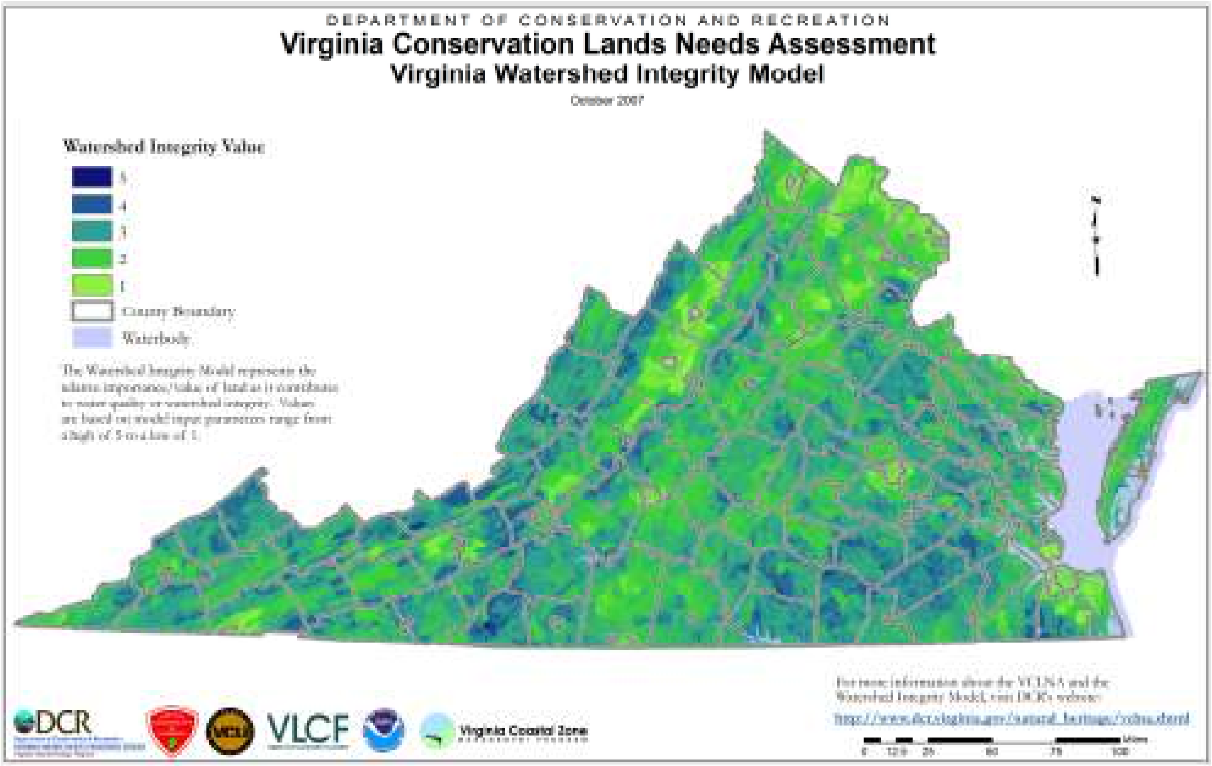
Virginia Conservation Lands Needs Assessment
Virginia Watershed Integrity Model



Virginia Department of Conservation and Recreation Division of Natural Heritage
Virginia Department of Forestry
Virginia Commonwealth University Center for Environmental Studies
Virginia DEQ Coastal Zone Management Program
October 2007
Prepared by:
Jennifer Ciminelli DCR-DNH
John Scrivani DOF

This work is funded by the Virginia Coastal Zone Management Program at DEQ through a grant from the National Oceanic and Atmospheric Administration to the Virginia Department of Conservation and Recreation's Natural Heritage Program.

TABLE OF CONTENTS

INTRODUCTION

The Virginia Watershed Integrity Model was developed to show the relative value of land as it contributes to watershed or water quality integrity. As development pressure continues across the state, remaining resources are being irretrievably lost to development. The Watershed Integrity Model represents important terrestrial features that should be conserved for water quality integrity based on the best available data.

Various studies have been conducted evaluating the relationship between land use and water resource quality. For the Watershed Integrity Model, the input parameters focused on identifying important terrestrial features that contribute to water resources, and, therefore watershed integrity.

Numerous studies have quantified the impacts of land use on watershed health (Roy 2007, Weber 2007, Atasoy 2006, Mehaffey 2005, Zielinksi 2002). There are strong relationships indicating negative correlations with an increase in impervious surfaces in a watershed and positive correlations with an increase in large forested areas, particularly forested riparian buffers (Weber 2007, Zielinski 2002, Roy 2007, Atasoy 2006).

Prioritizing watershed integrity on a large spatial scale involved the use of ecological indictors or indices that "include site-specific, field-derived metrics and landscape-level properties" in an effort to get at finer scale information (Tiner 2004). Accessibility to GIS and remotely sensed information makes these processes easier to run and can provide an important monitoring tool for watershed integrity. These indices also provide important information on aquatic and ecological health which can be used as indicators of overall stream and watershed health (Garman 2007). The indices used as part of the modeling effort serve as indicators of aquatic ecological health and terrestrial health. These serve as an important component of the model since these two factors are ecologically related.

There is established evidence that areas immediately adjacent to water bodies contribute to water quality health. These areas serve as groundwater recharge areas, filtration areas, temperature control, and as important habitat. Alteration to the natural ecological state of these areas will cause a negative impact the watershed (Meyer 2007). In particular, headwater streams and lands adjacent to headwater streams contribute significantly to overall stream health (Alexander 2007, Meyer 2007). Small, isolated headwater streams are often difficult to map and may not all be included in hydrologic GIS datasets (Meyer 2007). The use of slope as part of the modeling effort serves as a proxy for identifying areas that may support headwater streams and represent them appropriately in the model. Steep slopes along with landuse may increase runoff and effect water quality (Mehaffey 2005).

Watershed integrity affects the ecological integrity of terrestrial and aquatic resources and has a direct impact on human health. While this link would appear obvious, often citizens are not aware of the impacts from poor water quality. Conserving land directly around drinking water sources and reservoirs will provide a more effective ecological and economic benefit to water quality management. Lands around public source water intakes should be effectively managed to ensure water quality integrity (Mehaffey 2005).

The model serves as part of a larger green infrastructure plan, which aims to model where Virginia's conservation priorities are located to facilitate an integrated approach to planning and development. The development of a GIS model to delineate where lands important for watershed integrity exist may serve as a guide to local government, consultants, and developers. For information on the Virginia Conservation Lands Needs Assessment and the Green Infrastructure Modeling effort, please visit the VCLNA website at http://www.dcr.virginia.gov/natural_heritage/vclna.shtml.

The Virginia Department of Conservation and Recreation Division of Natural Heritage (DCR-DNH) collaborated with the Virginia Department of Forestry (DOF) and Virginia Commonwealth University Center for Environmental Studies (VCU-CES) in the development of the Watershed Integrity Model.

DOF previously undertook an effort as part of the Chesapeake Bay Executive Council Directive 06-1 to “identify areas where retention and expansion of forests is needed” (DOF 2007). This product was completed for the Virginia portion of the Chesapeake Bay in July 2007. The GIS methodology employed by DOF was utilized in the development of the VCLNA Watershed Integrity Model. The methods were altered for the VCLNA modeling effort and are detailed in the Methodology section.

VCU-CES has developed a Modified Index of Biotic Integrity (mIBI) for the state. “For watersheds and river basins, selected ‘universal’ metrics (e.g. combined native species richness, percent of pollution-tolerant species, combined non-indigenous species richness) are used ... to generate a modified Index of Biotic Integrity (mIBI) that classifies each of Virginia’s watersheds (hydrologic units, HUCs) and basins as a function of collective stream health, using both quantitative and qualitative (species occurrences) records available for the watershed” (VCU 2006). The use of the mIBI is detailed in the Methodology section. The use of the mIBI at the sixth order hydrologic unit was deemed appropriate as an indicator of stream health evaluation (Frimpong

Application of the Watershed Integrity Model

Some general categories of uses to which the Watershed Integrity Model can be applied include:

- Targeting – to identify targets for protection activities
- Prioritizing – to provide primary or additional justification for key conservation land purchases and other protection activities.
- Local planning – guidance for comprehensive planning and local ordinance and zoning development.
- Assessment – to review proposed projects for potential impacts to watershed integrity and/or water quality.
- Land Management – to guide property owners and public and private land managers in making land management decisions that enhance water resource values
- Public Education – to inform the citizenry about the importance of conserving lands which contribute to water quality and watershed integrity in their area. This information is important not only for ecological reasons, but for public health interest.

METHODOLOGY

A weighted overlay model was developed to identify and rank relative importance of land to watershed integrity. Input parameters are based on the best available datasets.

Input Parameters

Area Greater than the Average Slope

The National Watershed Boundary Dataset was obtained from the Virginia Department of Conservation and Recreation Division of Soil and Water (http://www.dcr.virginia.gov/soil_&_water/hu.shtml). Mean slope was calculated for each unique 6^{th} order National Watershed Boundary Dataset hydrologic unit using a slope layer derived from the National Elevation Dataset (USGS NED). The NED slope and watershed average slope grids were used to select out where the watershed grid had areas with greater than average slope. Data were recoded for the weighted overlay:

GRID VALUE	RANK
0	0
1	5

Source Water Protection Zones

Source water protection zones for all public drinking waters sources were collected from the Virginia Department of Health (VDH). The VDH delineated source water protection zones around public surface water intake points and attributed the zones as Zone 1 or 2. Data were converted to a grid based on zone designation and recoded for the weighted overlay.

GRID VALUE	RANK
0	0
1	5
2	3

Ecological Cores

The Virginia Natural Landscape Assessment (VANLA), an ecological component of the VCLNA, is a landscape-scale GIS analysis for identifying, prioritizing, and linking natural habitats in Virginia. The ecological cores were obtained from DCR Division of Natural Heritage (http://www.dcr.virginia.gov/natural_heritage/vclnavnla.shtml) and converted to a grid and recoded for the weighted overlay.

GRID VALUE	RANK
0	0
1	5
2	4
3	3
4	2
5	1

Streams, shorelines and floodplains

Streams, shorelines and floodplains were derived from the National Hydrography Dataset (NHD) and National Wetlands Inventory (NWI).

- NHD
  - NHD was downloaded from the NRCS soil data mart for the state.
  - NHD high resolution area, flowlines and waterbodies buffered at 15 meter (to ensure grid conversion, ½ pixel size negligible) and converted to a grid.
  - Euclidean distances run in ArcGIS.
  - Distance classed based on 100 meter increments (closer to a waterbody, higher rank):

- NWI
    - NWI data was obtained for the state from FWS.
    - NWI buffered at 15 meter and converted to a grid.
    - Grid values set to 5 for wetland, 0 for no data.
- NWI and NHD combined in a weighted overlay (each grid contributed 50%) to create final riparian grid.

Index of Terrestrial Integrity (ithi)
The index of terrestrial integrity was developed for Virginia based on the VA Department of Forestry's methodology for their Protecting the Forests of the Chesapeake Watershed effort. DOF's methods are adopted from methods by Tiner. The following description is based on the DOF GIS Methodology for their effort and represents the same effort DNH took to expand the metric to all 6^{th} order hydrologic units for the state while incorporating additional land cover types:

"Indices of watershed biological integrity were developed based upon some of the concepts and metrics presented in Tiner (2004).

The *Natural Cover Index* (I_{NC}) (Tiner 2004) is based on the proportion of a watershed that is represented by natural vegetation; it provides information on how much of a watershed is not developed and may be serving as important wildlife habitat.
$I_{NC} = A_{NV} / A_W$,
where $A_{\mathbf{NV}}$ (area in natural vegetation) equals the area of the watershed's land surface in natural vegetation and $A_{\mathbf{W}}$ is the total land surface area of the watershed.

The *River-Stream Corridor Integrity Index* (I_{RSCI}) (Tiner 2004) provides information on the status of vegetated riparian corridors.
$I_{RSCI} = A_{VC} / A_{TC}$,
where $A_{\mathbf{VC}}$ (vegetated river-stream corridor area) is the area of the river-stream corridor that is colonized by natural vegetation and $A_{\mathbf{TC}}$ (total river-stream corridor area) is the total area of the river-stream corridor.

The *Habitat Fragmentation/Road Index* (I_{HF}) (Tiner 2004) attempts to address habitat fragmentation by roads and reflects degradation of water quality, and terrestrial and aquatic ecosystems from associated development.
$I_{HF} = A_R / A_W \times 16$,
where A_R is the area of roads (interstates, state/county and other roads) and A_W is the total land area of the watershed.

The *Imperviousness Index* (I_P) was not used by Tiner 2004 but was added to this analysis to indicate degree of human development. It is based upon the proportion of a watershed that is identified as impervious cover and used the NLCD 2001 impervious dataset. While strongly correlation with the road density (and thereby I_{HF}) it should add information where high density development adds considerably more buildings and non-road pavement.
$I_P = A_P / A_W$,
where A_P equals the area of the watershed's land surface classified as impervious and $A_{\mathbf{W}}$ is the total land surface area of the watershed. Results are shown in Figure 4.

The four indices were use to compute a composite *Index of Terrestrial Habitat Integrity* (I_{THI}). The following formula was used to compute the index:
$I_{THI} = (0.75 * I_{NC}) + (0.25 * I_{RSCI}) – (0.25 * I_{HF}) – (0.25 * I_P)$" (J. Scrivani, Virginia Department of Forestry, unpublished report).

Modified Index of Biotic Integrity (mIBI)
The Modified Index of Biotic Integrity was developed by Virginia Commonwealth University Center for Environmental Studies. The metrics were run for all sixth order hydrologic units for the entire state of Virginia.
"The *mIBI* is computed from six metrics that are used to determine watershed biotic integrity across broad spatial scales.

- Number of intolerant species
- Native species richness

- Number of RTE species
- Number of non-indigenous species
- Number of Critical/Significant species
- Number of Tolerant Species

Each metric has potential values of 1, 3, or 5, for a total possible score of 30. The correlation between the *mIBI* and I_{THI}, while positive as might be expected, is relatively low at r = 0.107. Thus the two indices are both contributing additional information to the prioritization" (DOF 2007).

Approximately 160,000 records were used for the statewide mibi analyses. Data were ranked for the final weighted overlay:

MIBI	RANK
8 - 12	5
12 - 14	4
14 - 16	3
16 - 18	2
18 - 24	1
NODATA	0

Final Weighted Overlay Grid

The Weighted Overlay function in ArcGIS was used to combine the final grids. Each grid was weighted and reclassed to a 5 to 1 rank system. The grids were weighted as:

GRID	% Influence
drinking source	10
riparian	10
slope	10
eco cores	15
mIBI	25
ITHI	30

RESULTS

The final watershed integrity grid values range from a high of 5 to a low of 1.

Maps were produced for the State, Coastal Zone and the Planning District Commissions (PDC) and are included as part of this report. The report is available via FTP and on CD by request and includes:

- Maps
- Metadata
- Personal geodatabase and shapefiles

The data is also available for viewing on the Department of Conservation and Recreation Division of Natural Heritage Land Conservation Data Explorer accessible at www.vaconservedlands.org.

DISCUSSION

Constraints

Development of a statewide model constrains the model to the best available statewide datasets. Input parameters used in the development of the model have temporal and spatial considerations. Additional land use information should be used to assess on the ground condition, as new subdivisions and development are introduced into the landscape daily.

Application

The Watershed Model can be used alone or integrated with other datasets, such as the DNH Conservation Lands database, the VCLNA Vulnerability Model (growth prediction model) or Ecological Model, to identify which resources are most valuable to conservation prioritization or most at risk to growth pressures.

The model may also be used to help guide local land use planners in the development of their comprehensive plans. It is important to look at the landscape as a whole and assess how growth may impact the water resources and where to focus preservation or acquisition efforts.

The VCLNA models serve as part of a larger green infrastructure plan, which aims to model where Virginia's conservation priorities are located to facilitate an integrated approach to planning and development. For information on the Virginia Conservation Lands Needs Assessment and the Green Infrastructure Modeling effort, please visit the VCLNA website at http://www.dcr.virginia.gov/natural_heritage/vclna.shtml.

Future Applications

A separate blue-green integration analysis will be run for the Coastal Zone. This analysis will use the VCU Center for Environmental Studies INSTAR database in place of the mIBI. The INSTAR data are point locations that model stream health based on ecological and aquatic indices.

REFERENCES

Alexander, R. B., Boyer, E. W., Smith, R. A., Schwarz, G. E., and R. B. Moore. 2007. The role of headwater streams in downstream water quality. Journal of the American Water Resources Association 43(1): 41 – 59.

Atasoy, M., Palmquist, R. B., and D. J. Phaneuf. 2006. Estimating the effects of urban residential development on water quality using microdata. Journal of Environmental Management 79: 399 – 408.

Frimpong, E. A., Engel, B. A., and T. P. Simon. 2005. Spatial-scale effects on relative importance of physical health predicators of stream health. Environmental Management 36(6): 899 -917.

Garman, G., Shuart, W., and S. McInich. 2007. Development of Freshwater Nutrient Criteria for Non-wadeable Streams in Virginia: Fish Community Assessment, Phase I. Virginia Commonwealth University Center for Environmental Studies, Richmond, Virginia. <http://www.deq.virginia.gov/wqs/documents/Fish_Nutrient_report1.pdf>. Accessed September 2007.

King, R. S., Baker, M. E., Whigham, D. F., Weller, D. E., Jordan, T. E., Kazyak, P. F., and M. K. Hurd. 2005. Spatial Considerations for linking watershed land cover to ecological indicators in streams. Ecological Applications 15(1): 137 – 153.

Mehaffey, M. H., Nash, M. S., Wade, T. G., Ebert, D. W., Jones, K. B., and A. Rager. 2005. Linking land cover and water quality in New York City's water supply watersheds. Environmental Monitoring and Assessment 107: 29 – 44.

Meyer, J. L., Kaplan, L. A., Newbold, D., Strayer, D. L., Woltemade, C. J., Zedler, J. B., Beilfuss, R., Carpenter, Q., Semlitsch, R., Watzin, M. C., and P. H. Zedler. 2007. Where Rivers are Born: The Scientific Imperative for Defending Small Streams and Wetlands. Sierra Club Foundation.

Roy, A. H., Freeman, B. J., and M. C. Freeman. 2007. Riparian influences on stream assemblage structure in urbanizing streams. Landscape Ecology 22: 385 – 402.

Scrivani, J. 2007. GIS Analysis Methodology. Virginia Department of Forestry, Charlottesville, Virginia. Unpublished Report.

Tiner, R. W. 2004. Remotely-sensed indicators for monitoring the general condition of natural habitat in watersheds: an application for Delaware's Nanticoke River watershed. Ecological Indicators 4: 227 – 243.

Virginia Commonwealth University Center for Environmental Studies. 2006. INSTAR. <http://instar.vcu.edu/stream_watershed.html>. Accessed September 2007.

Weber, T. 2007. Land conservation for water quality benefits in Baltimore County, Maryland. The Conservation Fund, Maryland.

Zielinski, J. 2002. Watershed Vulnerability Analysis. Center for Watershed Protection, Ellicott City, MD. < http://www.cwp.org/Vulnerability_Analysis.pdf>. Accessed 2002.

Figure 1. Watershed Integrity Model Methodology Overview.

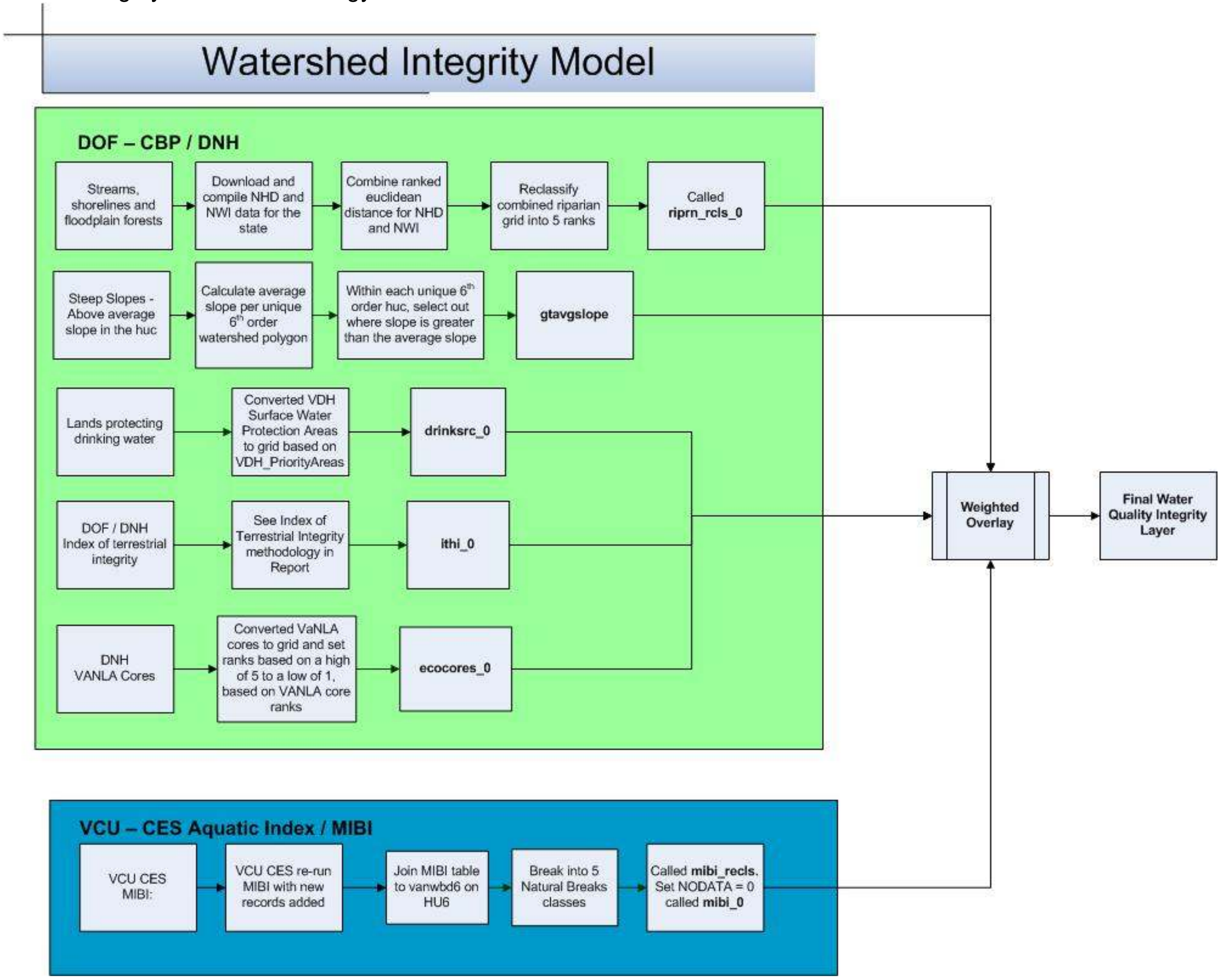


Figure 2. PDC 1 LENOWISCO Watershed Integrity Model.

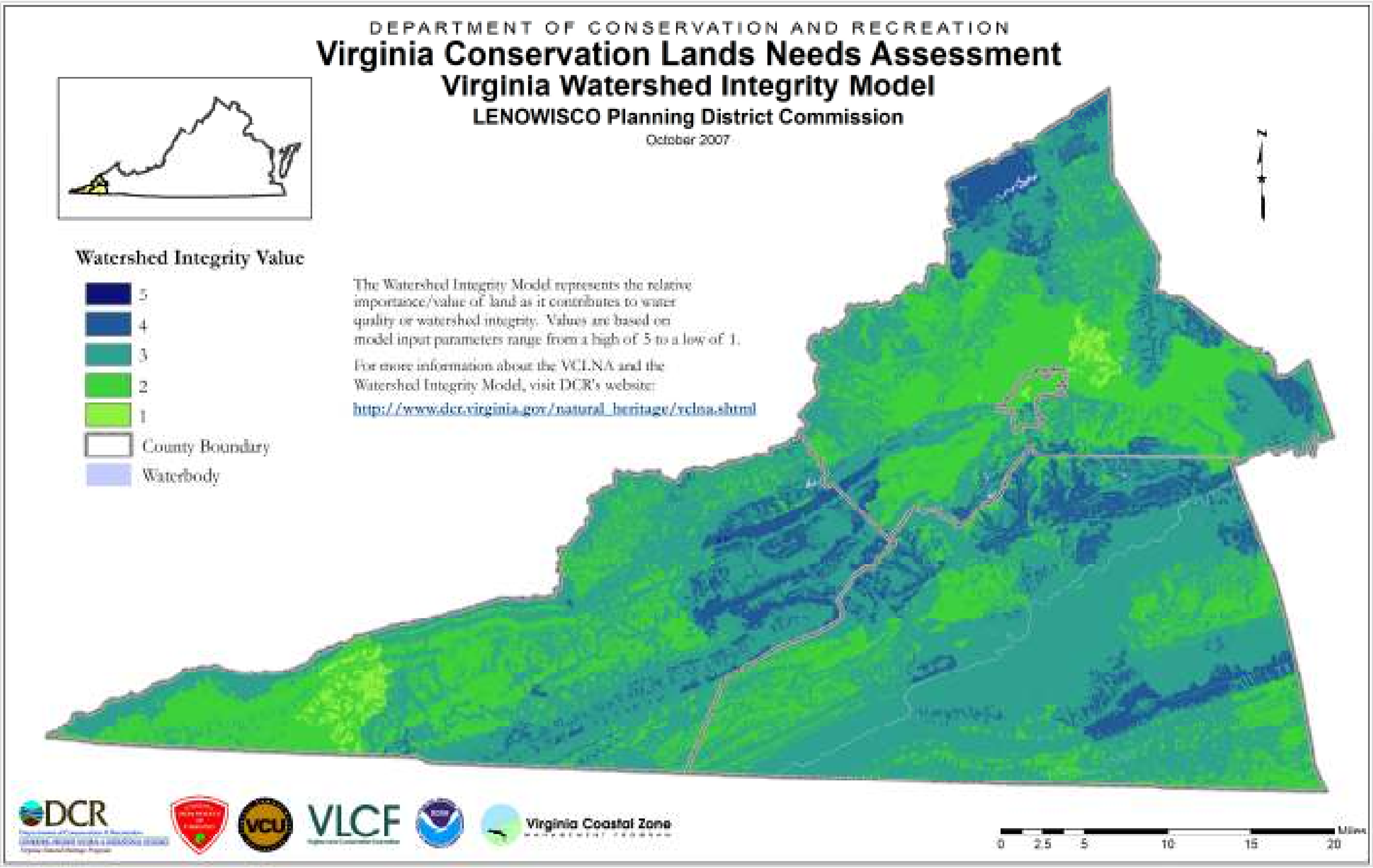


Figure 3. PDC 2 Cumberland Plateau Watershed Integrity Model.

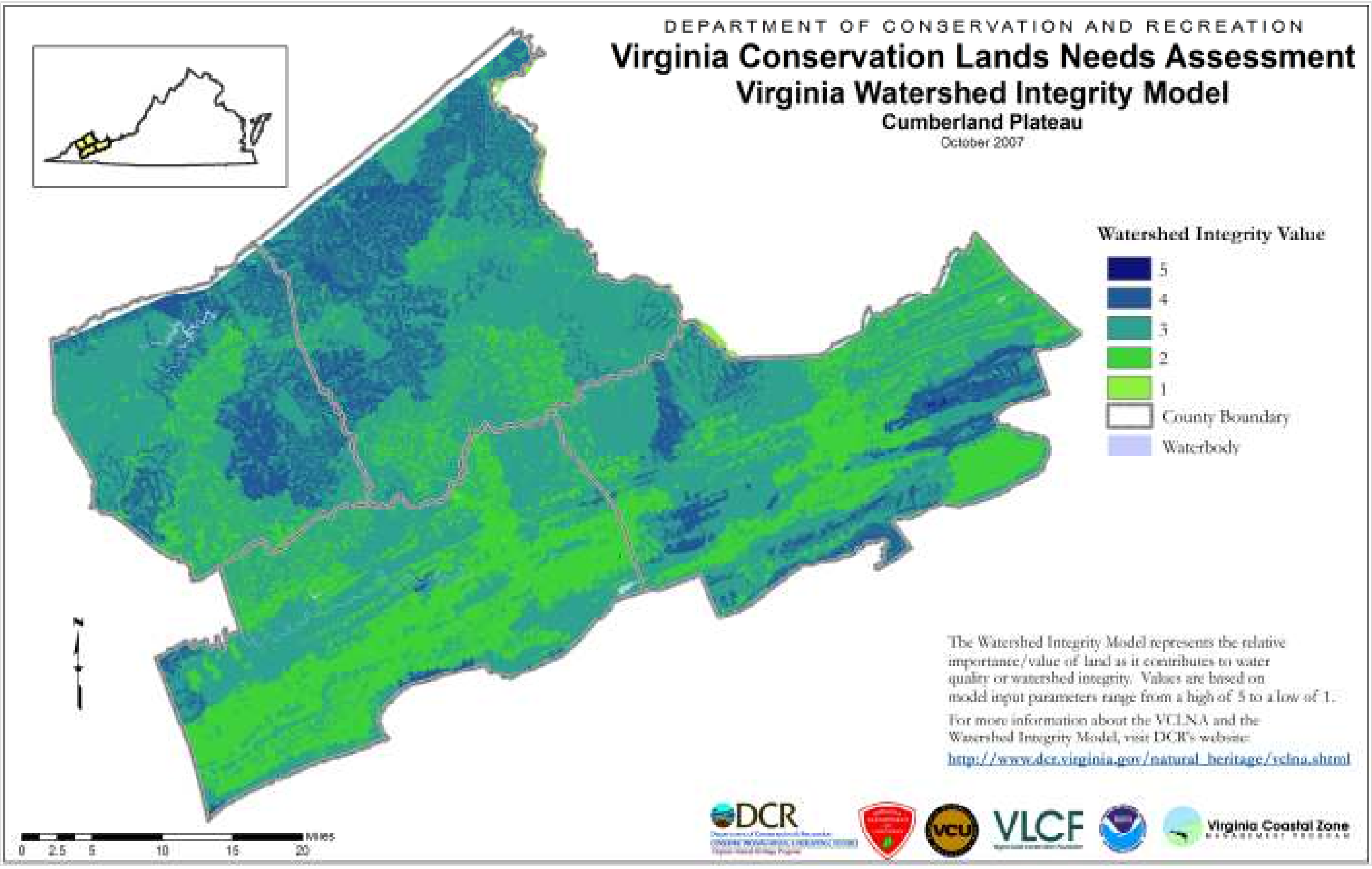


Figure 4. PDC 3 Mount Rogers Watershed Integrity Model.

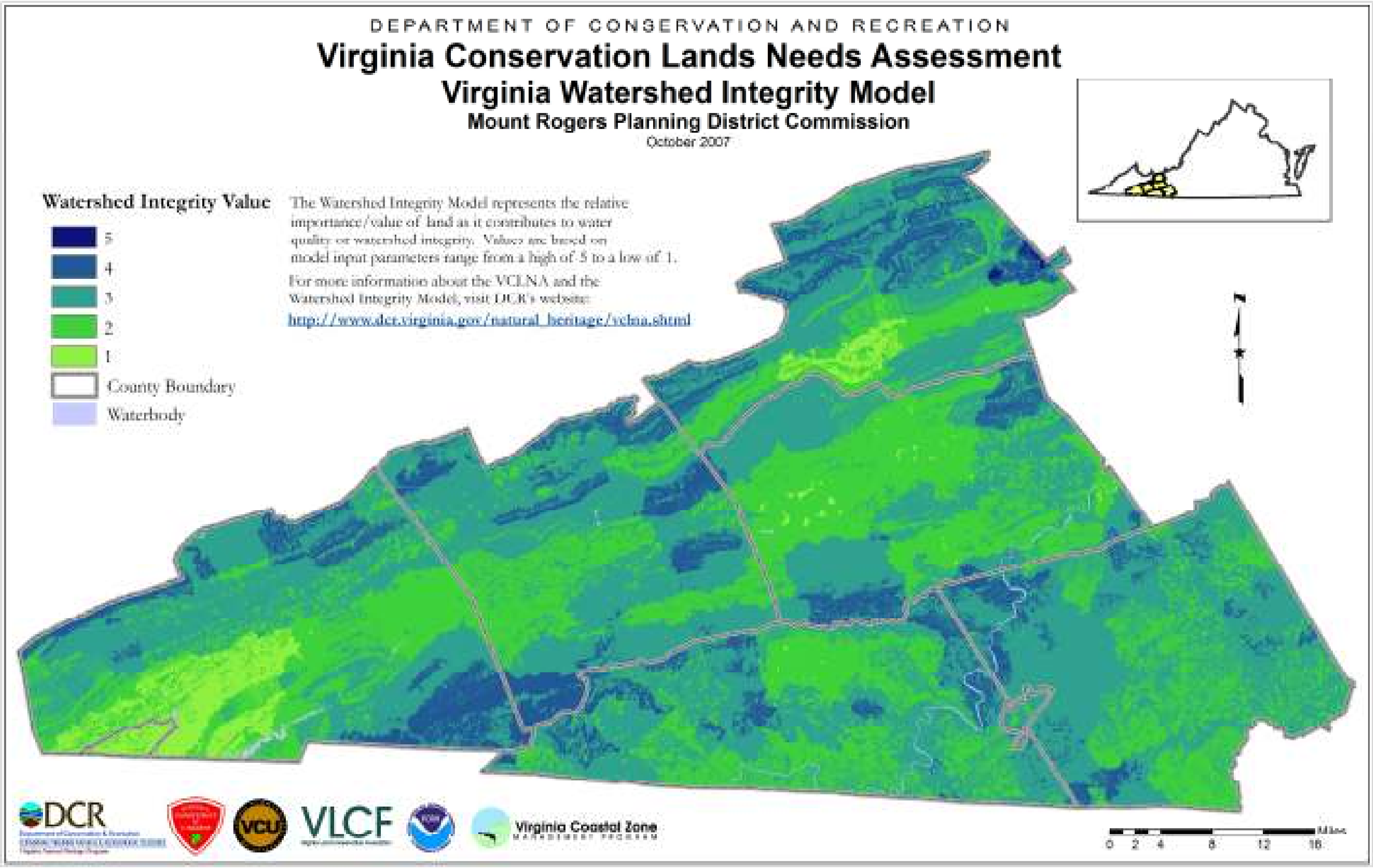


Figure 5. PDC 4 New River Valley Watershed Integrity Model.

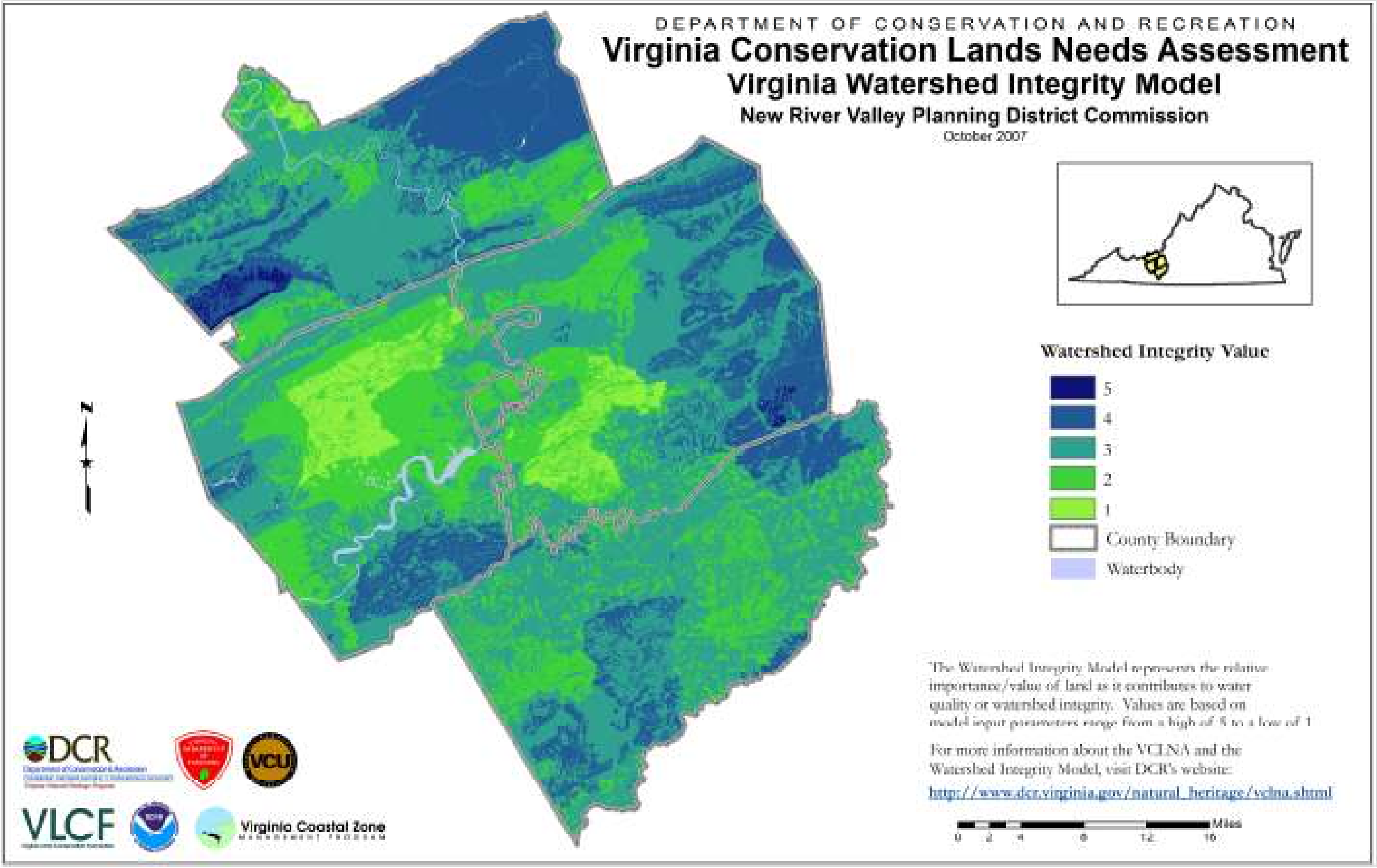


Figure 6. PDC 5 Roanoke Valley-Alleghany Regional Commission Watershed Integrity Model.

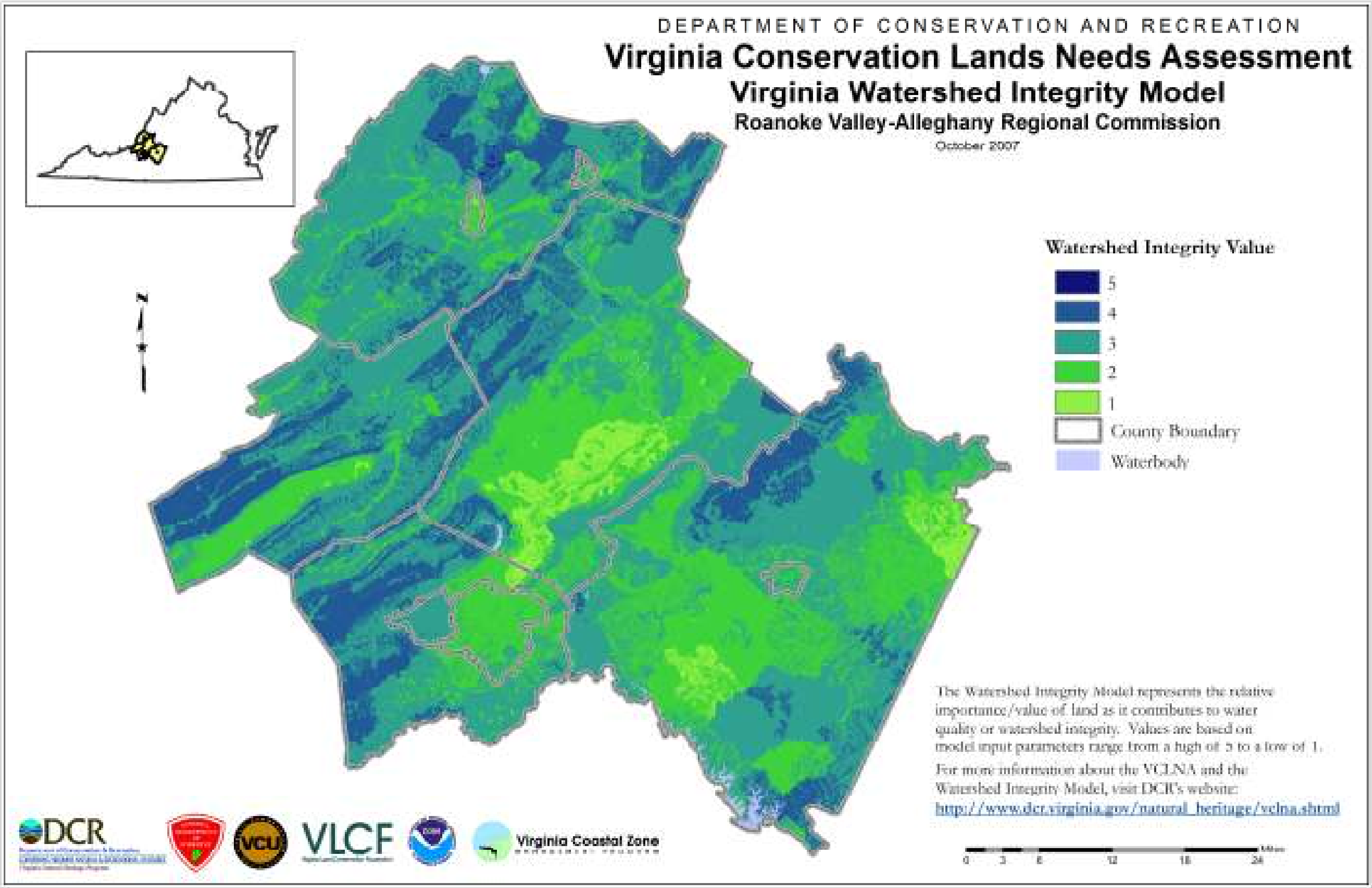


Figure 7. PDC 6 Central Shenandoah Watershed Integrity Model.

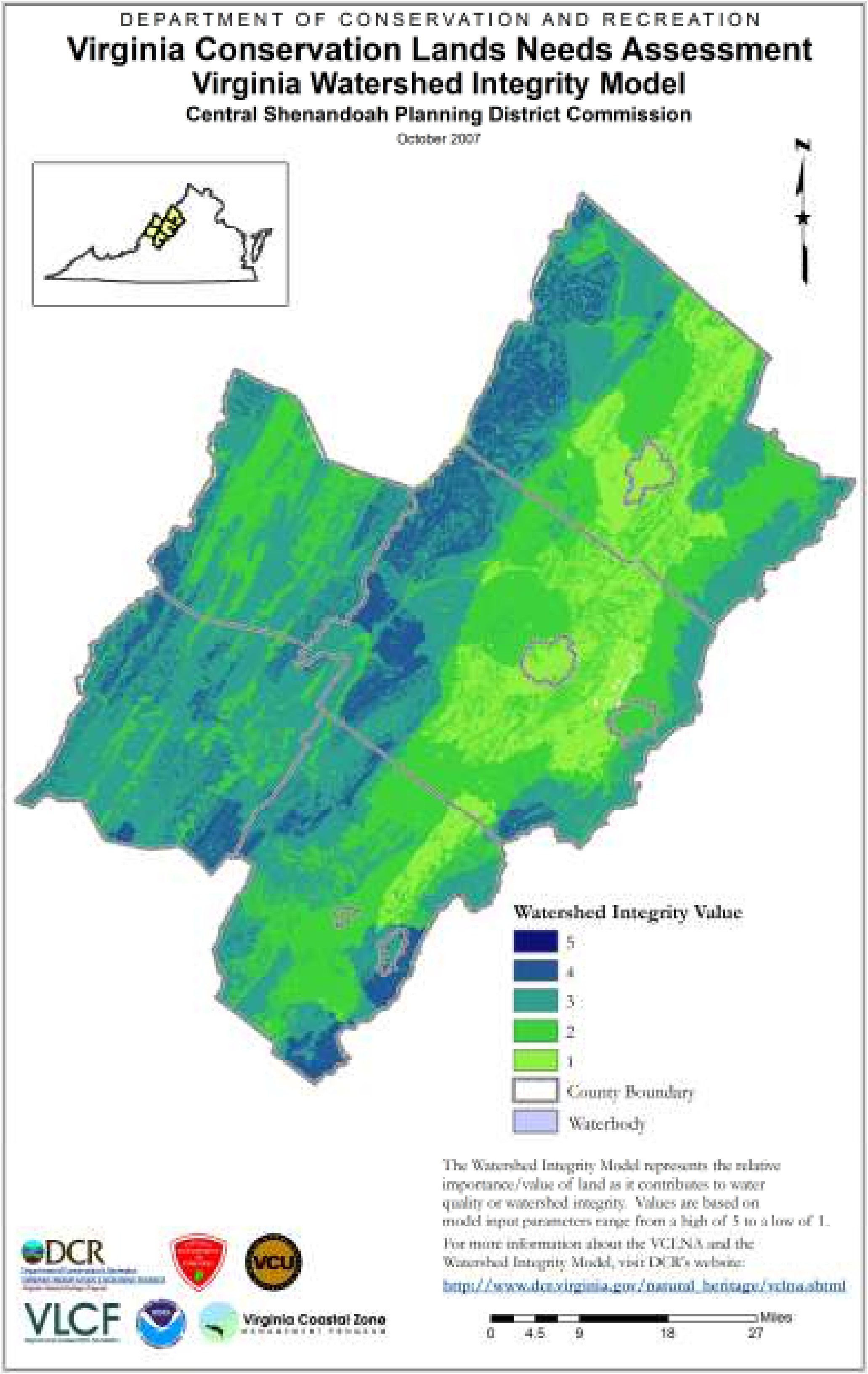


Figure 8. PDC 7 Northern Shenandoah Valley Regional Commission Watershed Integrity Model.

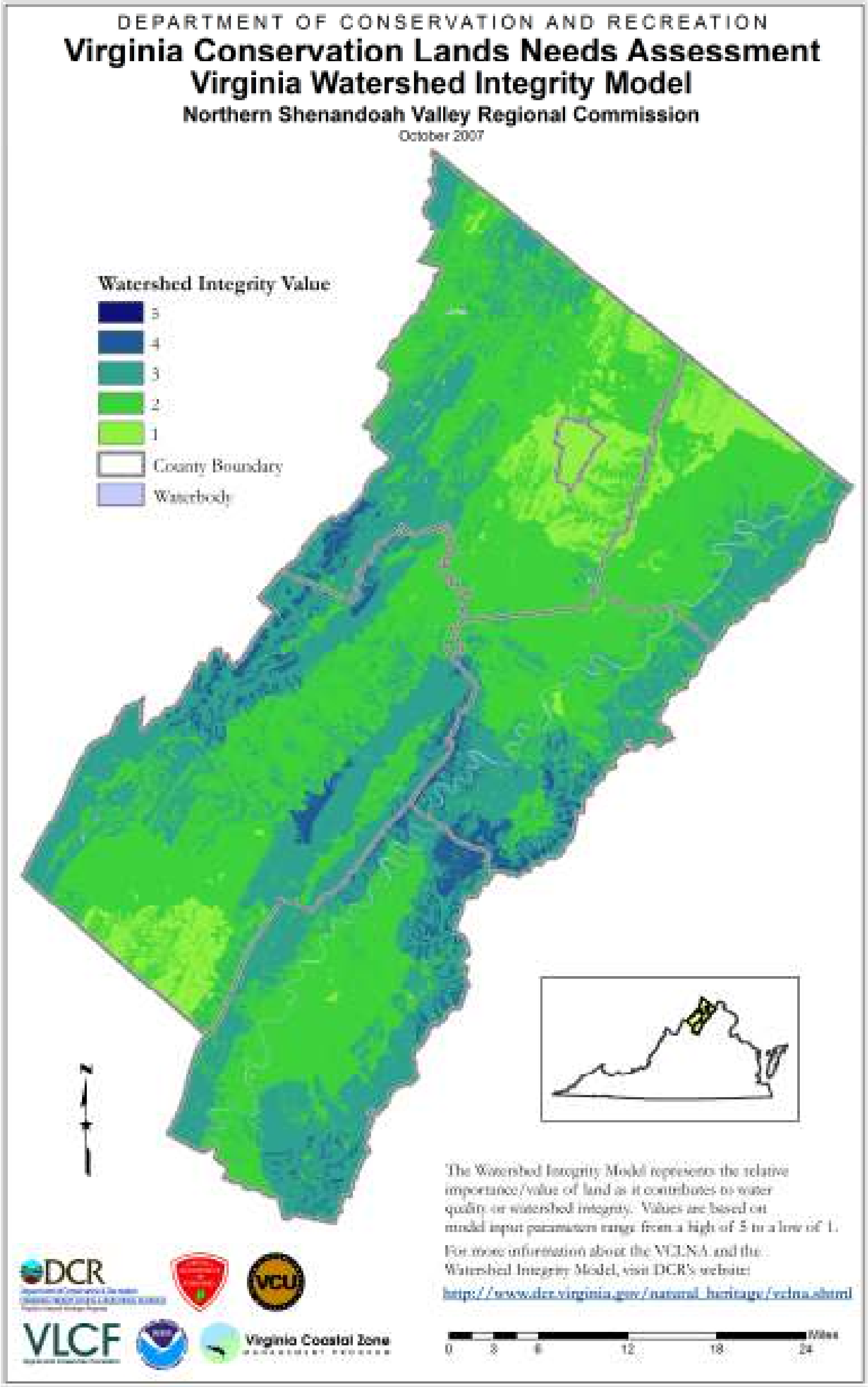


Figure 9. PDC 8 Northern Virginia Regional Commission Watershed Integrity Model

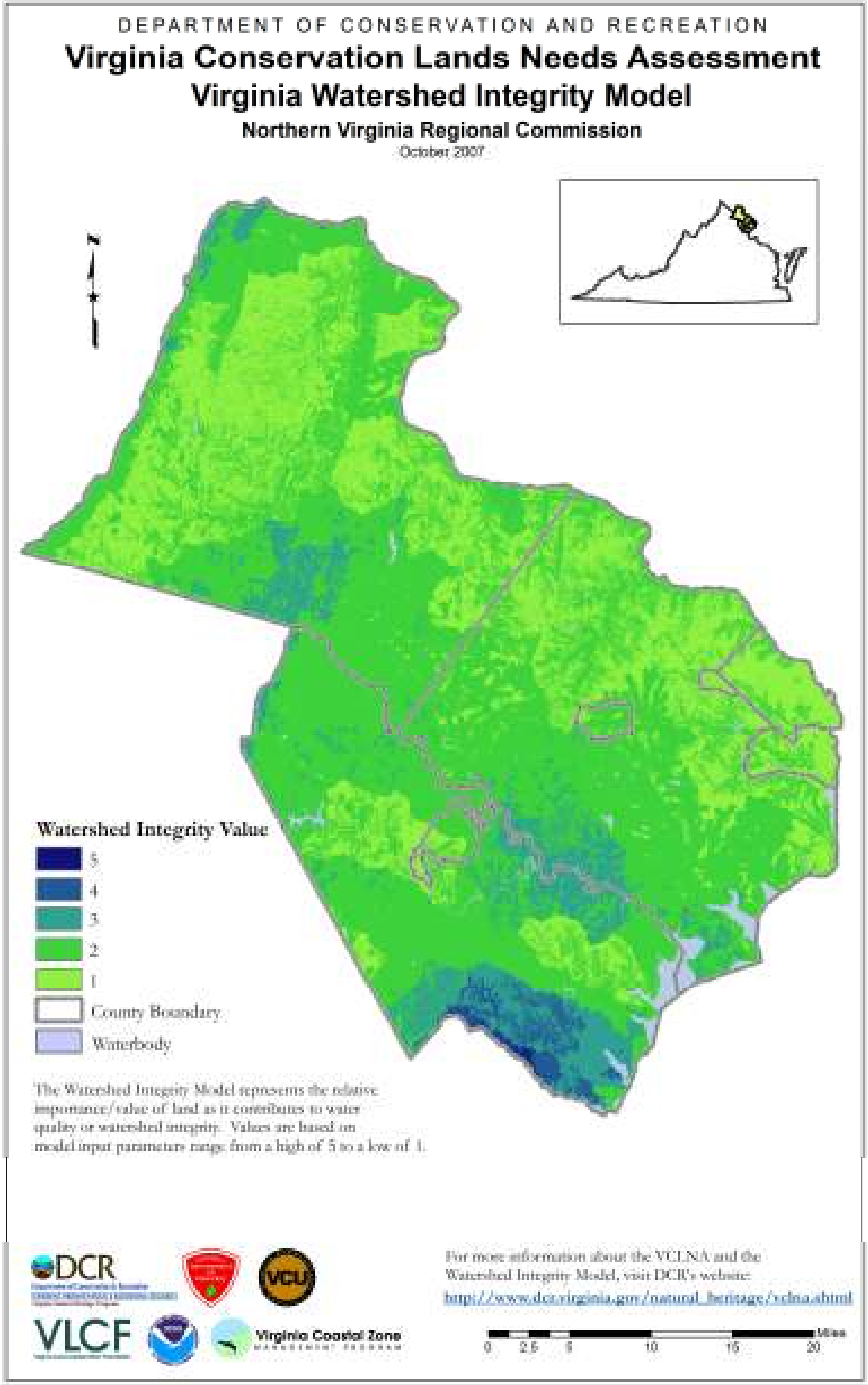


Figure 10. PDC 9 Rappahannock-Rapidan Regional Commission Watershed Integrity Model.

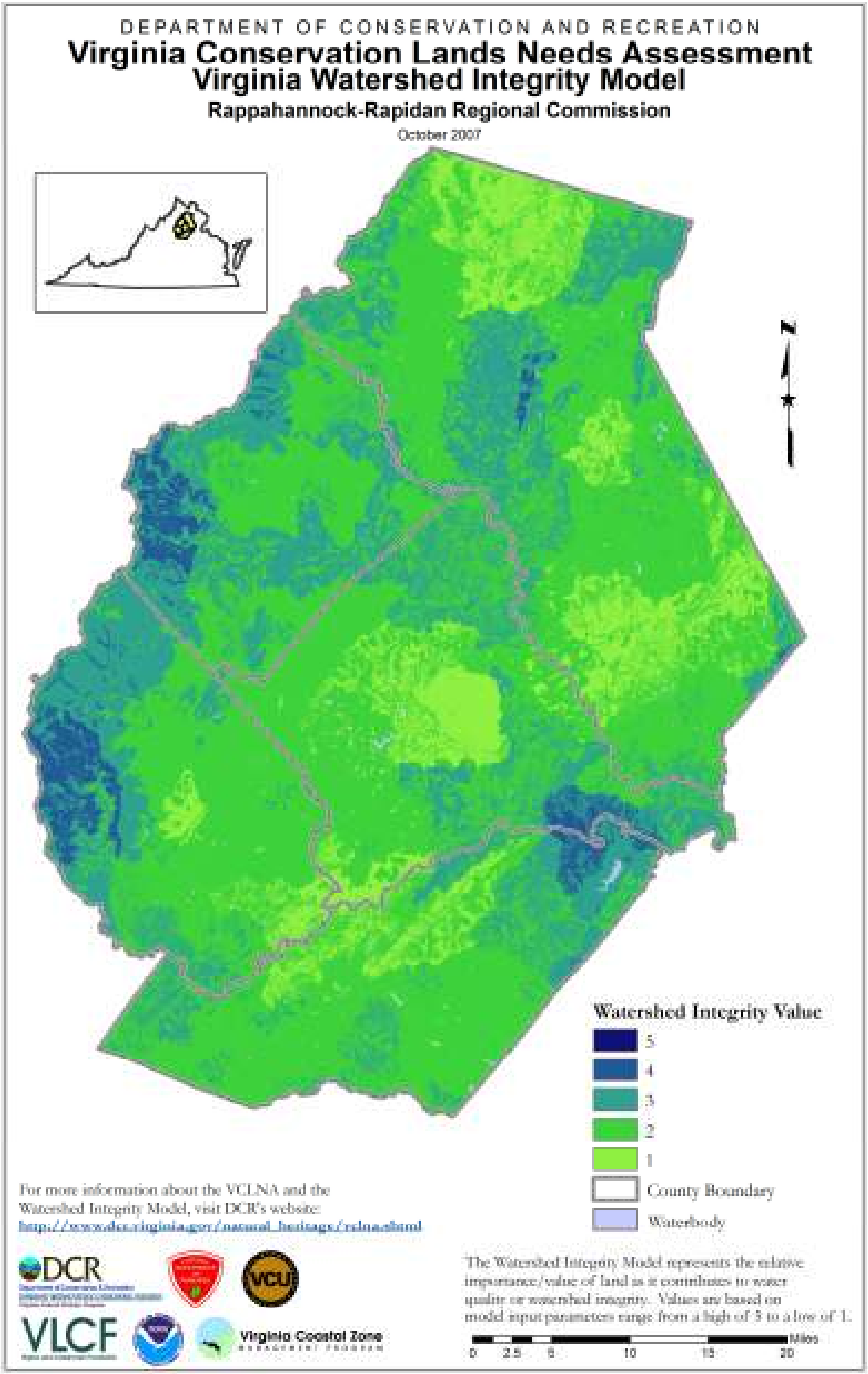


Figure 11. PDC 10 Thomas Jefferson Planning District Commission Watershed Integrity Model.

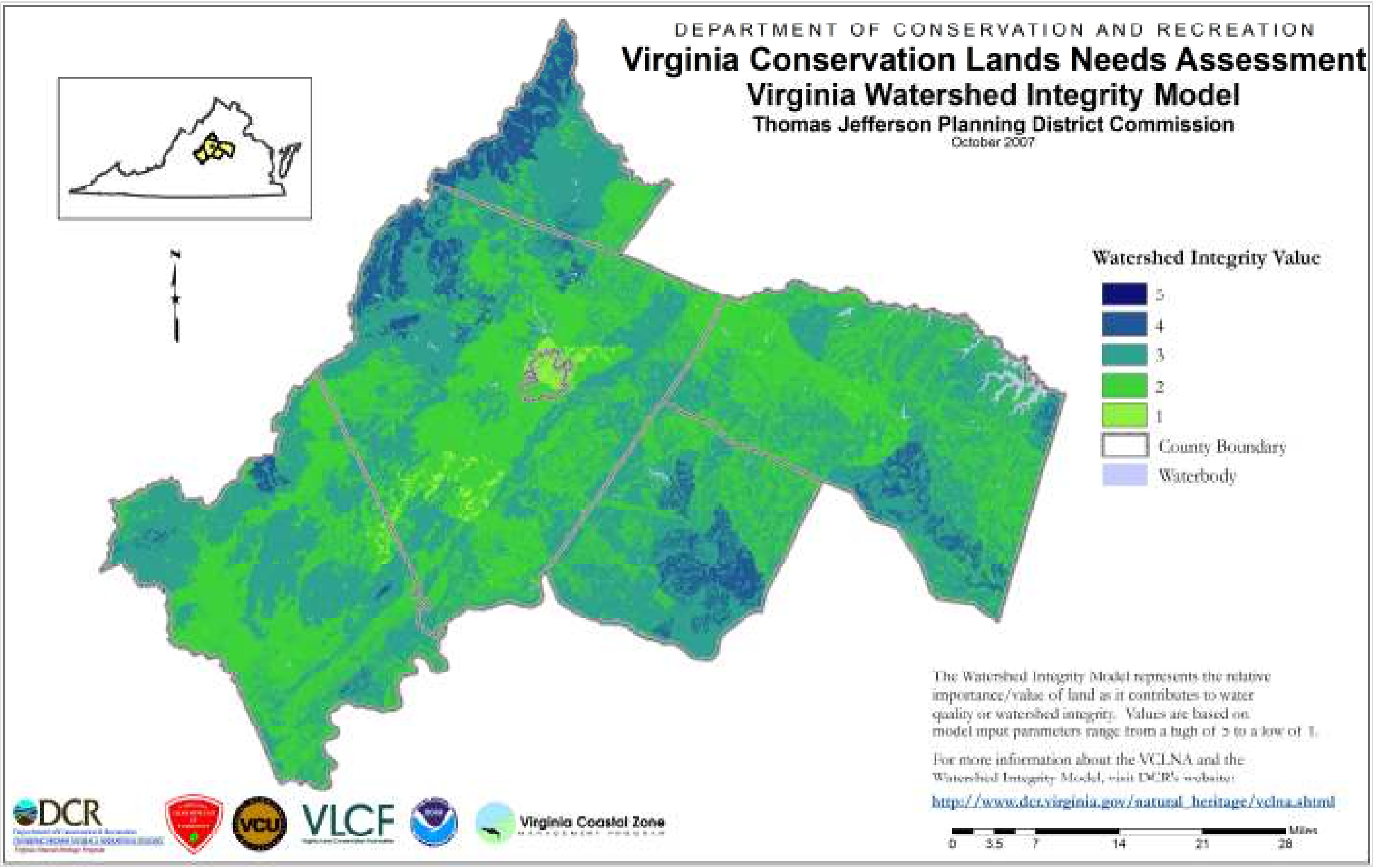


Figure 12. PDC 11 Region 2000 Local Government Council Watershed Integrity Model.

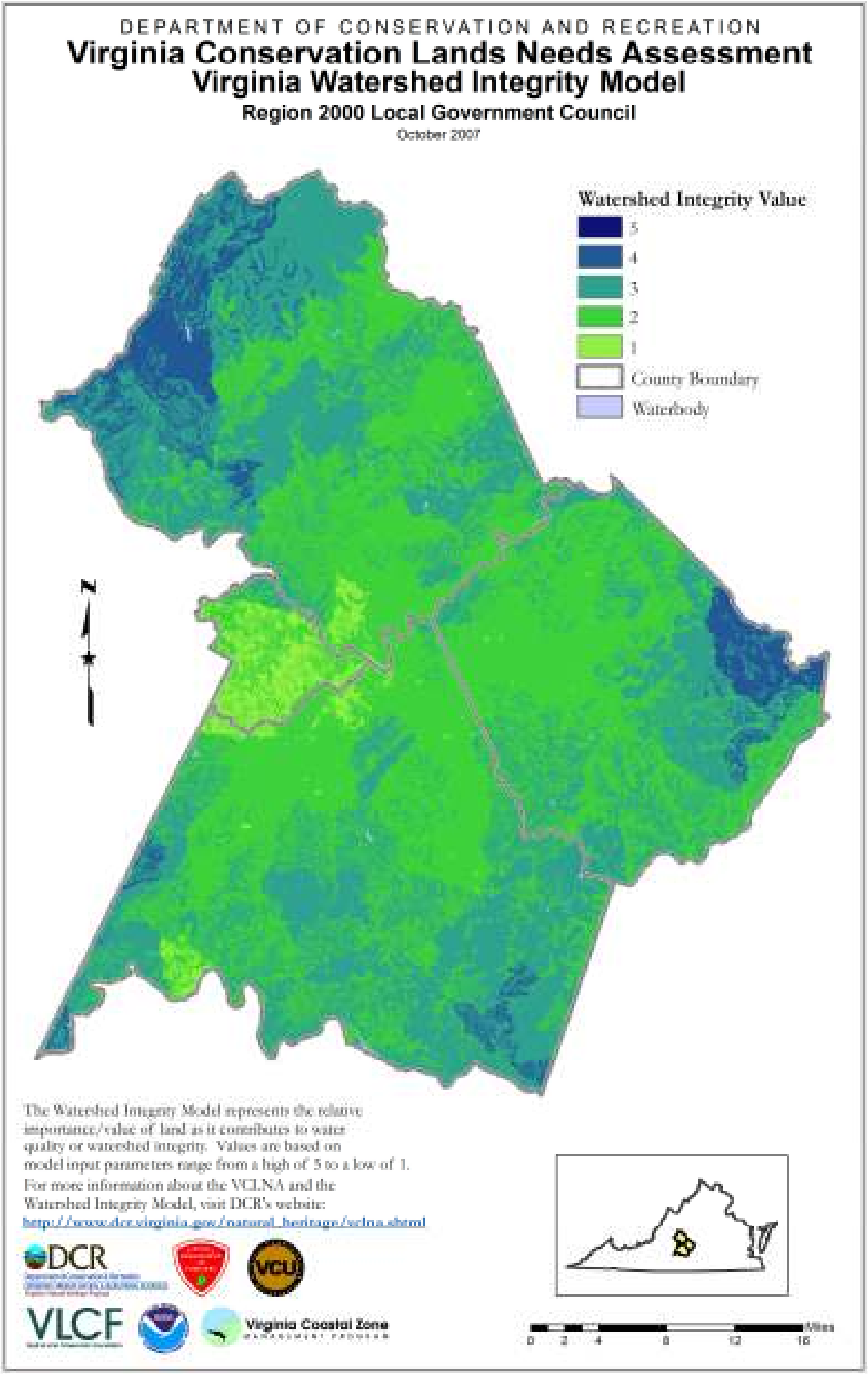


Figure 13. PDC 12 West Piedmont Planning District Commission Watershed Integrity Model.

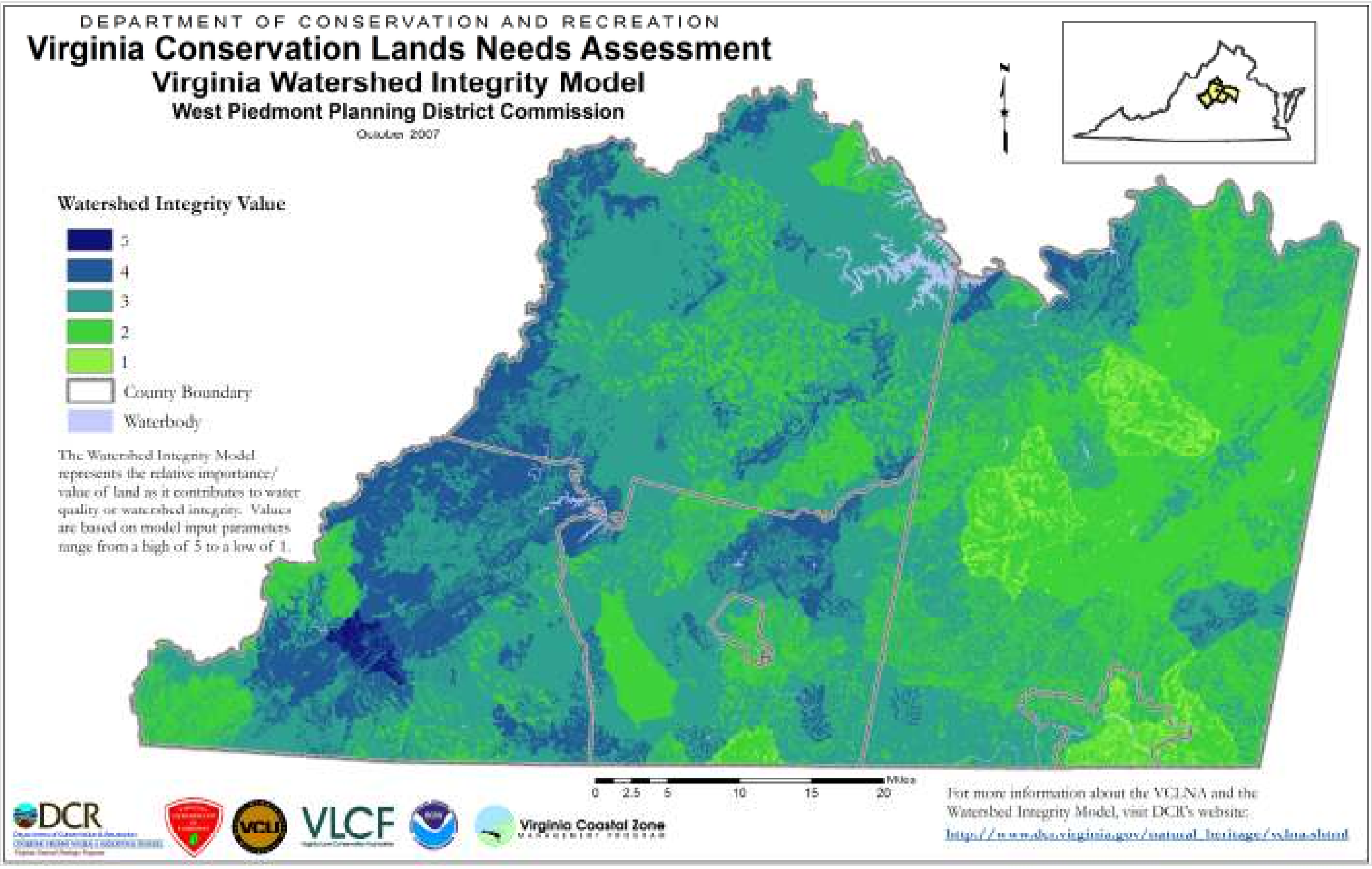


Figure 14. PDC 13 Southside Watershed Integrity Model.

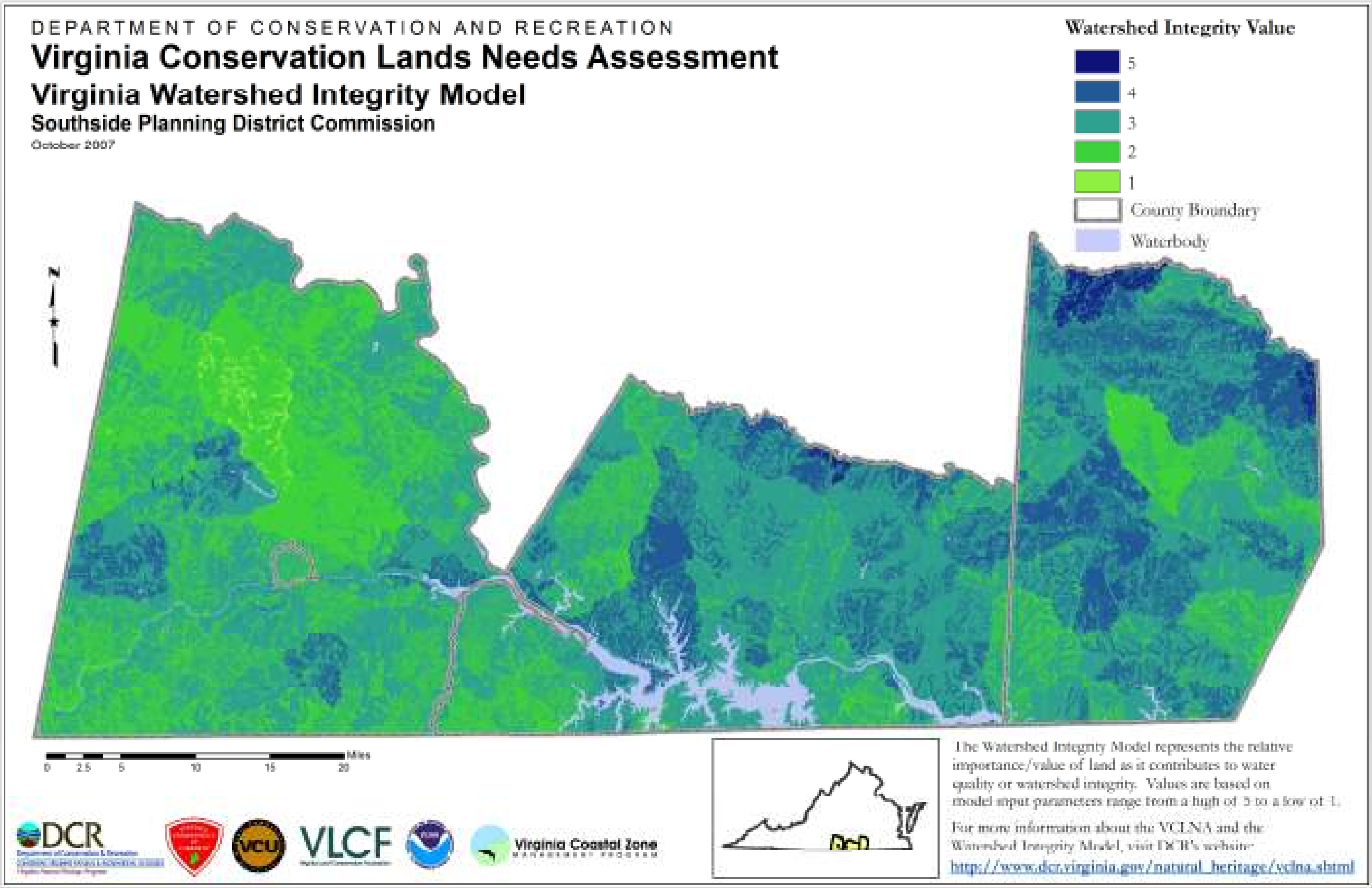


Figure 15. PDC 14 Commonwealth Regional Council Watershed Integrity Model.

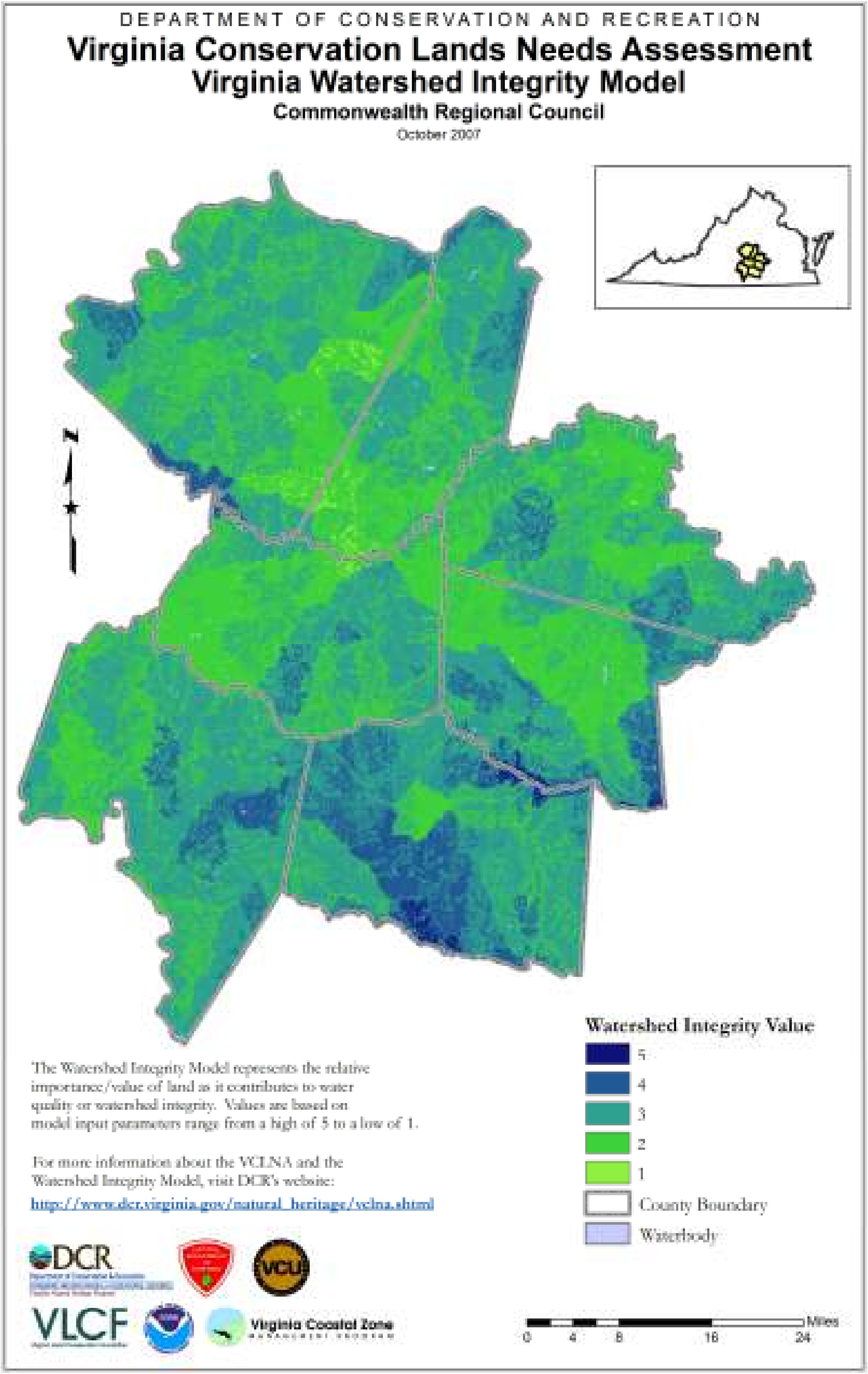


Figure 16. PDC 15 Richmond Regional Watershed Integrity Model.

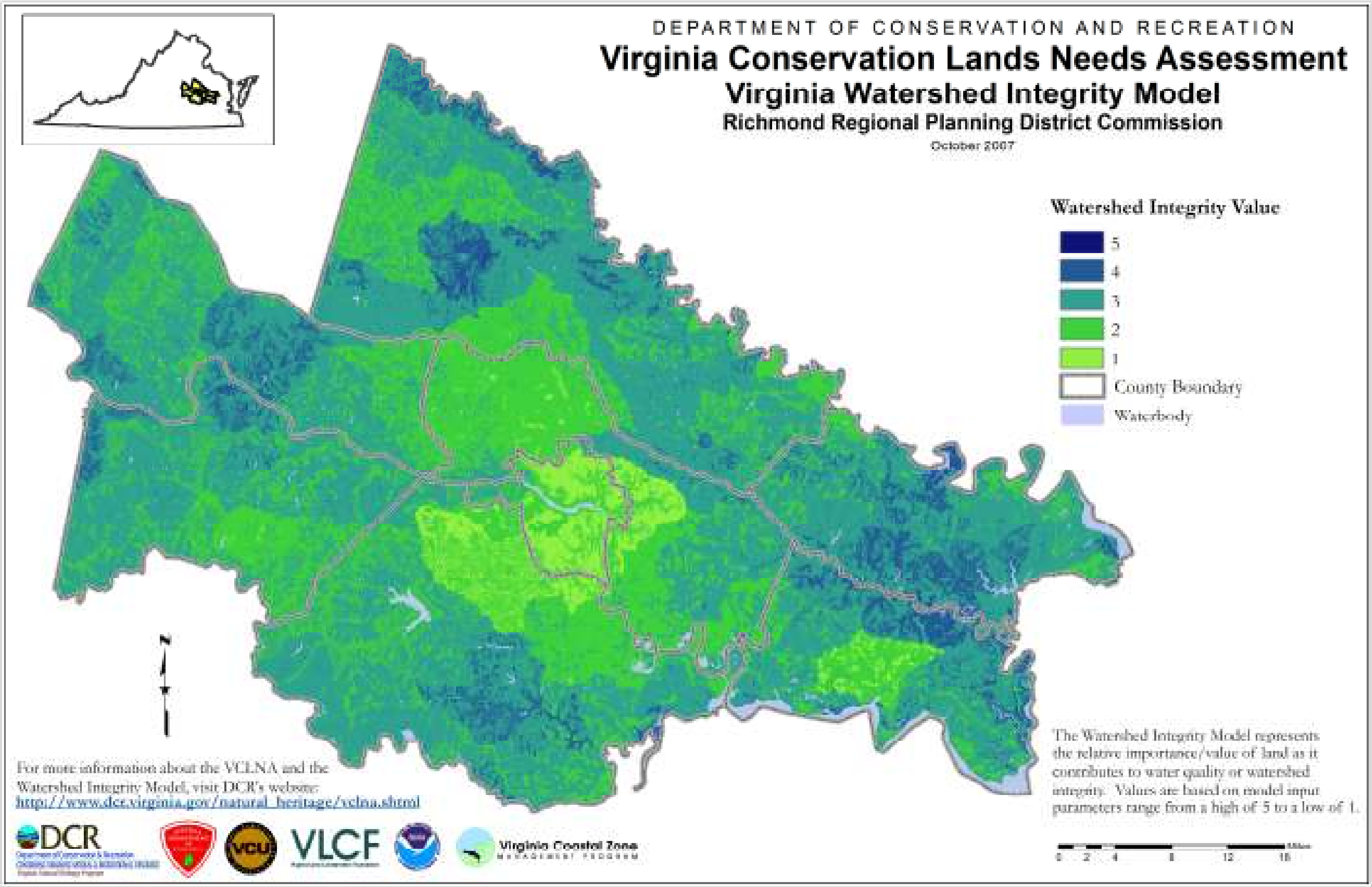


Figure 17. PDC 16 George Washington Regional Commission Watershed Integrity Model.

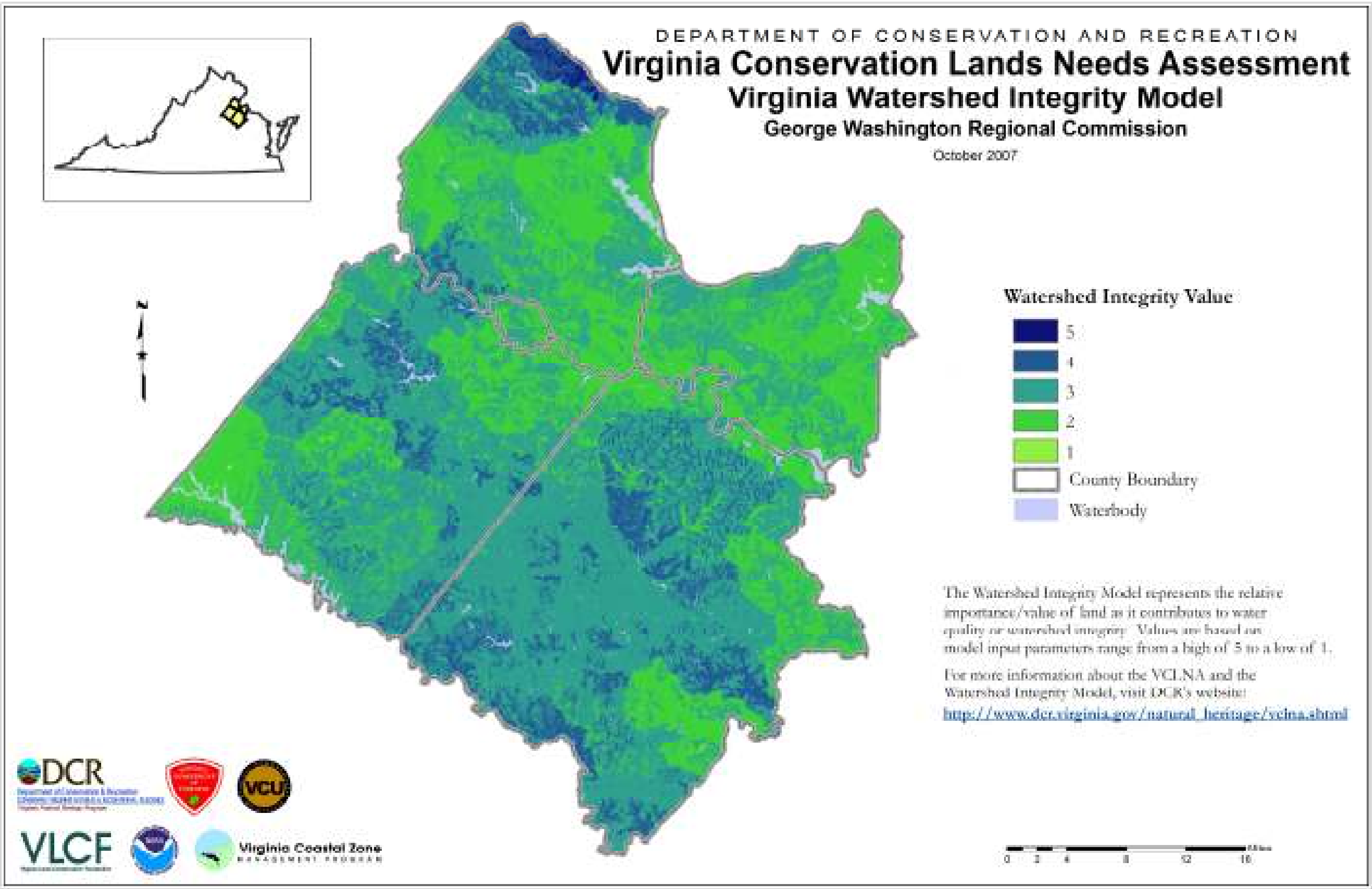


Figure 18. PDC 17 Northern Neck Watershed Integrity Model.

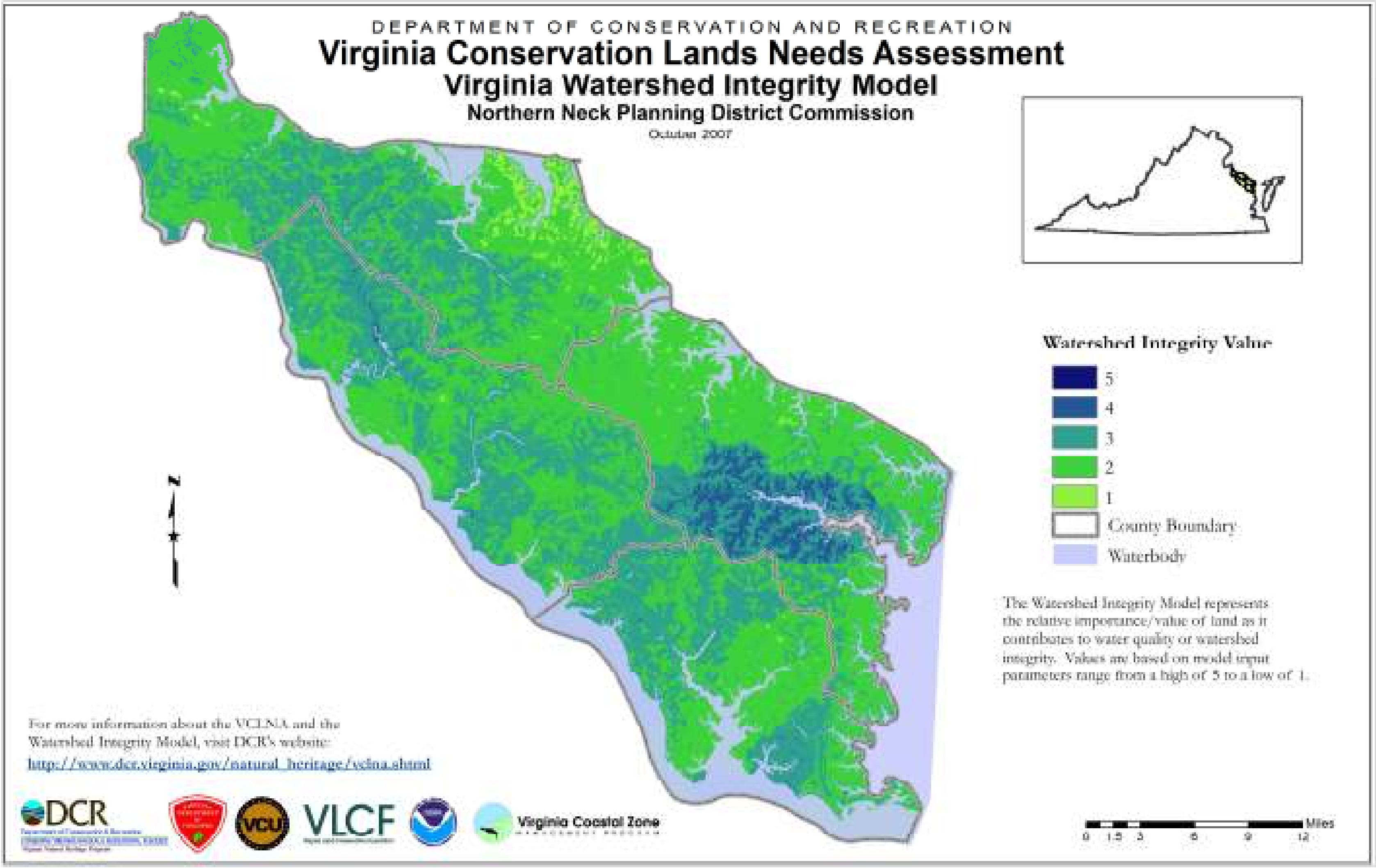


Figure 19. PDC 18 Middle Peninsula Watershed Integrity Model.

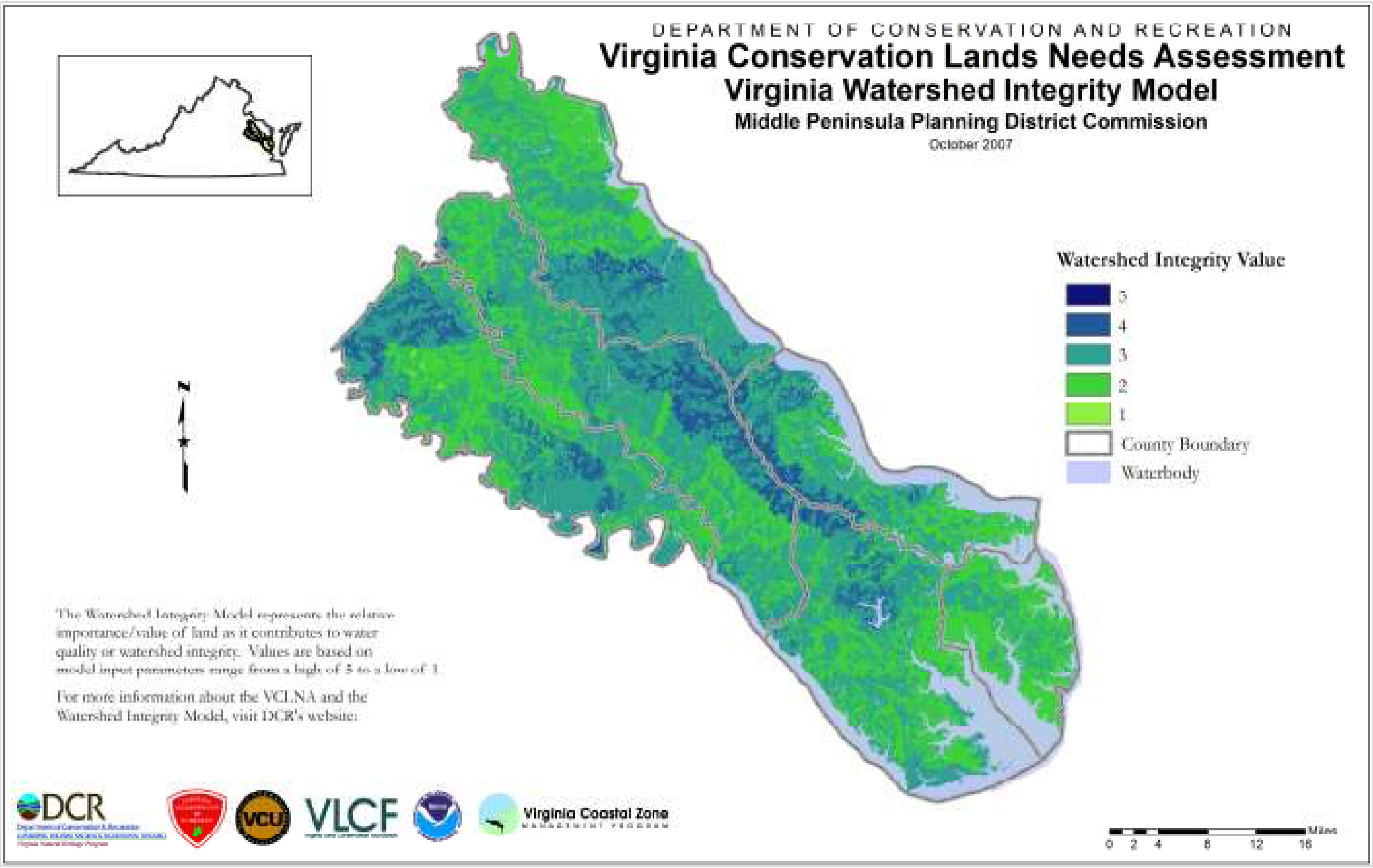


Figure 20. PDC 19 Crater Watershed Integrity Model.

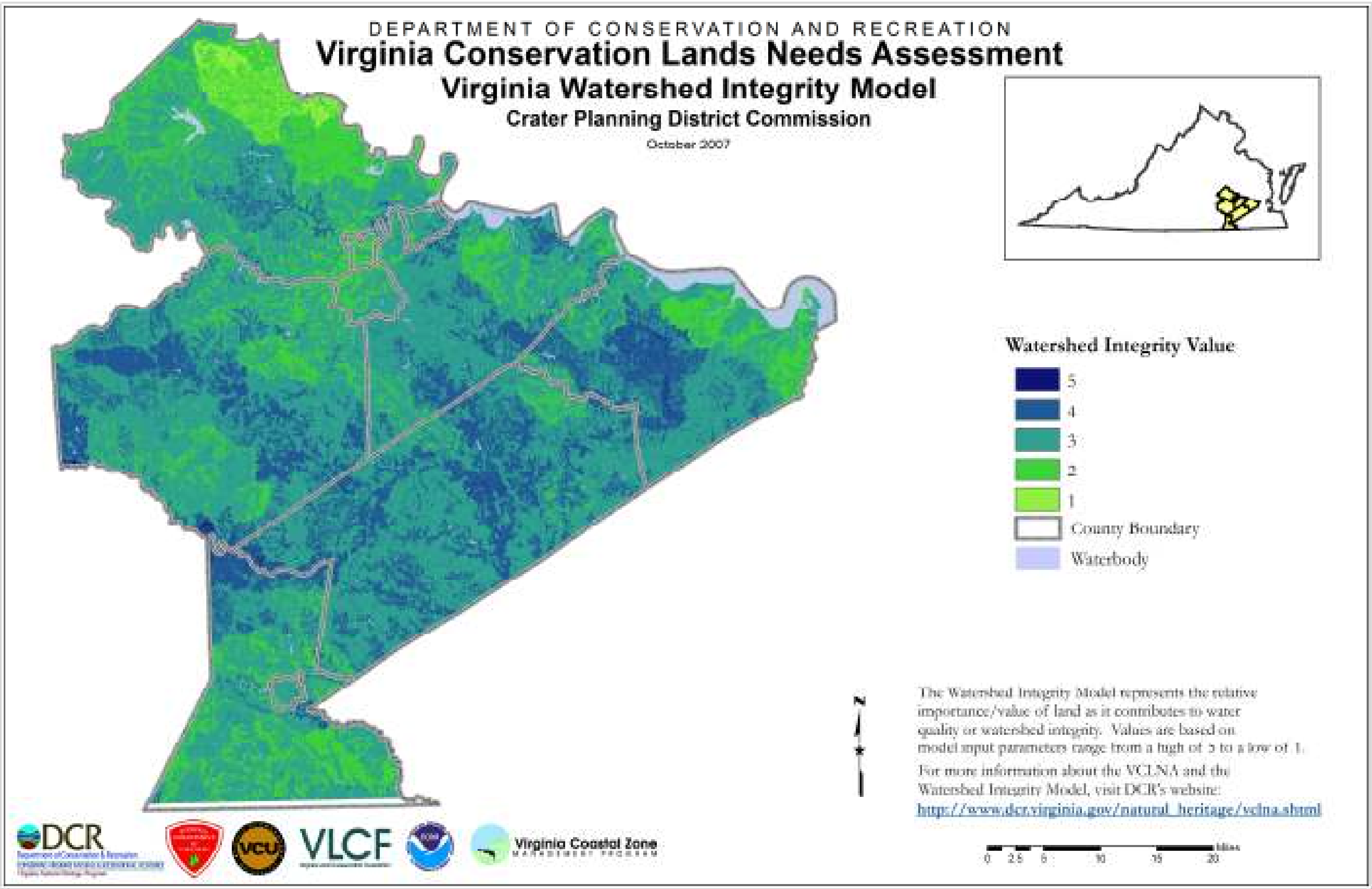


Figure 21. PDC 22 Accomack-Northampton Watershed Integrity Model.

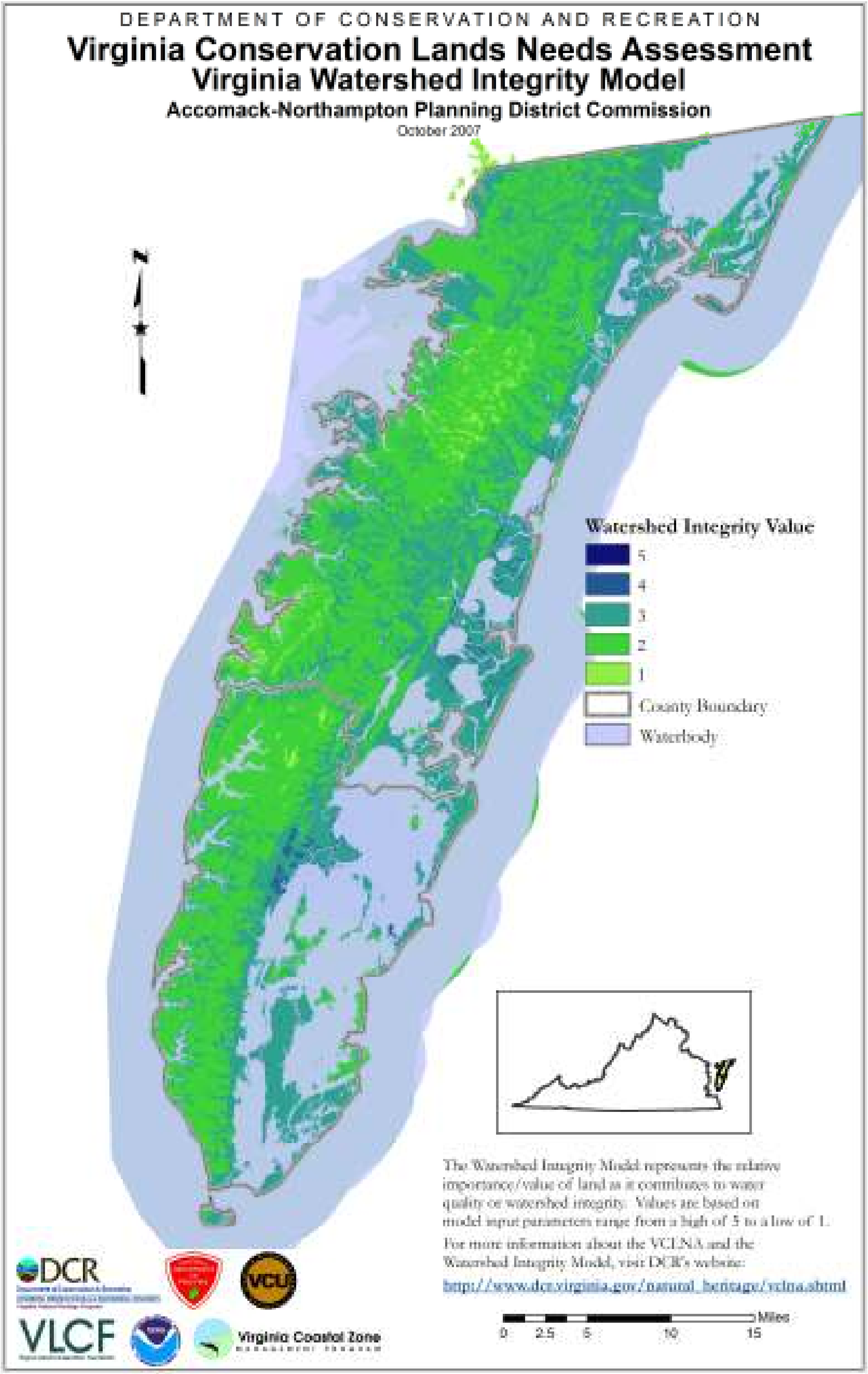


Figure 22. PDC 23 Hampton Roads Watershed Integrity Model.

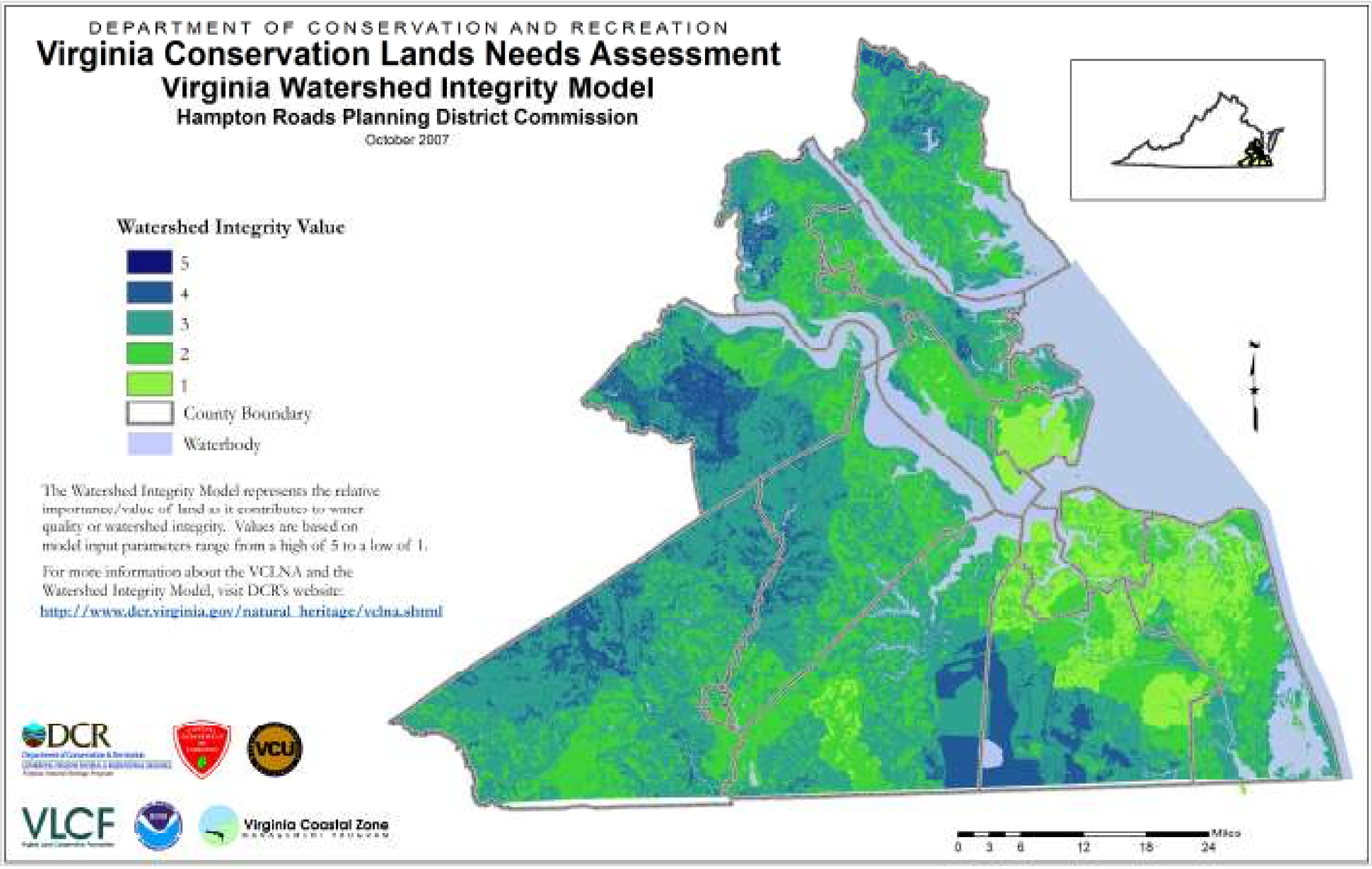


Figure 23. Coastal Zone Watershed Integrity Model.

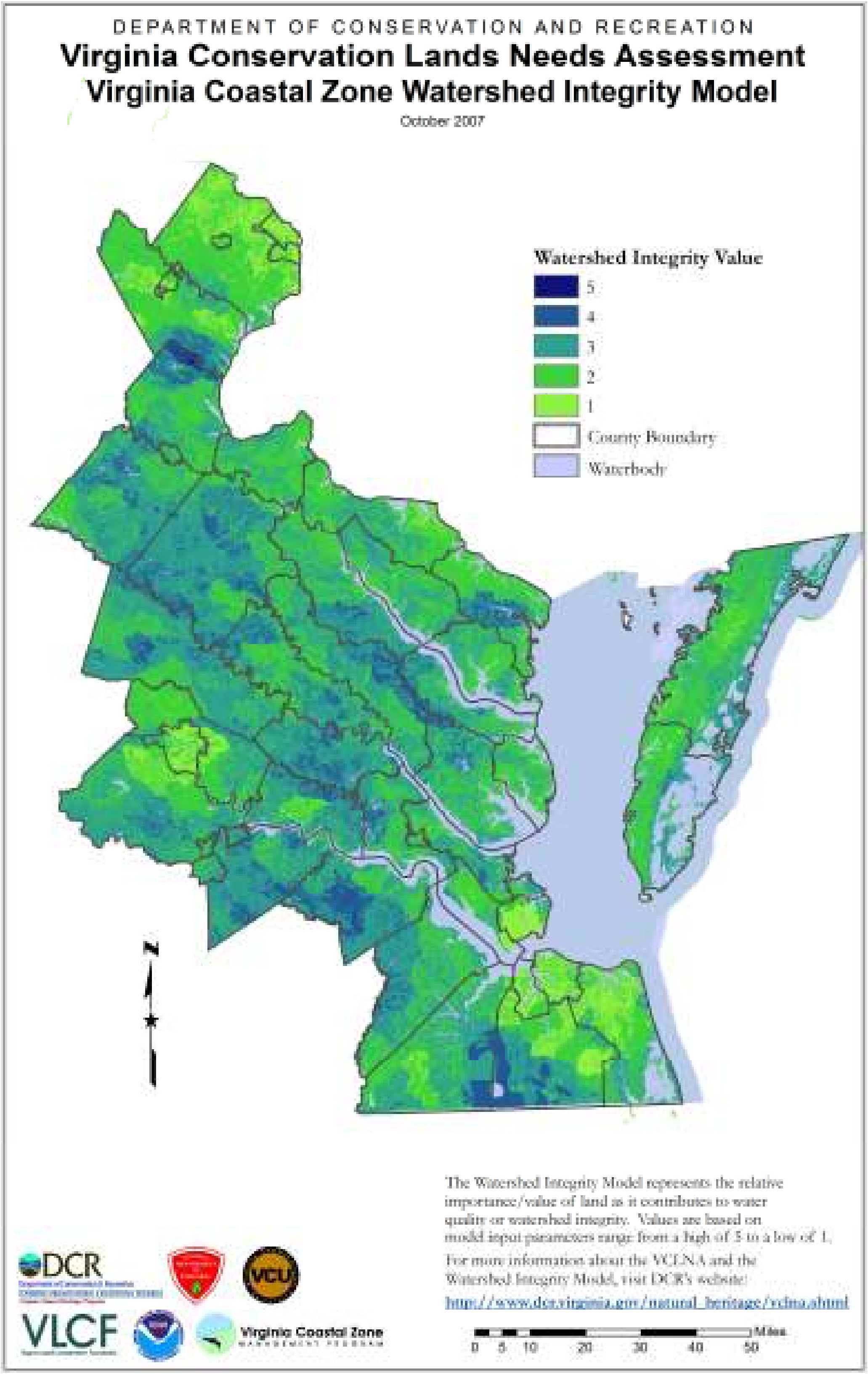


Figure 24. Statewide Watershed Integrity Model.