreage of disturbance, as follows:

$$L_{reduction} = L_{Post-Redevelopment} - L_{Pre-Redevelopment} (1 - 0.1)$$

*or*

$$L_{reduction} = L_{Post-Redevelopment} - L_{Pre-Redevelopment} (1 - 0.2)$$

Where:

$L_{reduction}$  = Load reduction required for the Redeveloped Area in lb/yr (cell F63)

$L_{Post-Redevelopment}$  = Post Redevelopment load (cell F59)  
(Equation 12.4 using the Post-Redevelopment Site Data)

$L_{Pre-Redevelopment}$  = Adjusted Pre-Redevelopment load (cell C59)  
(Equation 12.4 using the Adjusted Pre-Redevelopment Site Data)

### TP Load Reduction Required for New Impervious Area (cell I63)

The TP load reduction for the new impervious area is the difference between the *New Impervious* Post-Redevelopment load (cell I59) and the new development site-based load limit of 0.41 lb/ac/yr established by the VSMP Regulations, using **Equation 12.5**, with “site” defined as *the area of new impervious cover*.

### Total Load Reduction Required (cell F65)

The Total Load Reduction Required cell includes three different computations that result in the total load reduction required for the redevelopment project:

1. If there is *no* net increase in impervious cover (cell I51 is zero), then the total load reduction (cell F65) is the same as that computed in cell F63.

2. If there *is* a net increase in impervious cover (cell I51 is **not** zero), the total load reduction is the sum of the percent load reduction from the redevelopment area of the site (cell F63) plus the load reduction to meet the new development criteria (cell I63).
3. The final check is to verify that the total load reduction required (as computed by item 1 or 2 as appropriate) does not exceed that which would be required to achieve the new development standard of 0.41 lb/ac/yr for the *entire* redevelopment project site. The smaller of the two reduction requirements is displayed in cell F65.

For redevelopment projects, the **Drainage Areas, Water Quality Compliance, Channel and Flood Protection, and Summary Tabs** are used exactly as described in **Section 12.2**.

## 12.4 THE VRRM COMPLIANCE SPREADSHEET DOCUMENTATION

This section provides the equations used in the calculation cells of the *VRRM Compliance Spreadsheet*.

### 12.4.1 Site Data Tab

#### *Equation 12.1: Composite Land Cover (Rv)*

##### *Equation 12.1a – Forest:*

$$\begin{aligned} Rv(F) &= [(A(fA) \times 0.02) + (A(fB) \times 0.03) + (A(fC) \times 0.04) + (A(fD) \times 0.05)]/SA \\ \%Forest &= (A(fA) + A(fB) + A(fC) + A(fD))/A_{site} \times 100 \end{aligned}$$

##### *Equation 12.1b – Turf:*

$$\begin{aligned} Rv(T) &= [(A(tA) \times 0.15) + (A(tB) \times 0.20) + (A(tC) \times 0.22) + (A(tD) \times 0.25)]/SA \\ \%Turf &= (A(tA) + A(tB) + A(tC) + A(tD))/A_{site} \times 100 \end{aligned}$$

##### *Equation 12.1c – Impervious:*

$$\begin{aligned} Rv(I) &= 0.95 \\ \%Impervious &= (A(iA) + A(iB) + A(iC) + A(iD))/A_{site} \times 100 \end{aligned}$$

Where:

Rv(F) = composite forest runoff coefficient  
 A(fA) = area of post-development forest and open space in A soils (acres)  
 A(fB) = area of post-development forest and open space in B soils (acres)  
 A(fC) = area of post-development forest and open space in C soils (acres)  
 A(fD) = area of post-development forest and open space in D soils (acres)

Rv(T) = composite turf runoff coefficient  
 A(tA) = area of post-development managed turf in A soils (acres)  
 A(tB) = area of post-development managed turf in B soils (acres)  
 A(tC) = area of post-development managed turf in C soils (acres)



$A(tD)$  = area of post-development managed turf in D soils (acres)

$Rv(I)$  = composite impervious cover runoff coefficient

$A(iA)$  = area of post-development impervious cover in A soils (acres)

$A(iB)$  = area of post-development impervious cover in B soils (acres)

$A(iC)$  = area of post-development impervious cover in C soils (acres)

$A(iD)$  = area of post-development impervious cover in D soils (acres)

$A_{site}$  = total site area (acres)

**Equation 12.2: Site Rv**

$$Rv_{site} = Rv(F) \times \%Forest + Rv(T) \times \%Turf + Rv(I) \times \%Impervious$$

Where:

$Rv_{site}$  = unit less composite volumetric runoff coefficient for the site

$Rv(F)$  = composite forest runoff coefficient

$Rv(T)$  = composite turf runoff coefficient

$Rv(I)$  = composite impervious cover runoff coefficient

**Equation 12.3: Post-Development Site Treatment Volume**

$$Tv_{site} = Rd \times Rv_{site} \times A_{site}/12$$

Where:

$Tv_{site}$  = post-development treatment volume for site (acre-ft)

$Rd$  = target rainfall event depth (1" for water quality storm)

$Rv_{site}$  = runoff coefficient for the site

$A_{site}$  = total site area (acres)

**Equation 12.4: Post-Development Site TP Load**

$$L = P \times P_j \times [Tv_{site}/Rd] \times C \times 2.72$$

Where:

$L$  = post-development pollutant load for site (pounds / year of total phosphorus)

$P$  = average annual rainfall depth (inches) = 43 inches for Virginia

$P_j$  = fraction of rainfall events that produce runoff = 0.9

$Tv_{site}$  = post-development treatment volume for site (acre-ft) Equation 12.3

$Rd$  = rainfall depth for target event (1" for water quality storm)

$C$  = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus

2.72 = unit adjustment factor, converting milligrams to lbs. and acre-feet to liters

**Equation 12.5: Required Site TP Load Reduction**

$$L_{\text{reduction}} = L - P_{\text{target}} \times A_{\text{site}}$$

Where:

- $L_{\text{reduction}}$  = required TP Load Reduction (pounds/year of total phosphorous)  
 $L$  = post-development pollutant load for site (pounds year of total phosphorus)  
 $P_{\text{target}}$  = target phosphorous load (pounds / acre / year) = 0.41 lb/ac/yr  
 $A_{\text{site}}$  = total site area (acres)

**12.4.2 D.A. Tabs****Equation 12.6: Runoff Volume from Contributing Drainage Area**

**Note:** This includes the volume of runoff generated by the drainage area and the volume of runoff from the upstream RR practice times the volume reduction credit:

$$C_v = R_d \times R_{VCA} \times CA \times 3,630$$

Where:

- $C_v$  = Runoff volume from contributing drainage area, or Credit Area (cubic feet)  
 $R_d$  = rainfall depth for target event (1" for water quality storm)  
 $R_{VCA}$  = composite runoff coefficient for credit area (CA) land cover being treated by credit practice  
 $CA$  = credit area applied to practice (acres, column G)  
 3,630 = unit adjustment factor, converting acre-inches to cubic feet

**Equation 12.7: Total Runoff Volume to Practice**

**Note:** This includes the runoff volume from the contributing drainage area + the runoff volume from the upstream practice:

$$C_{v_{\text{total}}} = C_v + V_{\text{upstream}}$$

Where:

- $C_{v_{\text{total}}}$  = Total runoff volume to practice  
 $C_v$  = Runoff volume from credit area (cubic feet, Equation 6)  
 $V_{\text{upstream}}$  = Volume from upstream runoff reduction practice (column H)

**Equation 12.8: Runoff Reduction Achieved by Practice (column I)**

$$C_{Vred} = (Rd \times R_{VCA} \times CA \times 3,630 + V_{upstream}) \times (CR)$$

Where:

- $C_{Vred}$  = runoff reduction achieved by practice (cubic feet)  
 $Rd$  = rainfall depth for target event (1" for water quality storm)  
 $R_{VCA}$  = composite runoff coefficient for the credit area (CA) land cover being treated by credit practice  
 $CA$  = credit area applied to practice (acres, column G)  
 $3,630$  = unit adjustment factor, converting acre-inches to cubic feet  
 $V_{upstream}$  = Upstream runoff volume directed to credit practice (column H)  
 $CR$  = volume reduction performance credit for the practice (column F)

**Equation 12.9: Remaining Runoff Volume Leaving the Practice (column J)**

$$C_{Vremaining} = (Rd \times R_{VCA} \times CA \times 3,630 + V_{upstream}) \times (1 - CR)$$

Where:

- $C_{Vremaining}$  = runoff reduction achieved by practice (cubic feet)  
 $Rd$  = rainfall depth for target event (1" for water quality storm)  
 $R_{VCA}$  = composite runoff coefficient for the credit area (CA) land cover being treated by credit practice  
 $CA$  = credit area applied to practice (acres, column G)  
 $3,630$  = unit adjustment factor, converting acre-inches to cubic feet  
 $V_{upstream}$  = Upstream runoff volume directed to credit practice (column H)  
 $CR$  = volume reduction performance credit for the practice (column F)

**OR**

$$C_{Vremaining} = C_{Vtotal} - C_{Vred}$$

Where:

- $C_{Vremaining}$  = remaining runoff volume (leaving practice, column J)  
 $C_{Vtotal}$  = total runoff volume to practice (Equation 7)  
 $C_{Vred}$  = runoff reduction achieved by practice (Equation 8, column I)

**Equation 12.10: Untreated Pollutant Load to Practice (Phosphorus, column M; Nitrogen, column N)**

$$L = P \times P_j \times [T_{VCA}/Rd] \times C \times 2.72 + L_{upstream}$$

Where:

- $L$  = untreated pollutant load to practice (pounds / year of total phosphorus)  
 $P$  = average annual rainfall depth (inches) = 43 inches for Virginia  
 $P_j$  = fraction of rainfall events that produce runoff = 0.9  
 $T_{VCA}$  = post-development treatment volume to practice from the credit area  
 in acre-ft =  $[Rd \times R_{VCA} \times CA] / 12$

Where:

- Rd = rainfall depth for target event (1" for water quality storm)  
 R<sub>VCA</sub> = drainage area composite R<sub>v</sub> for land cover (cell G6 or G7 based on contributing area being turf or impervious)  
 CA = credit area applied to practice (acres)
- Rd = rainfall depth for target event (1" for water quality storm)  
 C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus, 1.86 mg/l for nitrogen  
 2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters  
 Upstream = pollutant load from upstream treatment practice (pounds/yr, Column O)

**Equation 12.11: Total Load Reduction by Practice (Column N)**

$$L_{red} = L \times [C_{V_{total}} \times EFF_{TP}/100] / C_{V_{total}}$$

Where:

- L<sub>red</sub> = total load reduction by practice (lbs/year)  
 L = untreated pollutant load to practice (lbs/year, Equation 12.10, column M)  
 C<sub>V<sub>total</sub></sub> = total runoff volume to practice (Equation 7, or column I + J)  
 EFF<sub>TP</sub> = pollutant removal performance credit (column K)  
 100 = % conversion factor

**Equation 12.12: Remaining Phosphorus Load (Column O)**

$$L_{remaining} = L - L_{red}$$

Where:

- L<sub>remaining</sub> = remaining phosphorus load after treatment by the practice (lb/year)  
 L = untreated pollutant load to practice (lbs/year, Equation 12.10, column M)  
 L<sub>red</sub> = load reduction (lbs/year, Equation 11, column N)

**Equation 12.13: Composite Curve Number (CN)**

$$CN = [(A(fA) \times 30) + (A(fB) \times 55) + (A(fC) \times 70) + (A(fD) \times 77) + (A(tA) \times 39) + (A(tB) \times 61) + (A(tC) \times 74) + (A(tD) \times 80) + A(iA) \times 98 + (A(iB) \times 98) + (A(iC) \times 98) + (A(iD) \times 98)] / DA$$

Where:

- CN = composite curve number  
 A(fA) = area of post-development preserved or restored forest in A soils (acres)  
 A(fB) = area of post-development preserved or restored forest in B soils (acres)  
 A(fC) = area of post-development preserved or restored forest in C soils (acres)  
 A(fD) = area of post-development preserved or restored forest in D soils (acres)

A(tA) = area of post-development managed turf/open space in A soils (acres)  
 A(tB) = area of post-development managed turf/open space in B soils (acres)  
 A(tC) = area of post-development managed turf/open space in C soils (acres)  
 A(tD) = area of post-development managed turf/open space in D soils (acres)

A(iA) = area of post-development impervious cover in A soils (acres)  
 A(iB) = area of post-development impervious cover in B soils (acres)  
 A(iC) = area of post-development impervious cover in C soils (acres)  
 A(iD) = area of post-development impervious cover in D soils (acres)

DA = Drainage Area (acres)

**Equation 12.14: Potential Maximum Retention After Runoff Begins (S, cell H35)**

$$S = 1000 / (CN - 10)$$

Where:

S = potential maximum retention after runoff begins (inches)  
 CN = composite curve number

**Equation 12.15: Runoff Volume with no Runoff Reduction (row 37)**

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

Where:

$RV_{no-rr}$  = runoff volume with no runoff reduction (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 CN

**Equation 12.16: Runoff Volume with Runoff Reduction (row 38)**

$$V_{rr} = [RV_{no-rr} - (C_{vredDA} / 3,630)] / DA$$

Where:

$V_{rr}$  = Runoff volume with runoff reduction (watershed-inches)  
 $RV_{no-rr}$  = runoff volume with no runoff reduction (watershed-inches, Equation 12.15)  
 $C_{vredDA}$  = runoff reduction achieved in the drainage area practice (cubic feet, Equation 8)  
 3,630 = unit adjustment factor, cubic feet to acre-inches  
 DA = drainage area (acres)

**Equation 12.17: Adjusted Curve Number (row39)**

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

$$CN_{\text{adjusted}} \text{ such that the Runoff Volume, } V_{\text{rr}}, \text{ (watershed-in, Equation 16) = } \\ (P - 0.2 \times S_{\text{adjusted}})^2 / (P + 0.8 \times S_{\text{adjusted}}); \text{ and } S_{\text{adjusted}} = 1000 / (CN_{\text{adjusted}} - 10)$$

Where:

- $CN_{\text{adjusted}}$  = Adjusted curve number that generates a runoff volume (watershed-inches) equal to the drainage area runoff volume with runoff reduction practices ( $V_{\text{rr}}$ , Equation 16)
- $V_{\text{rr}}$  = Runoff volume with runoff reduction (watershed-inches)
- $P$  = Rd, rainfall depth for Target Rainfall Event (24-hour storm depth, inches)
- $S_{\text{adjusted}}$  = potential maximum retention after runoff begins (inches) based upon adjusted curve number

**12.5 REFERENCES**

Center for Watershed Protection (CWP), National Fish and Wildlife Foundation (NFWF) and Virginia Department of Conservation and Recreation (VADCR). 2008. *Technical Memorandum: The Runoff Reduction Method*. April 18, 2008.

U.S.D.A.-Natural Resource Conservation Service (NRCS). 1985. *National Engineering Handbook, Section 4: Hydrology*. Washington, DC.

U.S.D.A.-Natural Resource Conservation Service (NRCS). 1986. *Urban Hydrology for Small Watersheds*. Technical Release No. 55 (TR-55). Washington, DC.