Condition of Wetlands in the Christina River Watershed

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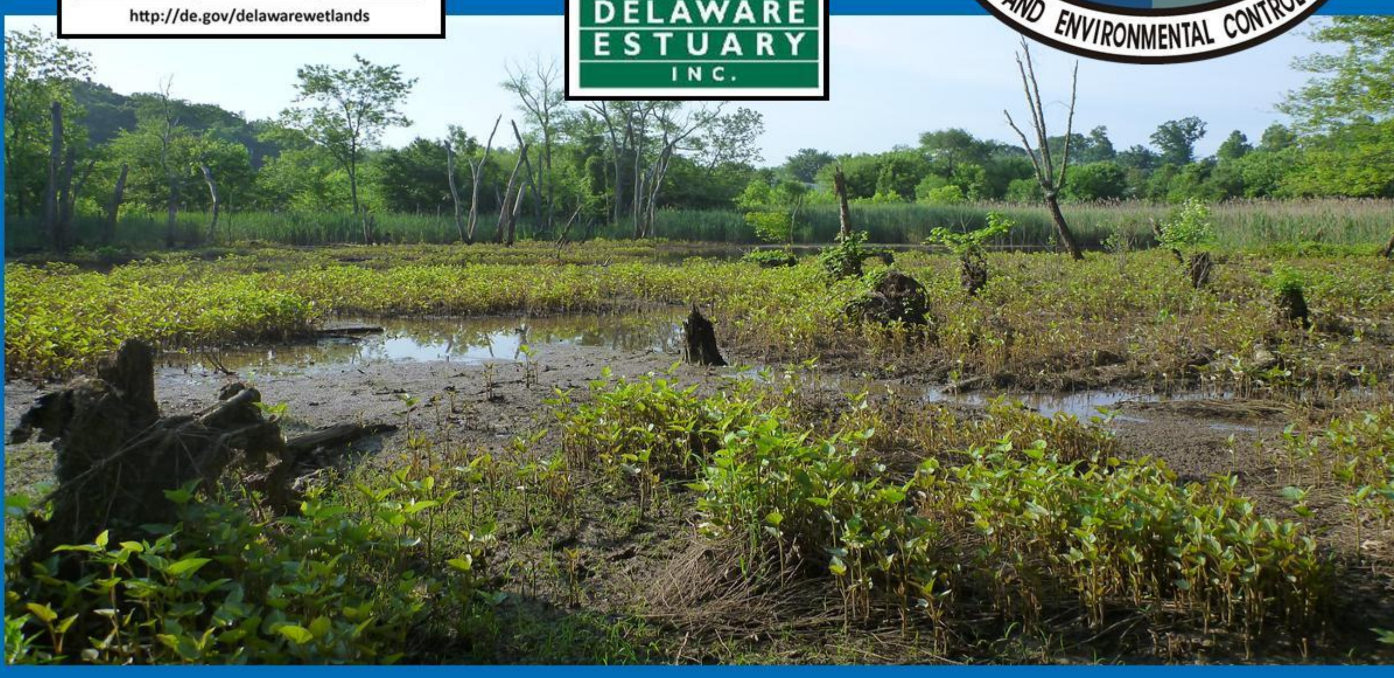

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EXECUTIVE SUMMARY

The Delaware Department of Natural Resources and Environmental Control (DNREC) and the Partnership for the Delaware Estuary (PDE) documented wetland trends and ambient condition of wetland resources in the Christina River Watershed in 2011. The goal of this project was to identify historic and recent changes in wetland acreage, assess the condition of tidal and non-tidal wetlands throughout the watershed, identify prevalent wetland stressors, and make watershed specific management recommendations. We will utilize information on wetland losses and sources of wetland impacts in the Christina Watershed to guide future protection and restoration activities and educate the public on watershed stewardship.

The Christiana River watershed encompasses 78 square miles (20,000 ha) of northern New Castle County, Delaware, northeastern Cecil County, Maryland, and southern Chester County, Pennsylvania. The Christina River drains four additional watersheds from the Piedmont Physiographic Province, which collectively forms the Christina River Basin. The Christina River originates in Landenburg, PA and flows 35 miles (55 km) eastward through Newark, Christiana, and Newport, DE before emptying into the Delaware River through the Port of Wilmington. Approximately 10% of the watershed (5,000 acres) is covered by wetlands, namely non-tidal headwater flats (40%), riverines (23%), depressions (16%), and tidal estuarine marshes (19%; State of Delaware 2007).

We estimated historic and recent wetland losses in the watershed based on historic hydric soil maps and past wetland mapping efforts. The Christina River and its tidal wetlands have been altered significantly since European settlement, including channel modifications and extensive diking for agriculture. As populations grew and heavy industries expanded, many wetlands in the eastern half of the watershed were filled to allow for development. Approximately 46% of the wetlands in the watershed have been filled or otherwise lost, primarily in Wilmington, southern Newark, and along the Interstate 95 corridor. Despite stricter wetland regulations in New Castle County, compared to Kent and Sussex counties, Delaware, approximately 81 acres of wetlands were converted between 1992 and 2007. These wetland losses were largely associated with residential development, road expansions, and disposal of dredged material along the Delaware River.

To assess wetland condition and identify stressors affecting wetland health we conducted rapid assessments at random wetland sites throughout the watershed. Wetland assessments were performed in 30 tidal wetlands using the Mid-Atlantic Tidal Rapid Assessment Method Version 3.0 with scoring adaptations for freshwater habitats, and in 40 non-tidal riverine wetlands, 32 non-tidal flat wetlands, and two non-tidal depression wetlands using the Delaware Rapid Assessment Method Version 6.0. Assessed wetland sites were located on public and private property and randomly selected utilizing a probabilistic sampling design with the assistance of the Environmental Protection Agency's Ecological Monitoring and Assessment Program.

Estuarine wetlands in the Christina River watershed were primarily tidal freshwater marshes dominated by emergent vegetation, which cover almost 1,000 acres of land in total. The buffers surrounding tidal marshes were generally in poor condition, with direct and indirect impacts as a result of human disturbance were found surrounding nearly every wetland sampled. Point source pollution inputs from these developed areas were found in 40% of the wetlands. Shorelines hardened by manmade structures were preventing marsh migration in the majority of these wetlands. Lastly, invasive plant species were pervasive in the watershed and found in a majority of the freshwater tidal marshes.

Non-tidal flat wetlands were typically found in the western half of the watershed near the headwaters, primarily in low-lying forested areas. Of the 2,000 acres of flat wetlands estimated to be in the Christina River watershed, only 14% were found to be in a minimally stressed condition, while 41% of flats were severely stressed. Altered plant communities were found in a majority of flat wetlands, including invasive plant cover and recent forestry activities. Ditching, filling, and disturbed wetland buffers were also common stressors found in non-tidal flat wetlands.

Riverine wetlands were found along the upper reaches of the Christina River, as well as its tributaries, and are vital for flood attenuation and improving surface water quality. Approximately 1,200 acres of non-tidal riverine wetlands were found in the watershed, with only 8% in a nearly undisturbed condition and 40% highly disturbed. Invasive plant species were found in nearly every riverine wetland, with almost half of the wetlands dominated by invasives. Alterations to the stream channel, as either channelization or stream incision, occurred along 60% of riverine wetlands, with another 53% of riverine wetlands partially filled with yard waste or spoil material.

Compared to five watersheds previously assessed in Delaware, wetlands in the Christina River watershed were in considerably worse condition. The Christina River watershed contained the highest proportion of severely stressed wetlands, as well as the lowest proportion of high-condition than any watershed in southern Delaware. A history of intense land manipulation coupled with a dense human populations and development have taken its toll on wetland resources.

Based on the findings of this study we propose seven management recommendations and needs for further data. One, preserve the unique and regionally rare Delmarva Bays remaining in the watershed. Two, incorporate wetland restoration and preservation into community planning and urban revitalization plans. Three, explore options for beneficially re-using dredged sediment for wetland creation and management. Four, encourage living shorelines and other natural methods as an alternative to bulkheads and rip-rap for shoreline stabilization. Five, educate landowners on the benefits of maintaining natural buffers along surface waters and wetlands, and incentivize landowners who preserve extensive buffers. Six, control the extent and spread of the invasive common reed (*Phragmites australis*) through state- and federally-funded programs. Seven, update tidal wetland regulatory maps using current aerial photography and georeferencing tools to aid landowners and regulators.

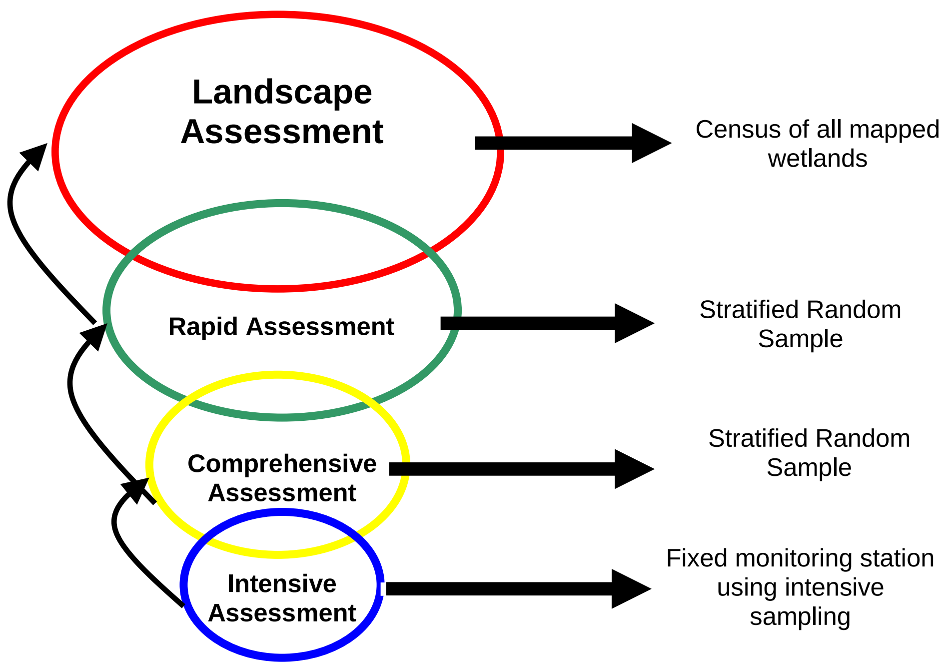
INTRODUCTION

Nontidal riverine wetland in the Christina River Watershed, DE.

The Christina River drains land in Delaware, Maryland, and Pennsylvania and the watershed is covered by various land-use types. Wetlands in the Christiana River Watershed provide many benefits to people, support natural processes, and provide habitats that are an integral part of the landscape. Wetlands act as the transition between terrestrial and aquatic habitats and are one of the most productive ecosystems in the world. Wetlands provide multiple ecosystem services including minimizing flooding from storms by storing excess water, controlling erosion through vegetation stabilization, and improving water quality by removing excess nutrient runoff and pollutants from non-point sources. Sediment loads may increase as a result of agricultural practices, land clearing, construction, and bank erosion. Wetlands throughout the watershed serve as a buffer by removing and retaining suspended sediment from waters before they enter tidal and nontidal waterways. They also have substantial cultural and economic value as a source of recreation (e.g. hunting, fishing, birding) and livelihood (e.g. fishing, crabbing, fur-bearer trapping). Tidal wetlands are biologically rich habitats and are a critical resource for migrating shorebirds and wintering waterfowl, and serve as nurseries for commercial fish and shellfish species. Freshwater wetlands process and funnel ground and surface waters into our waterways, and provide wildlife and plant habitat for a wide array of species. Available data suggest that these wetlands continue to be lost and threatened by continued development and conversion, degradation, sea level rise, sudden marsh dieback and a host of other factors (Partnership for the Delaware Estuary 2012). From 1996-2006, the estimated loss of wetlands across the Delaware Estuary was 6568 acres (3%);(Partnership for the Delaware Estuary 2012).

Non-tidal flat wetland in the Christina River Watershed.

Wetlands have a rich history across the region and their aesthetics have become a symbol of the Mid-Atlantic Coast. The State of Delaware remains committed to improving wetlands through protection and restoration efforts, education, and effective planning to ensure that wetlands will continue to provide these services to the citizens of Delaware (DNREC 2008). In addition to assessing changes in wetland acreage over time, monitoring wetland condition and functional capacity is necessary to guide management and protection efforts. The Delaware Department of Natural Resources and Environmental Control (DNREC) has developed a wetland assessment and monitoring program to evaluate the health of wetlands. DNREC is also part of the Mid-Atlantic Coastal Wetlands Assessment (MACWA) program, a larger collaborative effort with the Partnership for the Delaware Estuary (PDE), Barnegat Bay Partnership, and Drexel University, to study wetland health throughout the Delaware Estuary. Evaluating wetland health, or condition, and documenting the stressors that are degrading wetlands and preventing them from working at their full potential on a watershed scale provides useful information that watershed organizations, state planning and regulatory agencies, and other stakeholders can use to improve wetland restoration and protection efforts. Protection efforts through acquisition or easements can be directed towards wetland types in good condition, allowing restoration efforts to target altered and degraded wetland types to increase functions and services. Wetland assessment information identifies specific stressors that are impacting wetlands, and can direct restoration projects and set priorities.



The EPA's multi-tiered approach to evaluating wetlands.

DNREC's Wetland Monitoring and Assessment Program and PDE have been developing scientifically robust methods using an EPA approved 4-tiered approach to evaluate and monitor wetlands across the Mid-Atlantic region: examining wetlands from the landscape level to site-specific studies. Three of these four tiers consist of active wetland monitoring—rapid assessment methods (Tier 2), comprehensive assessment methods (Tier 3), and intensive monitoring (Tier 4).

DNREC and its partners have developed, and continue to refine, scientifically valid methods to assess the condition of wetlands on a watershed scale. These methods are used to generate an overall evaluation of the ambient condition of wetlands in a watershed, as well as to identify common stressors by wetland type. In this report, we review the changes in wetland acreage, highlight potential changes in wetland function, summarize the condition of tidal and nontidal wetlands, identify common stressors impacting wetlands, and provide recommendations for improving the wetlands of the Christina River watershed.

Watershed Overview

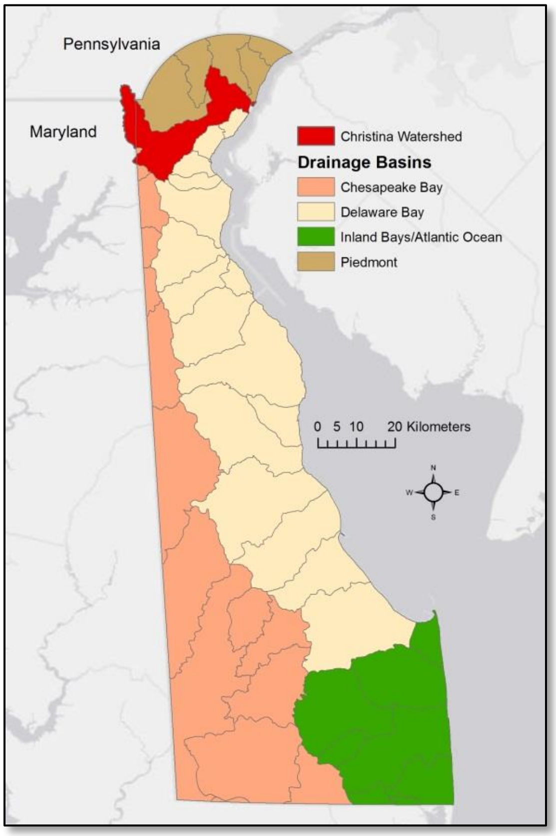


Figure 1. Location of the Christina River Watershed and the major basins of Delaware. Watersheds at the Hydrologic Unit Code 10 scale are outlined in gray.

The Christina River watershed is primarily located in New Castle County, Delaware with the upper headwater reaches extending into northeastern Cecil County, Maryland and southern Chester County, Pennsylvania (Figure 1). The Christina River watershed is approximately 78 square miles (20,000 ha) in size and is primarily urban and suburban land-use with isolated areas of forest and agriculture. The Christina River originates in Landenburg, PA and flows 35 miles (55 km) eastward through Newark, Christiana, and Newport, DE before emptying into the Delaware River through the Port of Wilmington. In addition to the main branch of the Christina River, the watershed also includes the Muddy Run and Little Mill Creek subwatersheds.

The Christina River watershed is bordered by the small Army Creek, Red Lion Creek, Dragon Run Creek, and Chesapeake & Delaware Canal watersheds of the Delaware River Basin to the south. To the north of the watershed are the White Clay Creek, Red Clay Creek, Brandywine Creek, and Shellpot Creek watersheds which also drain into the Christina River and collectively form the Christina Basin in the Piedmont region. The watershed is bound to the west by the Elk River watershed of the Chesapeake Bay Basin.

2.1 Geology and Hydrogeomorphology

The Christina River watershed lies primarily within the Atlantic Coastal Plain physiographic province with portions of the upper Christina River and Little Mill Creek extending north into the Appalachian Piedmont physiographic province. The boundary between these two provinces, known as the Fall Line, is located just north of the Interstate 95 corridor. The hills of the Piedmont are formed by remnant metamorphic rocks from the Appalachian Mountains, which are overlain by coastal and marine sediments forming the Coastal Plain (Plank and Schenck 1998). Groundwater for the Christina River watershed is supported by fractures in the crystalline bedrock of the Piedmont and pore spaces within unconsolidated sedimentary deposits of the Coastal Plain (Hodges 1984).

Hydrogeomorphology differs considerably between the Piedmont and Coastal Plain physiographic provinces due to topography, geology, and soil characteristics. Wetlands in the rolling hills of the Piedmont are primarily confined to riparian floodplains and few, isolated depressions within the landscape. The Atlantic Coastal Plain portion of the Christina River watershed can be further divided into two distinct regions: the inner coastal plain, and beaches/tidal marshes. When compared to the rest of Delmarva's Coastal Plain, the inner coastal plain region has significant topographic relief which is typified by fewer headwater flat wetlands with more incised stream channels (Fretwell et al. 1996). Tidal wetlands can be found along the Christina River, from DE Route 1 east to the Delaware River.

2.2 Watershed History and Land-use

The first permanent European settlement in Delaware was established by the Swedes in 1638 along the Christina River after the failed settlement in Lewes in 1631. Shortly after the establishment of Fort Christina, European settlers began altering the landscape significantly with dikes and impoundments to reclaim land for agriculture (Phillipp 1995; Figure 2). Wetlands

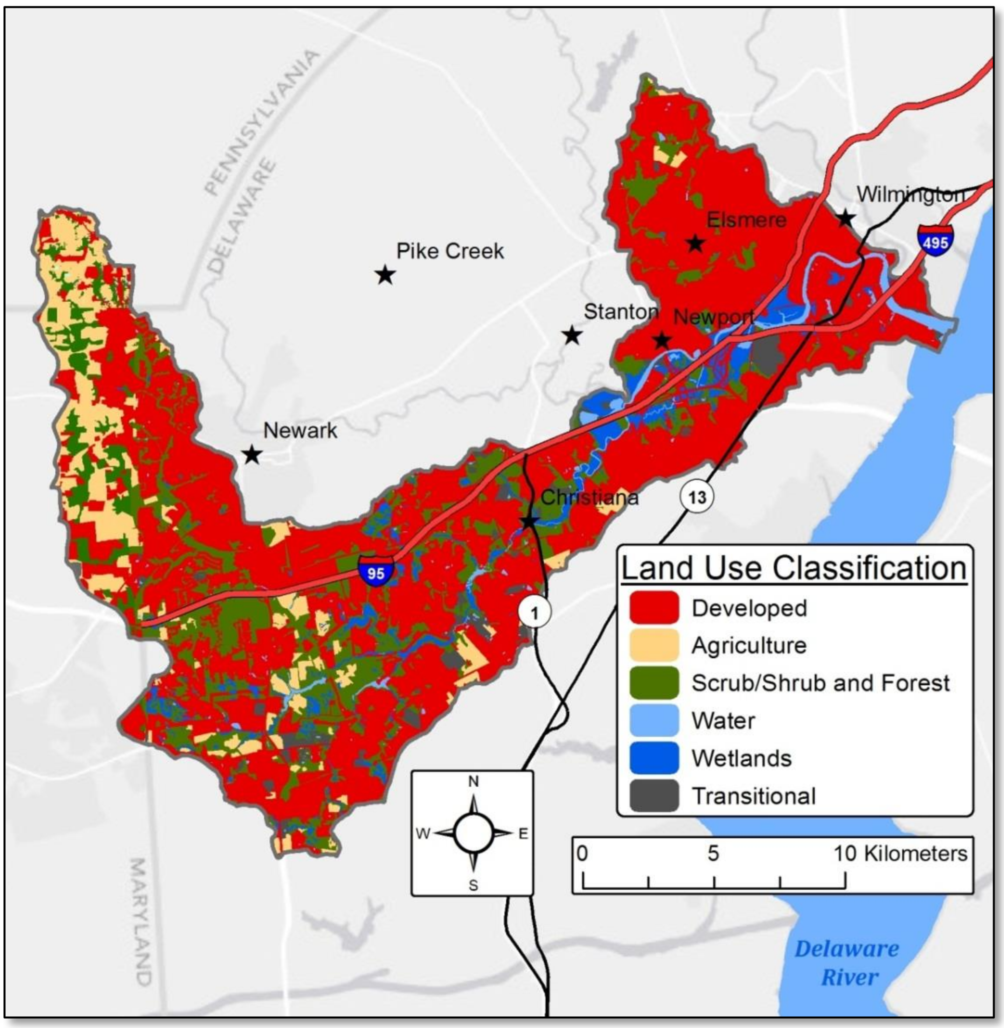


Figure 2. Land cover of the Christina River watershed based on 2005 (PA), 2007 (DE), and 2010 (MD) Land-use/Land-cover datasets.

throughout the region were ditched and filled to allow for transportation corridors and growing populations. During this period of reclamation, Phillipp (1995) estimated that nearly the entire tidal reach of the Christina River was diked and over 2,000 acres of tidal marshes were converted to upland. Marshes adjacent to navigational channels were filled and used as disposal sites for dredged material throughout the 1800s which allowed for the establishment and expansion of industries in Wilmington and northern Delaware. Dike maintenance declined during the Great Depression and World War II resulting in many of these systems falling into disrepair and ultimately returning to tidal marshes (Sebold 1992).

The main channel of the Christina River has also undergone significant modifications. The Christina River's confluence with the Delaware River has been channelized and dredged to accommodate cargo traffic, and a majority of the shoreline in Wilmington is armored with bulkheads and rip-rap revetments. One of the most notable impacts in recent history to the River, and surrounding tidal marshes, occurred with the construction of Interstate 95 in the 1960s. To create a direct route from Baltimore to Philadelphia, the Delaware Turnpike portion of the highway was built just south of the Fall Line along the Christina River floodplain. The alignment of the highway required a segment of the Christina River near Newport to be redirected 5 km northwest of its original location (Figure 3). Churchman's Marsh was also impounded during construction and converted to open-water. During construction over 400 hectares (1,000 acres) of tidal marsh were filled or otherwise impacted, primarily in Churchman's Marsh and Newport Marsh (Phillipp 1995).

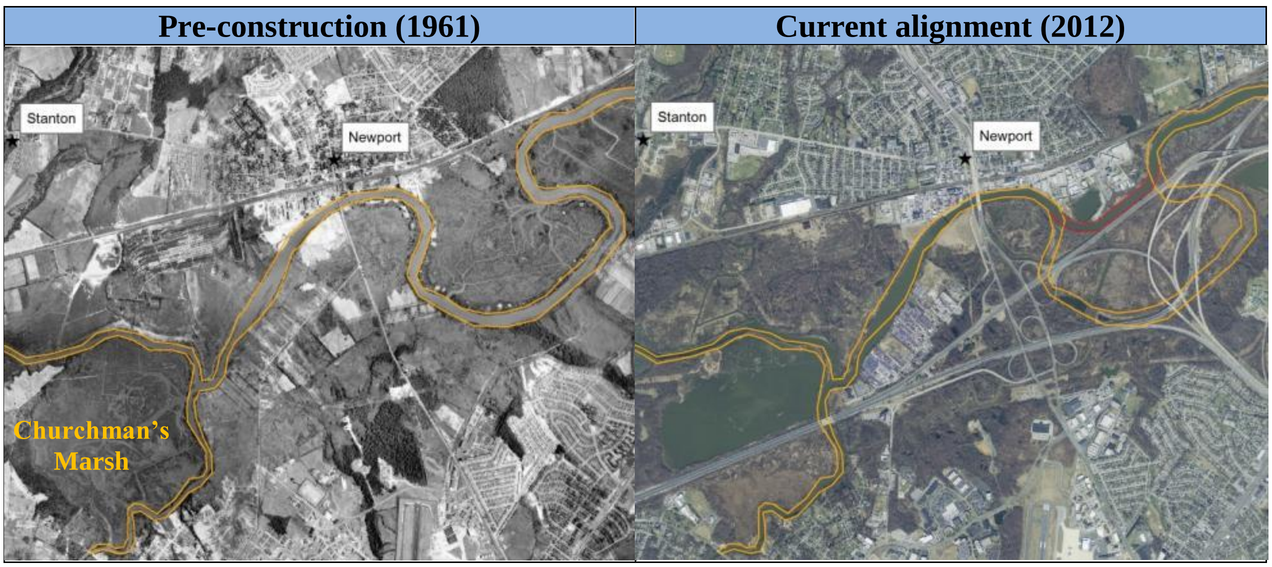


Figure 3. Pre- and post-construction alignment of the Christina River following the completion of Interstate 95. The pre-construction channel boundary is outlined in orange, and the current alignment southeast of Newport is outlined in red.

Coastal industries in Wilmington flourished during the Industrial Revolution and supplied much of the nation with goods during the Civil War and World War I. In 1913, planning and construction began for the Port of Wilmington, located at the mouth of the Christina River. The first marine terminal was completed in 1923 which opened the port to international trade. The port expanded considerably over the following decades to meet the needs of various companies, including Volkswagon and Del Monte (Baumbach *et al*. 2013). Businesses in Wilmington's downtown and Riverfront areas are significant contributors to the state's economy today, including DuPont, Gore, and many major financial institutions. Based on the most recent 2010 census, 186,680 people reside in the Christina River watershed, which grew by 20,245 people since 2000 (Baumbach *et al*. 2013).

Table 1. Land use cover in the Christina River watershed based on 2005 (PA), 2007 (DE), and 2010 (MD) Land-use/Land-cover datasets.

Land Use Category	Percent Coverage
Developed	60
Scrub-Shrub and Forest	20
Agriculture	11
Wetlands	5
Open Water	2
Transitional	2

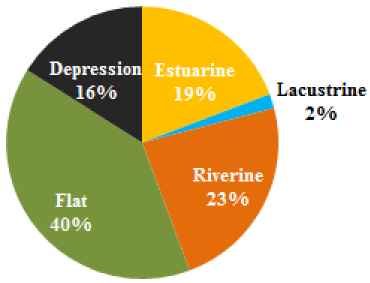
Land-use affects the health of wetlands directly through filling and conversion to other land uses, or indirectly via hydrologic alterations or runoff from intensive land cover. The Christina River watershed is currently among the most urbanized in Delaware, with over half of the watershed in residential or industrial development (Figure 2; Table 1). Extensive impervious surface cover and poorly-managed stormwater causes stream destabilization and soil erosion, while reducing groundwater recharge potential. Agricultural production is rare and found primarily along the western edge of the watershed in Maryland and Pennsylvania. Few large tracts of forest remain in the watershed, most notably being Iron Hill Park and Sunset Lake. Transitional land cover in the watershed encompasses land that has been cleared for development or areas that are frequently filled, including landfills.

Environmental contamination is a significant issue in the Christina River watershed, with four Superfund sites in the watershed and dozens of Brownfield sites in Wilmington. Sedimentation and runoff from impervious surfaces (including oil, salt, and heavy metals) all contribute to water quality concerns. The Christina River and its major tributaries exceed the Total Maximum Daily Load of pollutants and are listed as impaired due to nutrients from nonpoint source runoff and adjacent Superfund sites (USEPA 2006).

2.3 Wetland Resources

Wetlands, and the ecosystem services they provide, are crucial for the health of the Christina River watershed. Economic benefits from consumptive wetland products (fish, wildlife, timber, etc.) and the ecosystem services from water resources within the Christina River watershed exceeds $7 billion annually (Baumbach *et al.* 2013). Within this urbanized watershed, tidal and non-tidal wetlands are imperative for improving water quality, attenuating floodwaters, and providing habitats for wildlife. Many species of amphibians, reptiles, waterfowl, mammals, and insects rely on wetlands during various stages of their lives. Wetlands maintain and improve water quality by trapping sediments, excess nutrients, heavy metals, and pathogens, which benefits surface water and groundwater supplies. During storm events, tidal wetlands along the Christina River act as a buffer by absorbing wave energy and storing excess floodwaters to protect coastal businesses and residential properties. Non-tidal wetlands in urbanized areas of the watershed also act as reservoirs during storm events protecting properties downstream. Wetlands are also valuable recreational and educational resources, and downtown Wilmington is home to one of the nation's first urban wildlife refuges, the Russell Peterson Wildlife Refuge, located adjacent to the Christina River. Civic groups in downtown Wilmington and conservation partners are also experimenting with incorporating wetland restoration into a community revitalization plan to remedy chronic flooding in the neighborhood of Southbridge.

Table 2. Wetland acreage and proportion for each hydrogeomorphic wetland type in the Christina River Watershed.



Wetland Type	Hectares (Acres)	Proportion
Estuarine	395 (977)	19
Non-tidal Flat	815 (2,014)	40
Non-tidal Riverine	481 (1,191)	23
Non-tidal Depression	330 (817)	16
Non-tidal Lacustrine	35 (87)	2
Total	**2,058 (5,085)**	

Based on combined National Wetland Inventory (NWI) and Delaware's State Wetland Mapping Project (SWMP; State of Delaware 2007)) maps, wetlands cover approximately 10% of the Christina River watershed. Wetland inventory maps are created by digitizing orthophotos and supplemented with historical aerial imagery and soil, topography, and hydrology datasets. The wetland acreage identified using this mapping criteria is 5% greater than the wetland acreage identified by coarser land-use/land-cover datasets and reflects differences in mapping standards and data resolution. Non-tidal flats and riverines are the most common wetland type found in the Christina River watershed (Table 2).

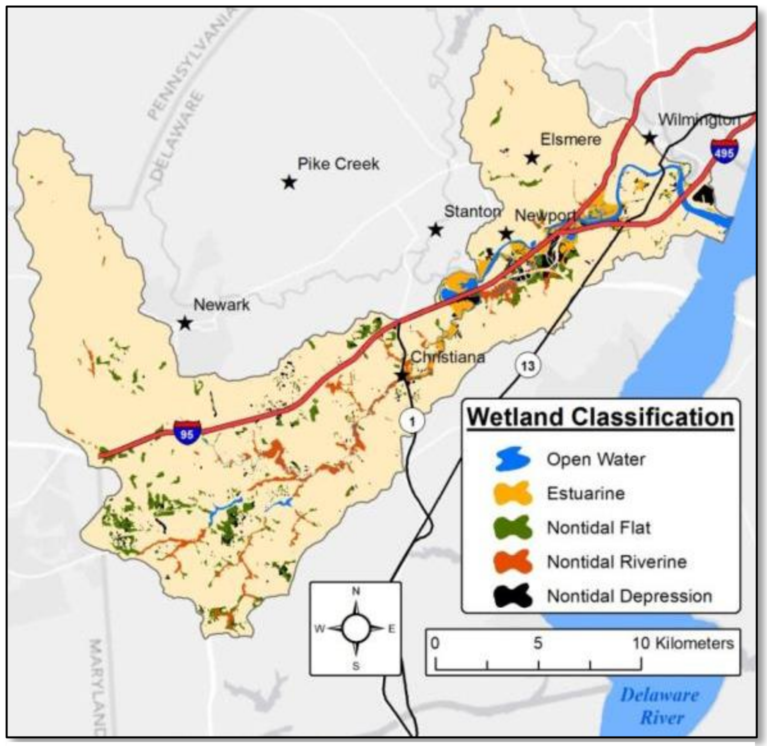


Figure 4. Distribution of wetlands in the Christina River watershed, based on 2007 mapping.

Tidal wetlands along the Christina River extend from its confluence with the Delaware River west to Delaware Route 1 in Christiana (Figure 4). A majority of the non-tidal riverine wetlands are found south of Interstate 95 along much of the Christina River and its tributaries. Non-tidal flat wetlands are also found primarily south of Interstate 95 in southern Newark within forested headwaters areas. Natural and man-made depressions make up a significant portion of the wetland acreage and can be found throughout the watershed. Of particular note are Delmarva Bays, one of the region's most unique and irreplaceable wetland types. These isolated depressions are shallow, seasonally flooded systems that support an abundance of rare plants and animals. Approximately 30 ha (73 ac) of Delmarva Bays remain in the Christina River watershed, most notably in the towns of Brookside and Bear, Delaware. Lacustrine fringe wetlands (not pictured) are uncommon in the Christina River watershed and are found exclusively along Beck's Pond and Sunset Lake in Bear, Delaware. These emergent systems differ from other non-tidal wetlands in the watershed in that they are influenced by water levels in the lakes and can be subject to wind-driven wave energy.

CONDITION OF WETLANDS IN THE CHRISTINA RIVER WATERSHED

METHODS

We documented the distribution of wetlands within the Christina River watershed and estimated the number of wetlands that have been lost, both recently and historically. Wetland condition assessments were completed in tidal and non-tidal wetlands in the Christina River watershed during the summer of 2011. We used a probabilistic survey approach to assess wetlands on both private and public property throughout the watershed. Tidal wetlands were assessed using the Mid-Atlantic Tidal Rapid Assessment Version 3.0 (MidTRAM; Jacobs *et al*. 2010), and non-tidal wetlands were evaluated with the Delaware Rapid Assessment Protocol Version 6.0 (DERAP; Jacobs 2010).

3.1 Changes to Wetland Acreage

We used Delaware wetland maps to determine the current distribution of wetlands across the Christina River watershed, as well as where wetland loss has occurred in recent decades and since colonization. Historic wetland acreage was estimated using a combination of current U.S. Department of Agriculture soil maps and historic soil survey maps from 1915. These maps are based on soil indicators such as drainage class, landform, and water flow. Hydric soils occurring in areas that are currently not classified as wetlands due to significant human impacts, either through urbanization, land clearing, or hydrologic alterations, are assumed to be historic wetlands that have been lost. Recent losses are classified as wetlands converted during the 15-year period of 1992 and 2007. Current acreage represents wetlands that were mapped in 2007 during Delaware's most recent wetland mapping effort (State of Delaware 2007). Recent trends in wetland acreage are classified as wetlands lost, created, or otherwise changed since 1992 (State of Delaware 1994).

3.2 Field Site Selection

Statistical survey methods developed by the U.S. Environmental Protection Agency's Ecological Monitoring and Assessment Program (EMAP) are used to extrapolate results from random wetland sites to the condition of wetlands throughout the watershed. EMAP in Corvallis, Oregon assisted with selecting 250 potential sample sites in estuarine intertidal emergent wetlands and 500 potential sample sites in non-tidal wetlands using a generalized random tessellation stratified design (Stevens and Olsen 1999, 2000). A target population was created from all vegetated wetlands from the 2007 state wetland maps. Study sites were randomly chosen points within mapped wetlands, with each point having an equal probability of being selected. Sites were selected and sampled in numeric order as dictated by the EMAP design - lowest to highest. Sites were only excluded from sampling if permission for access was denied, the site was inaccessible, the site was of the wrong wetland classification, or if the site was upland. Our goal was to sample 30 tidal sites and 30 non-tidal sites in each common hydrogeomorphic (HGM) class (riverine, flats, and depression).

3.3 Data Collection

3.3.1 Landowner Contact and Site Access

We obtained landowner permission prior to assessing and sampling all sites. We identified landowners using county tax records and mailed each landowner a post card providing a brief description of our study goals, sampling techniques, and contact information. If a contact number was available we followed the mailings with a phone call to discuss the site visit and secure permission. If permission was denied the site was dropped and not visited. Sites were deemed inaccessible if a landowner could not be identified or if the site was unsafe to visit.

3.3.2 Assessing Tidal Wetlands

We evaluated the condition of tidal wetlands using the MidTRAM v3.0 protocol with modifications to the Habitat scoring for tidal freshwater conditions. MidTRAM was created by adapting the New England Rapid Assessment Method (NERAM; Carullo *et al*. 2007) and the California Rapid Assessment Method (CRAM; Collins *et al*. 2008) and consists of 14 scored metrics that represent the condition of the wetland buffer, hydrology, and habitat characteristics (Table 3). MidTRAM uses a combination of qualitative evaluation and quantitative sampling to record the presence and severity of stressors in the field or in the office using maps and digital orthophotos.

Figure 5. Standard assessment area, subplot locations, and buffer used to collect data for the Mid-Atlantic Tidal Rapid Assessment Method Version 3.0.

MidTRAM was designed and calibrated to assess polyhaline and mesohaline estuarine tidal wetlands and developed with pilot data from Delaware, Maryland, and Virginia. To more accurately score wetland condition in tidal freshwater wetlands, breakpoints for condition were created using data from 90 tidal freshwater wetland sites in Delaware (Christina 2011), New Jersey (Crosswicks 2012, 2013) and Pennsylvania (2010).

MidTRAM was completed at the first 30 random points that we could access, and which met our criteria of being of an estuarine intertidal emergent wetland. Prior to field assessments we produced site maps and calculated buffer metrics using ArcMap GIS software (ESRI, Redlands, CA, USA). The attributes measured included buffer width, surrounding development, percent of assessment area with a 5 m buffer, 250 m landscape condition, and barriers to landward migration (Table 3). All metrics measured in the office were field verified to confirm accuracy.

We navigated to the EMAP points with a handheld GPS unit and established an assessment area (AA) as a 50 m radius circle (0.78 ha) centered on each random point (Figure 5). If a 50 m radius circle went beyond the wetland into upland or open water, we moved the circle the least distance necessary (up to 50 m). We defined the AA buffer area as a 250 m radius area around the AA.

Once the AA was established, eight 1 m^2 subplots were placed along two perpendicular 100 m transects that bisected the AA. These subplots were used to measure horizontal vegetative obstruction and soil bearing capacity (Table 3). We oriented one transect perpendicular to the nearest source of open water (>30 m wide) and the other was perpendicular to the first. We placed subplots 25 m and 50 m from the center of the AA along each transect. Subplots were numbered clockwise starting with the plot 25 m from the AA center point, followed by the 50 m one towards open water (Figure 5). If a subplot fell in a habitat type or patch that was not characteristic of the site (e.g. in a ditch) we moved it along the transect to the nearest site representative of the site location.

We completed all metrics within the AA via visual inspection during the field visit, with the exception of horizontal vegetative obstruction and soil bearing capacity. Sampling and data collection were completed as described in the MidTRAM v3.0 protocol.

Table 3. Metrics measured with the Mid-Atlantic Tidal Rapid Method Version 3.0.

Attribute Group	***Metric Name***	***Description***	***Measured in AA or Buffer***	***Qualitative or Quantitative***
Buffer/Landscape	Percent of AA Perimeter with 5m-Buffer	Percent of AA perimeter that has at least 5m of natural or semi-natural condition land cover	Buffer	Quantitative (Office)
Buffer/Landscape	Average Buffer Width	The average buffer width surrounding the AA that is in natural or semi-natural condition	Buffer	Quantitative (Office)
Buffer/Landscape	Surrounding Development	Percent of developed land within 250m from the edge of the AA	Buffer	Quantitative (Office/Field)
Buffer/Landscape	250m Landscape Condition	Condition of surrounding landscape based on vegetation, soil compaction, and human visitation within 250m	Buffer	Quantitative (Office/Field)

Table 3, continued:

Attribute Group	***Metric Name***	***Description***	***Measured in AA or Buffer***	***Qualitative or Quantitative***
Buffer/Landscape	Barriers to Landward Migration	Percent of landward perimeter of marsh within 250m with physical barriers preventing marsh migration inland	Buffer	Quantitative (Office/Field)
Hydrology	Ditching & Draining	The presence and functionality of ditches in the AA	AA	Qualitative (Field)
Hydrology	Fill & Fragmentation	The presence of fill or marsh fragmentation from anthropogenic sources in the AA	AA	Qualitative (Field)
Hydrology	Diking/Restriction	The presence of dikes or other restrictions altering the natural hydrology of the wetland	AA and Buffer	Qualitative (Field)
Hydrology	Point Sources	The presence of localized sources of pollution	AA and Buffer	Qualitative (Field)
Habitat	Bearing Capacity	Soil resistance using a slide hammer	AA subplots	Quantitative Field)
Habitat	Horizontal Vegetative Obstruction	The amount of visual obstruction due to vegetation	AA subplots	Qualitative (Field)
Habitat	Number of Plant Layers	Number of plant layers in AA based on plant height	AA	Qualitative (Field)
Habitat	Percent Co-dominant Invasive Species	Percent of co-dominant species that are invasive in the AA	AA	Qualitative (Field)
Habitat	Percent Invasive	Percent cover of invasive species in the AA	AA	Qualitative (Field)

The average field time to sample each site was 2 h, with an average of 0.5 h needed to complete computer-based metrics. After completing the field assessments, the field crew assigned each site a Qualitative Disturbance Rating from 1 (least disturbed) to 6 (most disturbed) using best professional judgment (category descriptions can be found in Appendix A). A normalized final score was then computed, which provides a quantitative description of tidal wetland condition out of a total of 100 points. Detailed instructions for using MidTRAM are provided in the protocol (Jacobs et al. 2010).

3.3.3 Assessing Non-tidal Wetland Condition

DERAP is used to assess the condition of wetlands based on the presence and intensity of stressors related to habitat, hydrology, and buffer elements. DERAP scores are calibrated, separately for each HGM subclass, to comprehensive wetland condition data collected using the Delaware Comprehensive Assessment Procedure (DECAP; Jacobs et al. 2009). DERAP was completed at 32 non-tidal flats, 40 non-tidal riverines, and 2 depressions in the Christina River watershed.

We navigated to EMAP points with a handheld GPS unit and established an assessment area (AA) as a 40 m radius circle (0.5 ha) centered on each random point (Figure 6). If the 40 m radius circle extended beyond the wetland edge into upland or open water, we moved the AA the least distance necessary (up to 40 m) or changed to a rectangle of equal area in order to stay within the wetland. The entire AA was explored and evidence of wetland stressors were documented (Table 4). Current and historic aerial photos were used to determine forest activity and buffer stressors and verified in the field. Similar to MidTRAM, field investigators assign the wetland a Qualitative Disturbance Rating from 1 (least disturbed) to 6 (most disturbed; Appendix A).

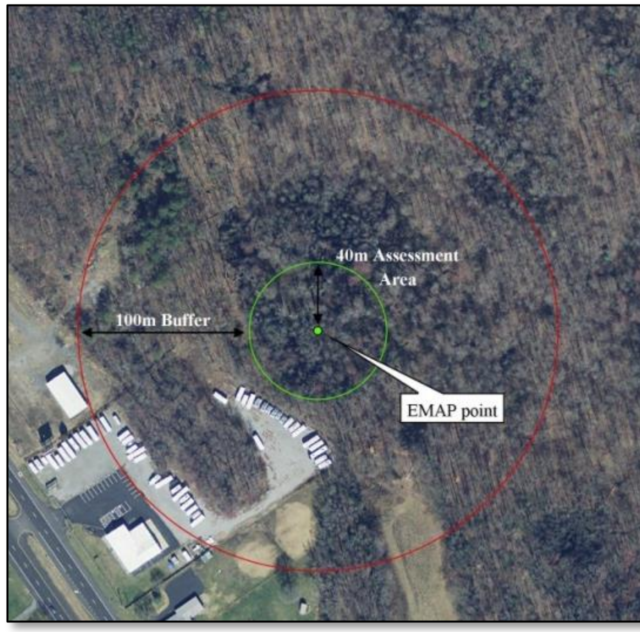


Figure 6. Standard assessment area and buffer used to collect data for the Delaware Rapid Assessment Procedure Version 6.0.

Table 4. Metrics measured with the Delaware Rapid Assessment Procedure Version 6.0.

Attribute Group	*Metric Name*	*Description*	*Measured in AA or Buffer*
Habitat	Dominant Forest Age	Estimated age of forest cover class	AA
Habitat	Forest Harvesting within 50 Years	Presence and intensity of selective cutting or clear cutting within 50 years	AA
Habitat	Forest Management	Conversion to pine plantation or evidence of chemical defoliation	AA
Habitat	Vegetation Alteration	Mowing, farming, livestock grazing, or lands otherwise cleared and not recovering	AA

Table 4, continued:

Attribute Group	*Metric Name*	*Description*	*Measured in AA or Buffer*
Habitat	Presence of Invasive Species	Presence and abundance of invasive plant cover	AA
Habitat	Excessive Herbivory	Evidence of herbivory or infestation by pine bark beetle, gypsy moth, deer, nutria, etc.	AA
Habitat	Increased Nutrients	Presence of dense algal mats or the abundance of plants indicative of increased nutrients	AA
Habitat	Roads	Non-elevated paths, elevated dirt or gravel roads, or paved roads	AA
Hydrology	Ditches (flats and depressions only)	Depth and abundance of ditches within and adjacent to the AA	AA and Buffer
Hydrology	Stream Alteration (riverines only)	Evidence of stream channelization or natural channel incision	AA
Hydrology	Weir/Dam/Roads	Man-made structures impeding the flow of water into our out of the wetland	AA and Buffer
Hydrology	Stormwater Inputs and Point Sources	Evidence of run-off from intensive land use, point source inputs, or sedimentation	AA and Buffer
Hydrology	Filling and/or Excavation	Man-made fill material or the excavation of material	AA
Hydrology	Microtopography Alterations	Alterations to the natural soil surface by forestry operations, tire ruts, and soil subsidence	AA
Buffer	Development	Commercial or residential development and infrastructure	Buffer
Buffer	Roads	Dirt, gravel, or paved roads	Buffer
Buffer	Landfill/Waste Disposal	Re-occurring municipal or private waste disposal	Buffer
Buffer	Channelized Streams or Ditches	Channelized streams or ditches >0.6 m deep	Buffer
Buffer	Poultry or Livestock Operation	Poultry or livestock rearing operations	Buffer
Buffer	Forest Harvesting in Past 15 Years	Evidence of selective or clear cutting within past 15 years	Buffer
Buffer	Golf Course	Presence of a golf course	Buffer
Buffer	Row Crops, Nursery Plants, Orchards	Agricultural land cover, excluding forestry plantations	Buffer

Table 4, continued:

Attribute Group	*Metric Name*	*Description*	*Measured in AA or Buffer*
Buffer	Mowed Area	Any re-occurring activity that inhibits natural succession	Buffer
Buffer	Sand/Gravel Operation	Presence of sand or gravel extraction operations	Buffer

DERAP produces one overall wetland condition score based on the presence and intensity of various stressors. The final score obtained by DERAP is supported by the intensive DECAP Index of Wetland Condition. The DERAP model was developed using a process to screen variables specific to each hydrogeomophic wetland class to select the most important variables that would represent wetland condition based on over 250 wetland sites (see Sifneos et al. 2010; Appendix B). Wetland stressors included in the DERAP model were selected using step-wise multiple regression and Akaike's Information Criteria (AIC) approach to develop the best model that correlated to DECAP data without over-fitting the model to this specific dataset. Therefore, certain wetland stressors are more important than other stressors, while some stressors are not included in final site scores. Coefficients, or stressor weights, associated with each stressor were assigned using multiple linear regression (Appendix C). The DERAP IWC score is calculated by summing the stressor coefficients for each of the selected stressors that were present and subtracting the sum from the linear regression intercept:

$$\textbf{DERAP IWC}_{\textbf{FLATS}} = 95 - (\sum\text{stressor weights})$$
$$\textbf{DERAP IWC}_{\textbf{RIVERINE}} = 91 - (\sum\text{stressor weights})$$
$$\textbf{DERAP IWC}_{\textbf{DEPRESSION}} = 82 - (\sum\text{stressor weights})$$

Example: Site D
Forested flat wetland with 25% of AA clear cut, 1-5% invasive plant cover, moderate ditching, and commercial development in the buffer:

DERAP condition score = 95 – (19+0+10+3)

DERAP condition score = 63

For all wetland subclasses, 23 terms were selected to be included in the DERAP IWC calculation: 7 habitat stressors, 6 hydrology stressors, and 10 landscape or buffer stressors (Appendix C).

3.4 Presenting Wetland Condition

We present our results at both the site- and population-level. We discuss site-level results by summarizing the range of scores that we found in sampled sites (e.g. Habitat attribute scores ranged from 68 to 98). Population level results are presented using weighted means and standard deviations (e.g. Habitat for tidal wetlands averaged 87 ± 13) or weighted percentages (e.g. 20% of riverine wetlands had channelization present). Population-level results have incorporated weights based on the probabilistic design and correct for any bias due to sample sites that could not be sampled and different rates of access on private and public lands to be able to extrapolate to the total area of wetland in the watershed. The cumulative results represent the total area of the respective wetland subclass for the entire watershed.

Sites in each HGM subclass were placed into 3 condition categories: Minimally stressed, Moderately stressed, or Severely stressed (Table 5). Condition class breakpoints were determined by applying a percentile calculation to the QDR's and condition scores from sites in several previously assessed watersheds. Freshwater tidal wetland regional datasets included combined MidTRAM data from Pennsylvania, New Jersey, and Delaware (n = 90), while non-tidal regional datasets includes DERAP data from St. Jones, Murderkill, Inland Bays, and Nanticoke watersheds (n = 160). Minimally stressed sites are those with a condition score greater than the 25^{th} percentile of sites assigned a QDR of 1 or 2. Severely stressed sites are those with a condition score less than the 75^{th} percentile of sites assigned a QDR of 5 or 6. Moderately stressed sites are those that fall between. Based on the three watersheds combined, the condition breakpoints for non-tidal sites that we applied in the Christina River watershed are provided in Table 5.

Table 5. Condition categories and breakpoint values for tidal and non-tidal wetlands in the Christina River watershed as determined by wetland condition scores.

Wetland Type	Method	Minimally or Not Stressed	Moderately Stressed	Severely Stressed
Estuarine	MidTRAM	≥ 83	< 83 ≥ 61	< 61
Estuarine Freshwater	MidTRAM	≥78.8	<78.8 ≥60.9	<60.9
Non-tidal Riverine	DERAP	≥ 85	< 85 ≥ 47	< 47
Non-tidal Flats	DERAP	≥ 88	< 88 ≥ 65	< 65
Non-tidal Depression	DERAP	≥ 73	< 73 ≥ 53	< 53

We used a cumulative distribution function (CDF) to display wetland condition on the population level. A CDF is a visual tool to extrapolate assessment results to the entire population and can be interpreted by drawing a horizontal line anywhere on the graph and reading that as: 'z' proportion of the area of tidal wetlands in the watershed falls above (or below) the score of 'w' for wetland condition. The advantage of these types of graphs is that they can be interpreted based on individual user goals, and break points can be placed anywhere on the graph to determine the percent of the population that is within the selected conditions. For example, in Figure 7 roughly 40% of the wetland area scored above an 80 for wetland condition. A CDF also highlights clumps or plateaus where either a large or small portion of wetlands are in similar condition. In the example, there is a condition plateau from 50 to approximately 75, illustrating that only a small portion of the population had condition scores in this range.

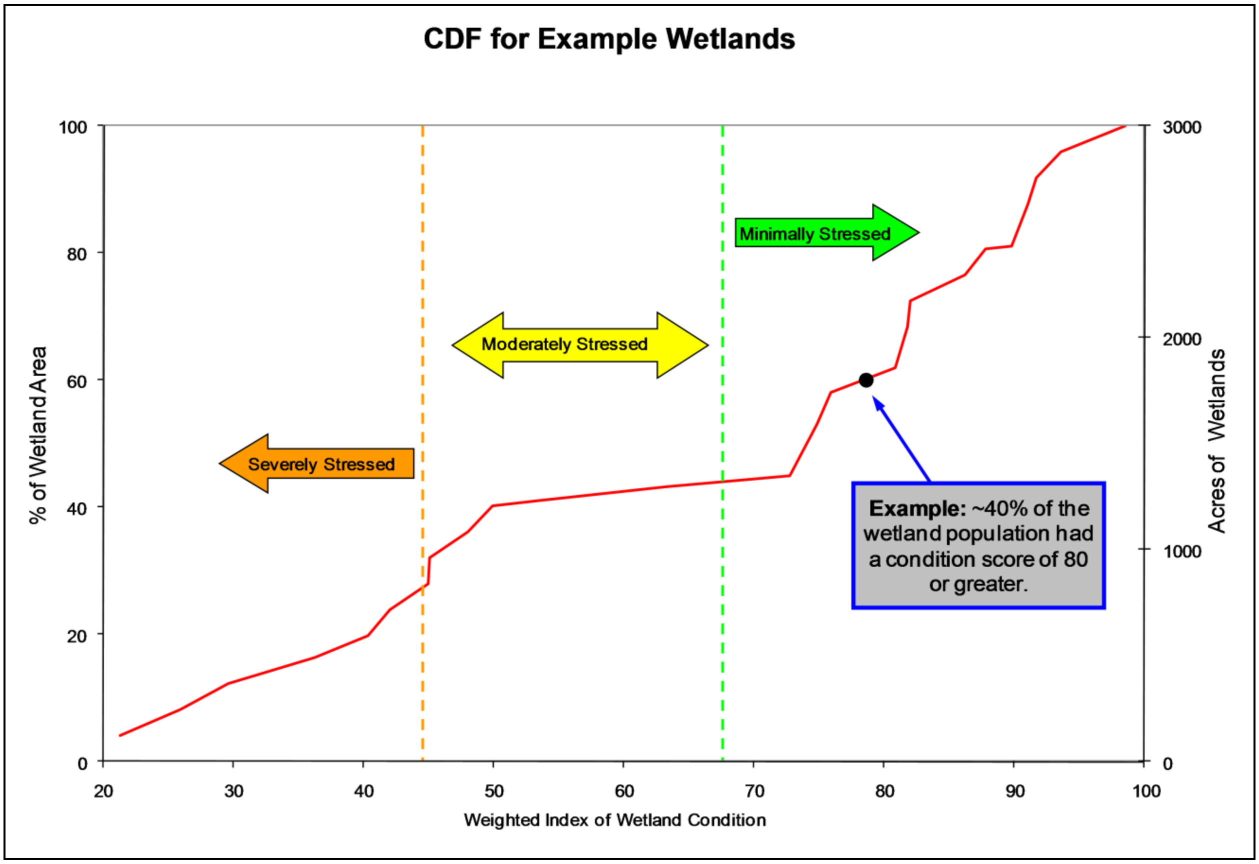


Figure 7. An example CDF showing wetland condition. The red line is the population estimate. The orange and green dashed lines show the breakpoints between condition categories.

RESULTS

4.1 Landscape Analysis of Changes in Wetland Acreage

Based on hydric soil mapping and evidence of historic wetland loss, wetlands formerly covered an estimated 9,163 acres (3,708 hectares) of the Christina River watershed. Compared to most recent wetland maps, this indicates a 46% loss of wetland acreage between the time of settlement and 2007 (Figure 8). A majority of these losses have occurred in the headwaters in southern Newark and along the Interstate 95 corridor.

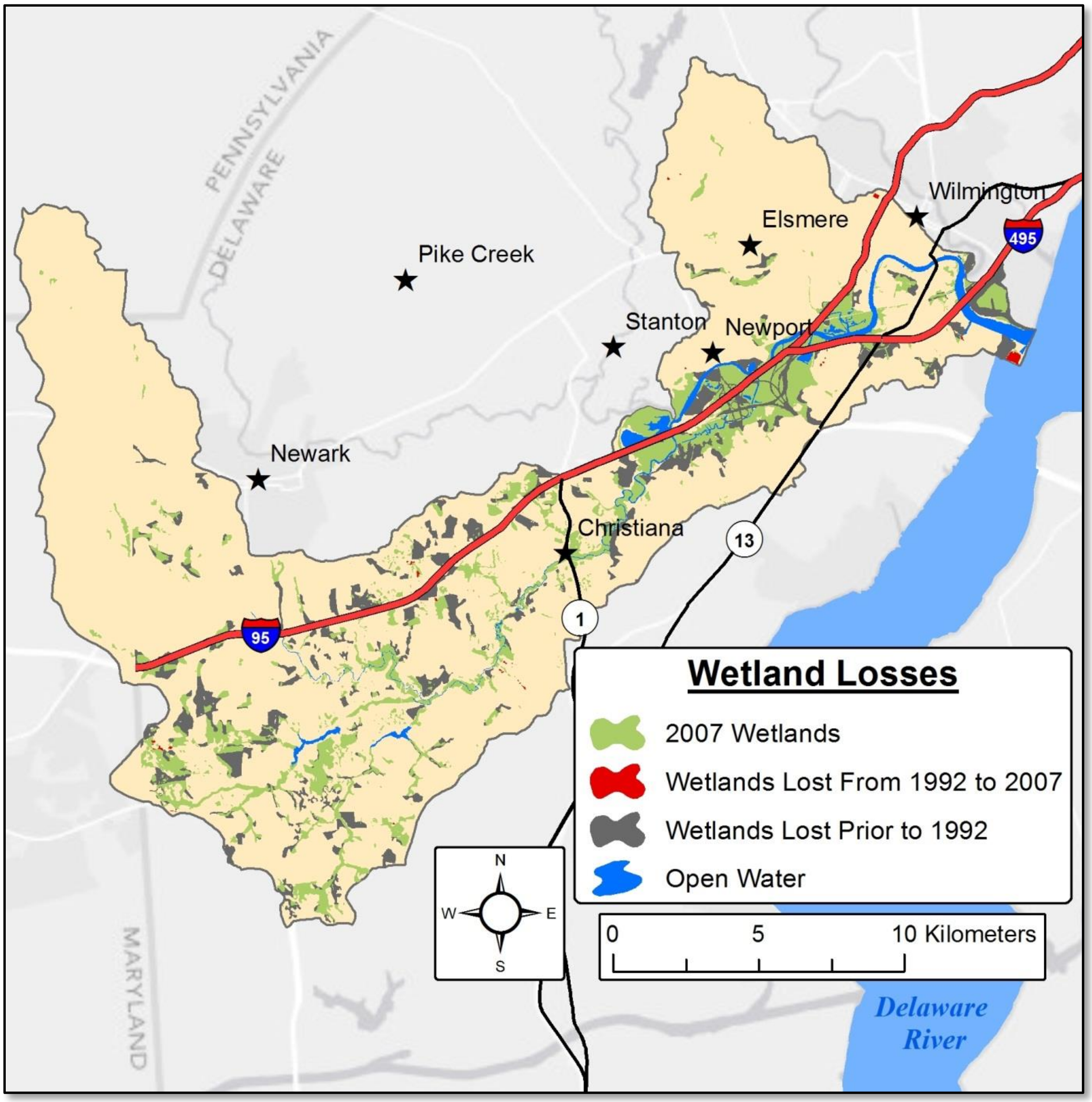
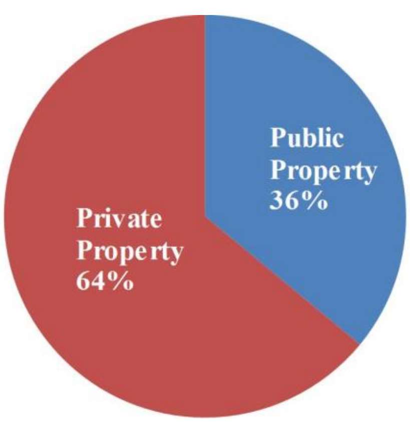


Figure 8. Estimated historic and more current wetland coverage in the Christina River watershed.

Despite strict zoning codes and open space requirements in New Castle County, approximately 81 acres (33 hectares) of wetlands were lost in the Christina River watershed between 1992 and 2007. Due to past land-use decisions and overdeveloped portions of New Castle County, the County ratified the Unified Development Code (UDC) in 1997. The UDC created stringent zoning specifications to guide development and protect the remaining natural resources in the County, including preserving 100% of wetlands (Section 40.10.320). However, wetland protection "may be reduced when a permit from the United States Army Corps of Engineers is issued for filling or disturbance" (§40.10.320). A majority of the wetlands lost during the 15-year period were non-tidal forested systems related to the construction of new housing developments, widening roadways, and the realignment of Route 273 through Ogletown, DE. The single largest wetland loss (33 acres) occurred along the Delaware Bay at a disposal site for dredged material which was covered with hydrophytic vegetation, most likely common reed (*Phragmites australis).* Comparisons between 1992 and 2007 wetland maps also revealed that 156 acres (63 hectares) of mapped wetlands were created in the Christina River watershed. However, this small increase in wetland acreage was due to construction stormwater retention ponds or excavated basins which do not function as natural wetlands.

As a result of recent changes in wetland acreage, the wetland functions potentially provided in the Christina River watershed have further been reduced. A recent landscape-level analysis of wetland function predicted that, as a result of wetland losses between 1992 and 2007, the potential for existing wetlands to perform nutrient transformation, sediment retention, surface water detention, and serve as wildlife habitat were reduced (Tiner 2011). The direct replacement of natural wetlands with stormwater retention ponds can also negatively affect wildlife that utilize these habitats for breeding, nesting, or foraging, as well as reduce the plant diversity. In developed landscapes, unnatural hydroperiods and the accumulation of contaminants in stormwater ponds can create ecological traps for birds, reptiles, and amphibians (Brand et al. 2010).

4.2 Landowner Contact and Site Access



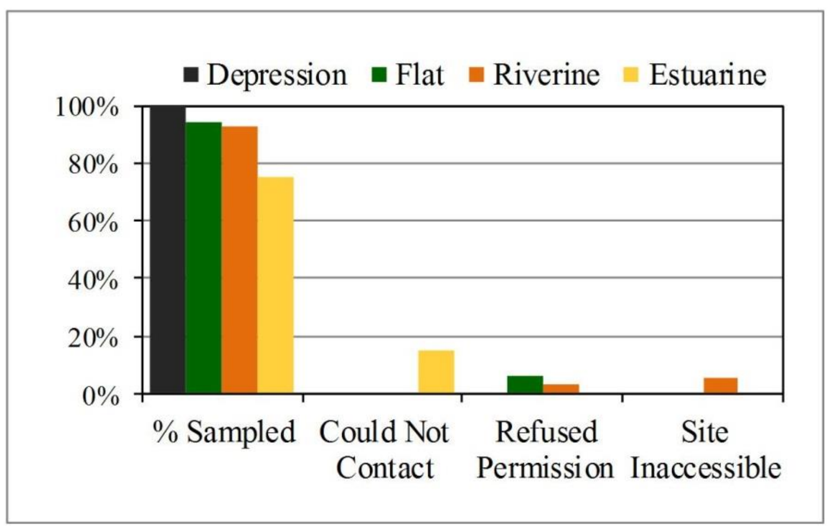


Figure 9. Ownership of sampled wetland sites in the Christina River watershed (left) and success rates for sampling private wetland sites (right).

The majority of our sampled sites were located on private property (Figure 9). Almost every assessed wetland was located in Delaware, with only one wetland assessment performed in Maryland and zero in Pennsylvania (Figure 10). We were granted permission to 32 of the 34 non-tidal flat wetlands we attempted to access, of which 66% of the wetlands were on private property and 34% were on public property. We were denied permission to one non-tidal riverine site, while two other riverine sites proved to be inaccessible. Of the 40 riverine wetlands that were sampled, 58% were privately owned and 42% were on public property. We only visited two depression wetlands in the Christina River watershed, with both sites found on private property. Tidal wetland assessments were conducted in 30 estuarine wetlands, though access was attempted at 40 sites. Six sites were dropped because landowners could not be contacted. Records are not available to determine why the other four sites were dropped, so it is unknown if these sites were upland, non-tidal, or if permission was denied. Of the 30 estuarine sites that were assessed, 30% were on public property and 70% were privately owned.

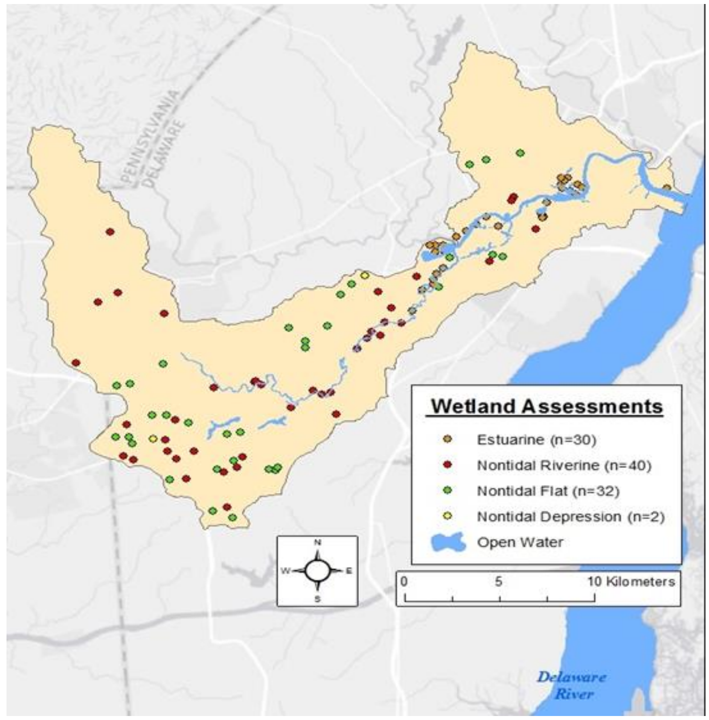


Figure 10. Location of wetland assessments performed in the Christina River watershed in 2011.

4.3 Condition of Tidal Wetlands

Tidal estuarine wetlands comprised 19% of the total wetland acreage in the Christina River watershed and provide many ecosystems services. These systems are crucial for buffering storm surges and storing floodwaters, controlling coastal erosion, and improving water quality by sequestering sediments and other pollutants. Within Delaware, a majority of tidal wetlands are fringing salt marshes with salinities between 5 and 30 ppt. Salt marshes are extremely productive systems that contain few species capable of surviving in these highly saline environments. Uncommon in Delaware are freshwater tidal wetlands which occur along the uppermost reaches of tidal rivers and streams that are still influenced by lunar tides. In these areas, salt water from the Atlantic Ocean is diluted by substantial upstream freshwater inputs and maintains salt concentrations below 0.5 ppt. These wetlands can be dominated by trees, shrubs, or herbs and are more diverse than typical salt marsh communities. Within the Christina River watershed, all of the 30 MidTRAM assessment sites were freshwater tidal marshes.

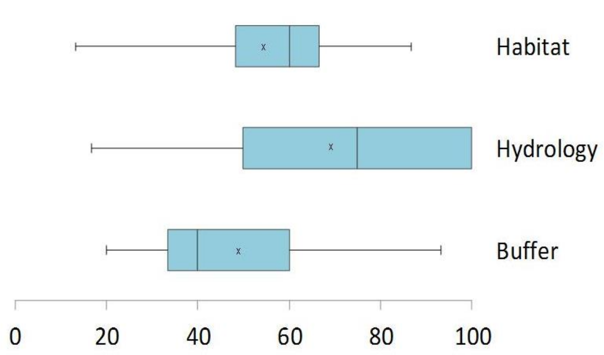


Figure 11. Habitat, hydrology, and buffer attribute group scores from tidal wetlands in the Christina River watershed.

The average score for the Buffer attribute group was 48± 23, with scores ranging from 20 to 93 (Figure 11). Intensive land uses were found around a majority of the tidal wetlands in the Christina River watershed, with 86% of wetlands having some degree of development in the surrounding buffer. Development covered approximately 19% of the 250 m buffers surrounding tidal wetlands in the watershed, due largely to the density of roadways and commercial properties surrounding marshes. Furthermore, hardened structures greatly impeded wetland migration in more than half of the wetland/upland boundaries in the watershed. In natural landscapes, tidal wetlands respond to rising sea levels by migrating inland and converting uplands to wetland ecosystems. In the Christina River watershed, the ability for marsh migration was obstructed by hardened structures such as rip rap, development, bulkheads and roads.

Hydrology scores were marginally better than buffer scores, ranging widely from 17 to 100 and averaging 69±27 (Figure 11). Thirty percent of the tidal wetlands in the watershed were found to have undisturbed hydrology. Evidence of historic diking, as well as recent road construction, affected the hydrology of 60% of the tidal wetlands. Pollution entering tidal wetlands was also pervasive in the Christina River watershed due to the close proximity of residential and commercial development. Point-source discharges into wetlands were typically pipes, culverts, or ditches originating from anthropogenic land uses and were found in 40% of marshes. Ditching freshwater tidal marshes is a less common practice than ditching salt marshes, with only 7% of the tidal wetlands in the watershed containing low ditching.

Scores for the Habitat attribute averaged 55±19 and ranged 13 to 87 (Figure 11). Tidal wetlands in the Christina watershed generally had a deep peat layer with an average depth of the organic later at 28.0 ±12.6 cm. Although these wetlands had a thick organic layer, the composition was not firm as evidenced by low bearing capacity. Bearing capacity is inversely associated with the amount of below ground root material. Soil bearing capacity depth, which measures marsh stability and reflects bulk density and below-ground biomass, averaged 4.88 ± 2.03 cm, which is deeper than typical salt marshes, but similar to other freshwater marshes. Invasive plant species were abundant in the watershed and found in 63% of freshwater tidal marshes. An estimated 34% of the tidal wetland acreage in the watershed was covered by invasive plants. Common reed (*Phragmites australis*) was the most prevalent invasive plant in tidal wetlands, though purple loosestrife (*Lythrum salicaria*), narrowleaf cattail (*Typha angustifolia*) and mile-a-minute weed (*Persicaria perfoliata*) also contributed to the invasive plant cover.

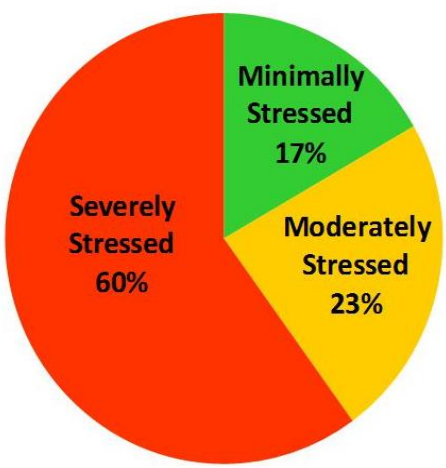


Figure 12. Proportion of tidal freshwater wetlands by condition class for the Christina River watershed, DE.

The final condition scores for freshwater tidal sites in the Christina River watershed ranged 18-84 and averaged a low 57.4±17.7. Based on the condition category cutoffs (see Page 19), 60% of the tidal wetlands in the Christina watershed were highly stressed, approximately 23% were moderately stressed, and 17% were minimally or not stressed (Figure 12). This suggests that 80% of freshwater tidal wetlands in Christina were in a disturbed state and functioning in a reduced capacity.

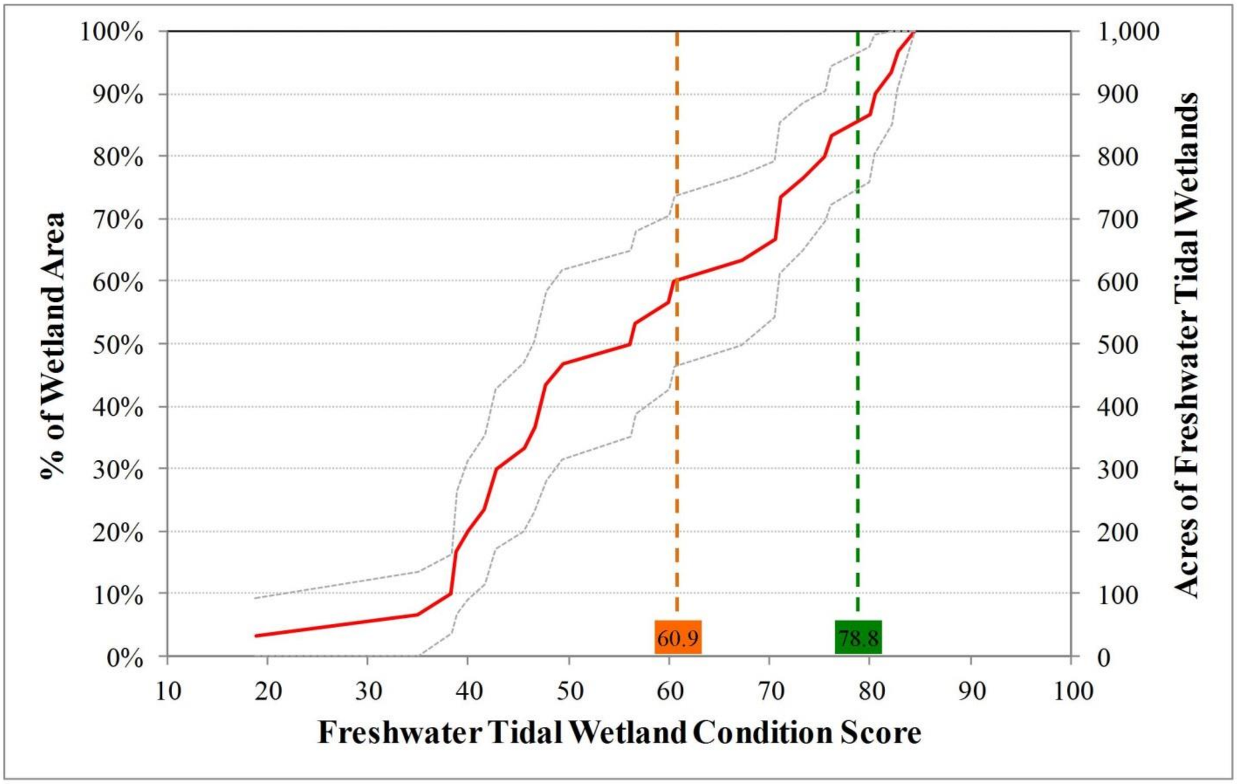


Figure 13. The cumulative distribution function for tidal wetlands in the Christina watershed. The orange and green dashed lines signify the condition category breakpoints dividing severely stressed from moderately and minimally stressed portions of the tidal wetland population.

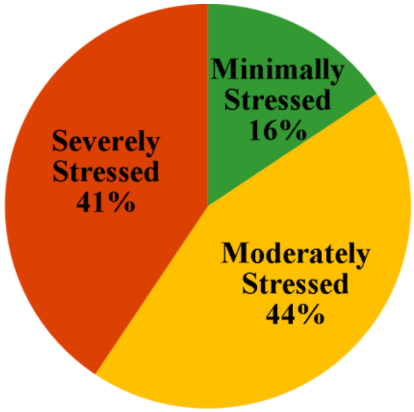
The cumulative distribution function graph for tidal wetlands in the Christina watershed shows that 50% of the watershed's wetlands scored a condition within 20 points of each other (40-60), indicated by a steep incline, with a small portion in the worst condition (<40; Fig. 13). MidTRAM data from the 30 freshwater tidal wetland assessment sites can be found in Appendix D.

4.4 Condition of Non-tidal Wetlands

4.4.1 Non-tidal Flat Wetland Condition

Flat wetlands total approximately 40% of the wetland acreage in the Christina River Watershed, primarily in low-lying, headwater forested areas. A majority of the non-tidal flat wetlands are found in the western half of the watershed within the Coastal Plain province. Sizable non-tidal flat wetlands can be found in Newport, south of the Interstates 95 and 295 interchange in an area that was historically covered with tidal wetlands.

Table 6. Composition of wetland condition classes (left) and the occurrence of common wetland stressors (right) of non-tidal flat wetlands in the Christina River watershed.



Wetland Stressor	Proportion of Sites with Stressor Present: Minimally Stressed (*n* = 5)	Moderately Stressed (*n* = 14)	Severely Stressed (*n* = 13)
Forest clear cutting	0%	0%	77%
Invasive plants present	40%	86%	100%
Ditching in wetland	0%	43%	62%
Fill material in wetland	20%	43%	85%
Development in buffer	80%	79%	69%

The highest possible score for non-tidal flats using DERAP is 95, and condition scores in the Christina River watershed ranged from 43 to 91, with an average of 70±16. Nearly all (85%) of flat wetlands in the watershed are at least moderately disturbed, while only 16% of the flats were in a minimally stressed condition (Table 6). Several common stressors increased in prevalence as condition decreased (Table 6). Invasive plant species were found in 85% of flat wetlands, with 13% being dominated (>50% cover) by invasives. Recent forest harvesting was documented in half of the non-tidal flat wetlands in the watershed, with clear cutting occurring in one third and selective thinning found in one fifth. Wetland draining was also pervasive in the watershed, with ditches found in 44% of flat wetlands. As expected within a heavily urbanized landscape, intensive land-uses were found in most of the buffers surrounding flat wetlands. Impervious surface cover, such as paved roads and development, occurred in 91% of the flat wetland buffers in the watershed. Regularly mowed and cleared areas were found in the buffers of 56% of flat wetlands in the watershed, which were typically maintained right-of-ways associated with high-voltage powerlines that traverse Bear and Newark.

Though intensive land-use was found in most wetland buffers, point source inputs (other than stormwater) were not observed in any sampled flats in the watershed. Notable stormwater inputs were found in 9% of flat wetlands, evident by wrack lines or stormwater drainage structures directly emptying into the wetland. Unlike Delaware's Kent and Sussex counties, forest conversion to pine plantations is rare in New Castle County and was not found in any sampled flat wetlands in the watershed. Excessive herbivory was documented in one flat wetland (3% of the population) due to heavy browsing by white-tailed deer (*Odocoileus virginianus*).

The cumulative distribution function for flat wetlands in the Christina River watershed shows a wetland population skewed towards lower condition classes (Figure 14). A plateau in the middle marks a gap in flats scoring 60-70. Approximately 900 acres of flat wetlands in the Christina watershed are functioning in a severely stressed condition. Generally, these wetlands have been extensively cleared or thinned of trees and contain plant communities with moderate to extensive coverage of invasive plant species. A majority of these sites have also been ditched and partially filled, and have multiple stressors in the surrounding landscape. Only 200 acres of flat wetlands in the watershed are estimated to be in a minimally stressed state. These wetlands have a low occurrence of invasive plants and selective forest thinning, intact hydrology, little to no fill material, and relatively intact buffers. The DERAP stressor checklist from the 32 flat wetland assessment sites in the Christina River watershed are provided in Appendix E.

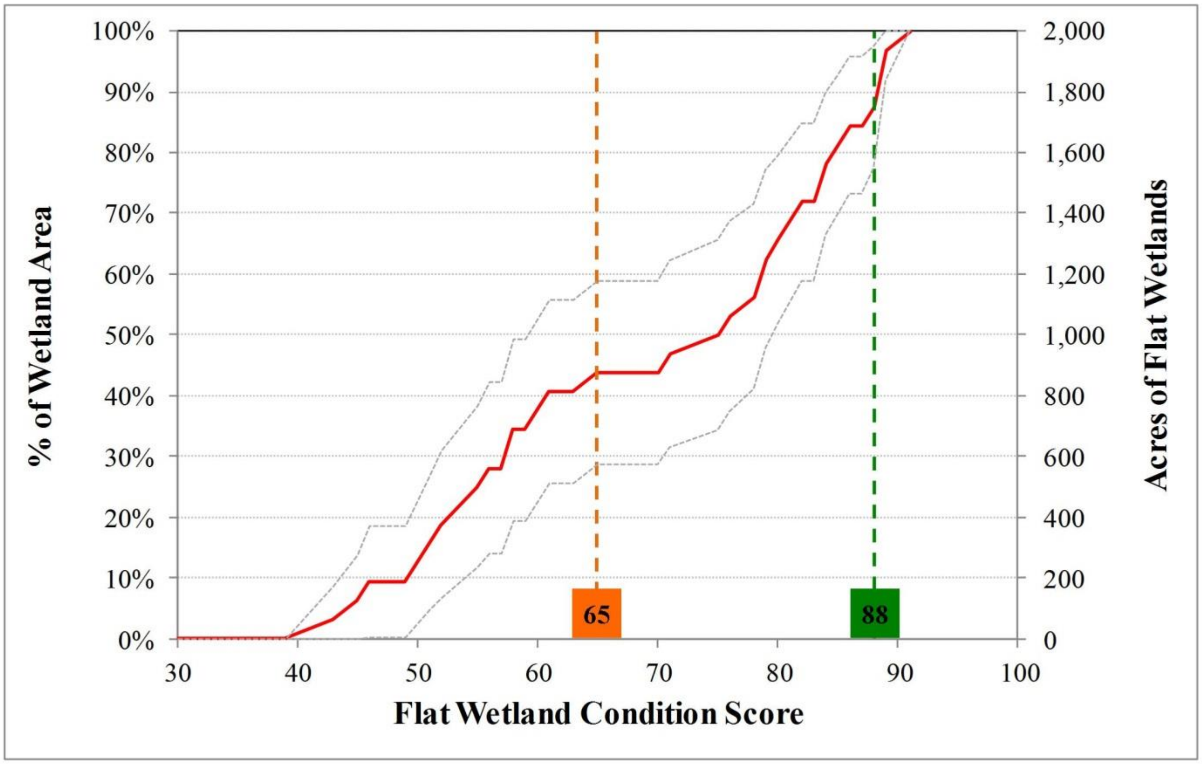


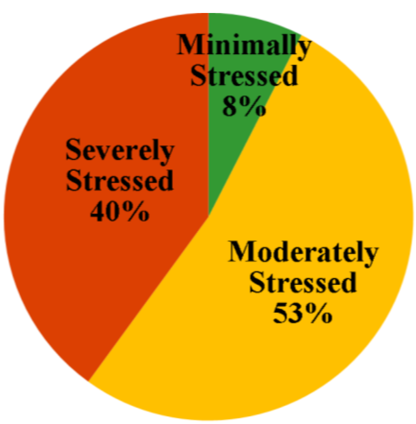
Figure 14. Cumulative distribution function for non-tidal flat wetlands in the Christina River watershed. Condition scores for the wetland population are represented as the red line with 95% confidence intervals (gray dashed lines). The orange and green dashed lines designate condition category breakpoints dividing severely stressed, moderately stressed, and minimally stressed wetlands.

4.4.2 Non-tidal Riverine Wetland Condition

Riverine wetlands in the Christina River watershed are associated with floodplains of the Christina River and its tributaries. These wetlands cover approximately 481 hectares (1,191 acres) which is 23% of the total wetlands acreage in the watershed. Riverine wetlands act as buffers between streams and adjacent habitat or land use and are valued for water quality maintenance through sediment retention and nutrient uptake. They are also vital for flood abatement by allowing for overbank flood water storage during storm events.

The maximum score possible for riverine wetlands using DERAP is 91, and riverine wetland scores in the Christina River watershed ranged from 6 to 88, with an average of 53±22. Only 8% of the riverine wetlands in the watershed were functioning in a minimally stressed state, while 40% of the wetlands were severely stressed (Table 7). A majority of the buffers surrounding riverine wetlands in the watershed were significantly impacted, with 95% of wetlands containing impervious surfaces in the buffer. Similar to flat wetlands in the watershed, regularly mowed areas were also found in a majority (83%) of riverine wetland buffers. Ten percent of the riverine wetlands also had reoccurring mowing within the wetland itself. As development and land clearing occurs adjacent to wetlands, edge effects, such as increased sunlight and wind penetration, have profound impacts on the remaining wetland habitat and increase the likelihood of colonization by invasive species. As expected, 95% of the riverine wetlands in this watershed contained invasive plant species, with 48% of riverine wetlands dominated by invasive plant cover. Stream channelization or natural channel incision was the most common impact to wetland hydrology, occurring in 60% of riverine systems. Fill material, such as spoil piles and yard waste, was also found in 53% of riverine wetlands. Forestry activity was less common in riverine wetlands than flats in the Christina River watershed, though 25% of riverine sites were selectively thinned or clear-cut.

Table 7. Composition of wetland condition classes (left) and the occurrence of common wetland stressors (right) of non-tidal riverine wetlands in the Christina River watershed.



Wetland Stressor	Proportion of Sites with Stressor Present: Minimally Stressed (*n* = 3)	Moderately Stressed (*n* = 21)	Severely Stressed (*n* = 16)
Forestry activity	0%	10%	50%
Dominated by invasive spp.	0%	38%	69%
Stream channelized/incised	0%	38%	100%
Fill material in wetland	0%	38%	81%
Development in buffer	67%	57%	88%

Evidence of stormwater inputs were more common in riverine wetlands than flats in the watershed. Excessive sedimentation was found in 8% of riverine wetlands, and stormwater inputs in another 10% of wetlands. Generally, elevated roads and all-terrain vehicle trails are less common in riverine wetlands due to the saturated soil conditions, though these features were nearly as common in riverine wetlands (28%) as they were in flats (31%) within the Christina River watershed. Excessive herbivory was slightly more common in riverine wetlands (5%) due to forest clearing and significant impounding by North American beavers (*Castor canadensis*).

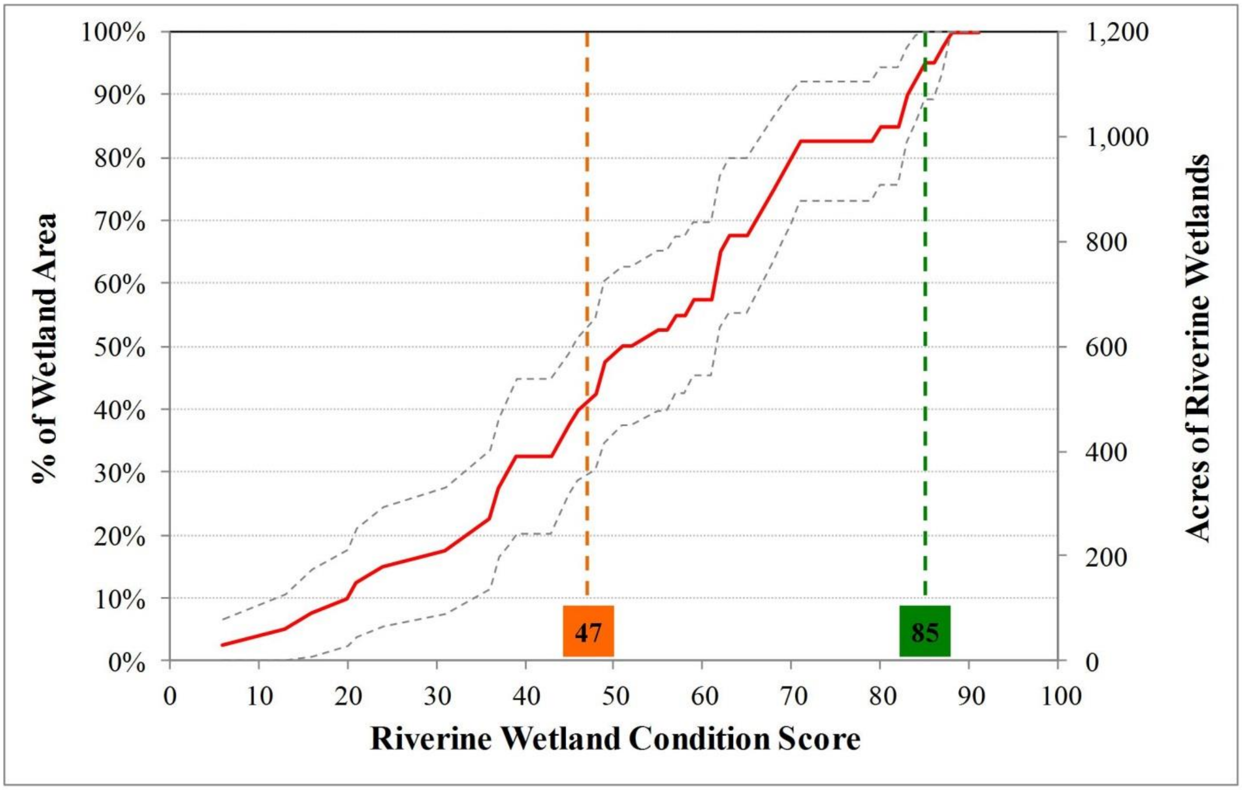


Figure 15. Cumulative distribution function for non-tidal riverine wetlands in the Christina River watershed. Condition scores for the wetland population are represented as the red line with 95% confidence intervals (gray dashed lines). The orange and green dashed lines designate condition category breakpoints dividing severely stressed, moderately stressed, and minimally stressed wetlands.

Fewer than 50 acres of minimally stressed riverine wetlands remain in the Christina River watershed based on cumulative distribution function estimates (Figure 15). These wetlands were absent of forest cutting, stream alterations, and fill material. However, these wetlands vary in the amount of invasive plant species present and the intensity of impacts to the surrounding buffer. Conversely, approximately 500 acres of riverine wetlands in the Christina River watershed were severely stressed. Invasive plant species were found in each of the severely stressed riverines, with invasives as the dominant plant cover in 69% of these wetlands. Stream morphology and wetland hydrology was also significantly altered, including channelization or incision (100%), fill material (81%), and constricted or impounded streamflow (63%; Table 7). Impervious landcover was also found in the buffers around each of the severely stressed riverine wetlands. The DERAP stressor checklist from the 40 riverine wetland assessment sites in the Christina River watershed are provided in Appendix F.

4.4.3 Non-tidal Depression Wetland Condition

Approximately 330 hectares (817 acres) of depression wetlands are found in the Christina River watershed. These wetlands naturally form in low-lying areas and topographical depressions within the landscape. Most of the natural depressions in the Christina River watershed occur in forested areas south of Newark, though they can be found throughout the watershed. The acreage of depression wetlands in the watershed is inflated by a number of large man-made impoundments within cloverleaf interchanges on Interstate 95 and a dredge disposal area south of the Cherry Island landfill in Wilmington. Natural depressions in the watershed are otherwise rare and only two depression wetlands were assessed, so conclusions on the condition of depressions at the watershed-scale cannot accurately be drawn. The DERAP stressor checklist from the two depression assessments can be found in Appendix G.

4.5 Overall Condition and Watershed Comparison

To review wetland conditions in the Christina River watershed, and to compare five recently assessed watersheds in southern Delaware, we created an overall condition score weighted by the acreage of tidal (and tidal freshwater), flat and riverine wetlands in each watershed.

Wetlands in the Christina River watershed were in considerably worse condition than wetlands in southern Delaware (Figure 16). The Christina River watershed contained the greatest proportion of severely stressed wetlands as well as the smallest proportion of minimally stressed wetlands than any other watershed.

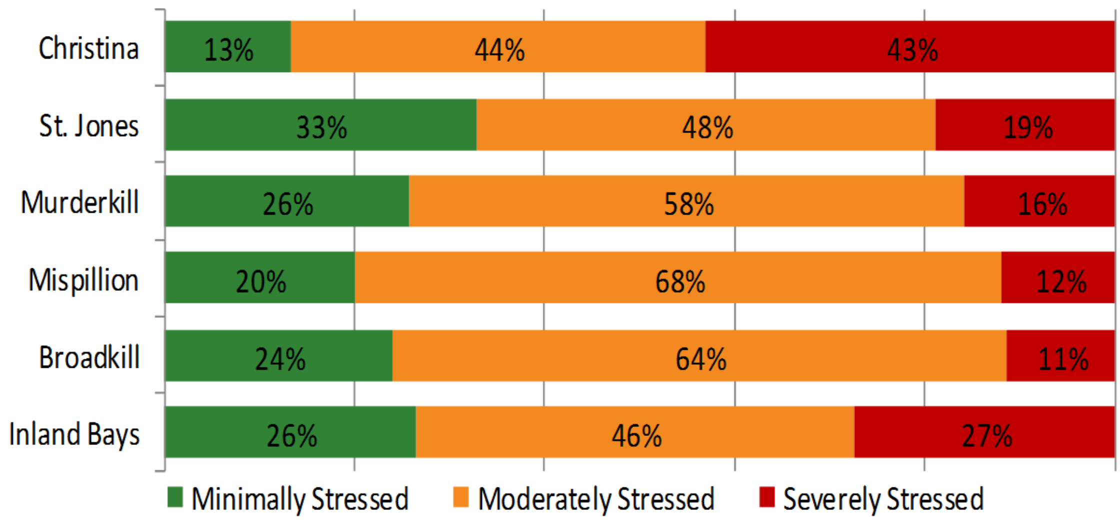


Figure 16. Combined condition of tidal, tidal freshwater, flat and riverine wetlands in the Christina River watershed, compared to wetland condition in the St. Jones, Murderkill, Mispillion, Broadkill, and Inland Bays watersheds.

MANAGEMENT RECOMMENDATIONS

Based on our study, we offer the following seven recommendations to improve ecosystems provided by wetlands, guide wetland restoration and management efforts, identify additional management needs, and encourage informed decisions concerning the future of wetland resources in the Christina River watershed.

1. **Preserve remaining Delmarva Bays.** Coastal Plain Seasonal Ponds, also known as Delmarva Bays, have been identified as a regionally-unique wetland type and are considered irreplaceable and a significant component of Delaware's natural heritage (McAvoy and Clancy 1994). These wetlands contain unique hydrological and biological characteristics that are imperative for the survival of many plants and animals in Delaware. Many Delmarva Bays throughout the state have traditionally been ditched, filled, or excavated and are exceedingly rare in Delaware, with only an estimated 73 acres of Delmarva Bays remaining in the Christina River watershed. New Castle County's Unified Development Code preserves 100% of wetlands (Section 40.10.32) unless a permit from the United States Army Corps of Engineers is issued for filling or disturbance (Section 40.10.320), leaving Delmarva Bays vulnerable to impacts. Protecting Delmarva Bays, and biologically-significant buffers, through easements and planning will preserve these irreplaceable wetlands.

2. **Incorporate wetland creation and restoration into urban planning.** Many neighborhoods in Wilmington are marred by chronic flooding and inadequate drainage which stifles local economies. An example of utilizing the natural ecosystem services provided by wetlands are found in the management plan developed for South Wilmington and the neighborhood of Southbridge. This large-scale community revitalization plan is held as a national model for incorporating wetland restoration to alleviate flooding, improve water quality, and provide habitat for wildlife. The 27-acre restored wetland will also serve as greenspace for the community and an educational resource for urban school students. Many opportunities for wetland restoration and outreach can be found along the Christina River and should be considered in land-use decisions.

3. **Utilize clean dredged material for wetland creation.** The mouth of the Christina River and the navigational channel in the Delaware Bay is frequently dredged to accommodate cargo ships reaching the Port of Wilmington. Traditionally, dredged materials are disposed of in confined upland disposal facilities found along the Delaware Bay. Re-using uncontaminated dredge material for wetland restoration and creation has been used elsewhere in the United States and Delaware, and can be explored in the Christina River watershed. Considerations must be made on the source of sediments used for restoration because a number of areas in the Delaware River and Bay have elevated concentrations of contaminants that would limit the feasibility of habitat restoration. In 2011 DNREC and its conservation partners began a project applying a thin layer of dredged material to a fragmenting salt marsh in Dagsboro to increase surface elevation and promote *Spartina alterniflora* growth. Dredge sediment has also been beneficially re-used throughout the country to create wetlands in areas that were previously open water. Opportunities for wetland creation should be investigated in open water areas of Churchman's Marsh and around the confluence of the Brandywine River. The Delaware Estuary Regional

Sediment Management Plan Workgroup has developed documents outlining potential uses of dredged sediments and special considerations.

4. **Encourage alternative shoreline protection designs.** Shorelines are dynamic systems that respond to sediment supply and wave energy through erosion, subsidence and accretion. Shorelines along the Christina River are significantly altered by bulkheads, gabions, revetments, and rip-rap which lack the capacity to respond to these natural processes. In these areas lacking estuarine wetlands, shorelines have reduced capacity to buffer storm surges, trap sediments and excess nutrients, and provide habitat for wildlife due to the hardened shorelines. Along shorelines with lower wave energy, alternative shoreline stabilization approaches should be considered if erosion threatens public infrastructure. Living shorelines are a natural alternative which can utilize coconut fiber logs and natural vegetation to anchor the shoreline and prevent erosion. Shellfish or low-profile rock sills can also be used with living shorelines to dissipate wave energy. In situations with greater energy or steeper banks, timber cribbing and log reinforcements may be employed. The Delaware Estuary Living Shoreline Initiative was developed to showcase natural alternative to protect shorelines (for more information, see http://delawareestuary.org/Living_Shorelines).

5. **Develop incentives and encourage maintaining natural buffers along riverine and tidal wetlands**. As sea levels rise and extreme storm events bring more flooding, the importance of wetland buffers between water and upland is taking center stage. The need exists to inform Delawareans on the importance of allowing tidal wetlands to migrate inland unobstructed by roads, rip-rap, development, and bulkheads. Sufficient buffers along streams and rivers stabilize shorelines and improve water quality by trapping sediments and pollutants before they reach surface waters. Landowners along riverine and estuarine wetlands, as well as those directly abutting surface waters, should be educated about the ecological and societal benefits that can be attained by preserving natural buffers. In addition to awareness, an incentive program could attract an interest in maintaining larger natural buffers between wetlands and development.

6. **Control the extent and spread of the non-native, invasive common reed (*Phragmites australis)***. Invasive plants such as *Phragmites* are capable of spreading rapidly, outcompeting native species, reducing plant diversity in undisturbed areas, and reducing the success of other organisms by changing habitat structure and food availability. The DNREC Phragmites Control Program in the Division of Fish and Wildlife has treated more than 20,000 acres on private and public property since 1986. Without continued support from state funds and federal State Wildlife Grant funds *Phragmites* will degrade more wetlands. *Phragmites* was the most abundant invasive species in estuarine wetlands in the Christina River watershed and a significant stressor in non-tidal flat and riverine wetlands.

7. **Update tidal wetland regulatory maps**. In addition to improving the protection of nontidal wetlands, it is prudent to maximize the authority that already exists within DNREC. Tidal wetland impacts are regulated by the State of Delaware and permit reviewers need accurate and recent wetland maps to guide wetland permitting. Currently 1988 wetland maps are used, which must be verified in person and are difficult to read. Evidence of recent coastal development and inundation of coastal wetlands due to sea level rise creates a greater need to adopt updated wetland maps as regulatory maps.

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APPENDIX A: Qualitative Disturbance Rating (QDR) Category Descriptions

Qualitative Disturbance Rating: Assessors determine the level of disturbance in a wetland through observation of stressors and alterations to the vegetation, soils, hydrology in the wetland site, and the land use surrounding the site. Assessors should use best professional judgment (BPJ) to assign the site a numerical Qualitative Disturbance Rating (QDR) from least disturbed (1) to highly disturbed (6) based on the narrative criteria below. General description of the minimal disturbance, moderate disturbance and high disturbance categories are provided below.

Minimal Disturbance Category (QDR 1 or 2): Natural structure and biotic community maintained with only minimal alterations. Minimal disturbance sites have a characteristic native vegetative community unmodified water flow into and out of the site, undisturbed microtopographic relief, and are located in a landscape of natural vegetation (100 or 250 m buffer). Examples of minimal alterations include a small ditch that is not conveying water, low occurrence of invasive species, individual tree harvesting, and small areas of altered habitat in the surrounding landscape, which does not include hardened surfaces along the wetland/upland interface. Use BPJ to assign a QDR of 1 or 2.

Moderate Disturbance Category (QDR 3 or 4): Moderate changes in structure and/or the biotic community. Moderate disturbance sites maintain some components of minimal disturbance sites such as unaltered hydrology, undisturbed soils and microtopography, intact landscape, or characteristic native biotic community despite some structural or biotic alterations. Alterations in moderate disturbance sites may include one or two of the following: a large ditch or a dam either increasing or decreasing flooding, mowing, grazing, moderate stream channelization, moderate presence of invasive plants, forest harvesting, high impact land uses in the buffer, and hardened surfaces along the wetland/upland interface for less than half of the site. Use BPJ to assign a QDR of 3 or 4.

High Disturbance Category (QDR 5 or 6): Severe changes in structure and/or the biotic community. High disturbance sites have severely disturbed vegetative community, hydrology and/or soils as a result of ≥1 severe alterations or >2 moderate alterations. These disturbances lead to a decline in the wetland's ability to effectively function in the landscape. Examples of severe alterations include extensive ditching or stream channelization, recent clear cutting or conversion to an invasive vegetative community, hardened surfaces along the wetland/upland interfaces for most of the site, and roads, excessive fill, excavation or farming in the wetland. Use PBJ to assign a QDR of 5 or 6.

APPENDIX B: DERAP Stressor Codes and Definitions

Habitat Category (within 40m radius of sample point)	
Hfor50	Forest age 31-50 years
Hfor30	Forest age 16-30 years
Hfor15	Forest age 3-15 years
Hfor2	Forest age ≤2 years
Hcc10	<10% of AA clear cut within 50 years
Hcc50	11-50% of AA clear cut within 50 years
Hcc100	>50% of AA clear cut within 50 years
Hforsc	Selective cutting forestry
Hpine	Forest managed or converted to pine
Hchem	Forest chemical defoliation
Hmow	Mowing in AA
Hfarm	Farming activity in AA
Hgraz	Grazing in AA
Hnorecov	Cleared land not recovering
Hinv1	Invasive plants cover <1% of AA
Hinv5	Invasive plants cover 1-5% of AA
Hinv50	Invasive plants cover 6-50% of AA
Hinv100	Invasive plants cover >50% of AA
Hherb	Excessive Herbivory/Pinebark Beetle/Gypsy Moth
Halgae	Nutrients dense algal mats
Hnis50	Nutrient indicator plant species cover <50% of AA
Hnis100	Nutrient indicator plant species cover >50% of AA
Htrail	Non-elevated road
Hroad	Dirt or gravel elevated road in AA
Hpave	Paved road in AA
Hydrology Category (within 40m radius of sample point)	
Wditchs	Slight Ditching; 1-3 shallow ditches (<.3m deep) in AA
Wditchm	Moderate Ditching; 3 shallow ditches in AA or 1 ditch >.3m
Wditchx	Severe Ditching; >1 ditch .3-.6 m deep or 1 ditch > .6m deep
Wchannm	Channelized stream not maintained
Wchan1	Spoil bank only one side of stream
Wchan2	Spoil bank both sides of stream
Wincision	Natural stream channel incision
Wdamdec	Weir/Dam/Road decreasing site flooding
Wimp10	Weir/Dam/Road impounding water on <10% of AA
Wimp75	Weir/Dam/Road impounding water on 10-75% of AA
Wimp100	Weir/Dam/Road impounding water on >75% of AA
Wstorm	Stormwater inputs
Wpoint	Point source (non-stormwater)
Wsed	Excessive sedimentation on wetland surface

Hydrology Category (continued)	
Wfill10	Filling or excavation on <10% of AA
Wfill75 Wfill100	Filling or excavation on 10-75% of AA Filling or excavation on >75% of AA
Wmic10	Microtopographic alterations on <10% of AA
Wmic75	Microtopographic alterations on 10-75% of AA
Wmic100	Microtopographic alterations on >75% of AA
Wsubsid	Soil subsidence or root exposure
Landscape/Buffer Category (within 100m radius outside site/AA)	
Ldevcom	Commercial or industrial development
Ldevres3	Residential development of >2 houses/acre
Ldevres2	Residential development of ≤2 houses/acre
Ldevres1	Residential development of <1 house/acre
Lrdgrav	Dirt or gravel road
Lrd2pav	2-lane paved road
Lrd4pav	≥4-lane paved road
Llndfil	Landfill or waste disposal
Lchan	Channelized streams or ditches >0.6m deep
Lag	Row crops, nursery plants, or orchards
Lagpoul	Poultry or livestock operation
Lfor	Forest harvesting within past 15 Years
Lgolf	Golf course
Lmow	Mowed area
Lmine	Sand or gravel mining operation

APPENDIX C: DERAP IWC Stressors and Weights

Category/Stressor Name*	Code	Stressor Weights**		
**DERAP stressors excluded from this table are not in the rapid IWC calculation.*		Flats	Riverine	Depression
Habitat Category (within 40m radius site)				
Mowing in AA	Hmow	15	3	24
Farming activity in AA	Hfarm			
Grazing in AA	Hgraz			
Cleared land not recovering in AA	Hnorecov			
Forest age 16-30 years	Hfor16	5	4	2
≤10% of AA clear cut within 50 years	Hcc10			
Forest age 3-15 years	Hfor3	19	7	12
Forest age ≤2 years	Hfor2			
11-50% of AA clear cut within 50 years	Hcc50			
>50% of AA clear cut within 50 years	Hcc100			
Excessive Herbivory	Hherb	4	2	2
Invasive plants dominating	Hinvdom	2	20	7
Invasive plants not dominating	Hinvless	0	5	7
Chemical Defoliation	Hchem	5	9	1
Managed or Converted to Pine	Hpine			
Non-elevated road in AA	Htrail	2	2	2
Dirt or gravel elevated road in AA	Hroad			
Paved road in AA	Hpave			
Nutrient indicator species dominating AA	Hnutapp	10	12	10
Nutrients dense algal mats	Halgae			
Hydrology Category (within 40m radius site)				
Slight Ditching	Wditchs	10	0	5
Moderate Ditching	Wditchm		0	
Severe Ditching	Wditchx	17	0	
Channelized stream not maintained	Wchannm	0	13	0
Spoil bank only one side of stream	Wchan1	0	31	0
Spoil bank both sides of stream	Wchan2	0		0
Stream channel incision	Wincision	0	21	0
WeirDamRoad decreasing site flooding	Wdamdec	2	2	2
WeirDamRoad/Impounding <10%	Wimp10			
WeirDamRoad/Impounding 10-75%	Wimp75			
WeirDamRoad/Impounding >75%	Wimp100			
Stormwater Inputs	Wstorm	2	2	2
Point Source (non-stormwater)	Wpoint			
Excessive Sedimentation	Wsed			

*** Stressors with weights in boxes were combined during calibration analysis and are counted only once, even if more than one stressor is present.*

APPENDIX C continued

Hydrology Category (continued)	Code	Flats	Riverine	Depression
Filling, excavation on <10% of AA	Wfill10	2	0	8
Filling, excavation on 10-75% of AA	Wfill75	16	11	2
Filling, excavation on >75% of AA	Wfill100			
Soil Subsidence/Root Exposure	Wsubsid	7	0	0
Microtopo alterations on <10% of AA	Wmic10			
Microtopo alteations on 10-75% of AA	Wmic75	16	11	2
Microtopo alterations on >75% of AA	Wmic100			
Buffer Category (100m radius around site)				
Development- commercial or industrial	Ldevcom			
Residential >2 houses/acre	Ldevres3	1 buffer stressor = 3	1 buffer stressor = 1	1 buffer stressor = 4
Residential ≤2 houses/acre	Ldevres2			
Residential <1 house/acre	Ldevres1			
Roads (buffer) mostly dirt or gravel	Lrdgrav			
Roads (buffer) mostly 2- lane paved	Lrd2pav			
Roads (buffer) mostly 4-lane paved	Lrd4pav	2 buffer stressors = 6	2 buffer stressors = 2	2 buffer stressors = 8
Landfill/Waste Disposal	Llndfil			
Channelized Streams/ditches >0.6m deep	Lchan			
Row crops, nursery plants, orchards	Lag			
Poultry or Livestock operation	Lagpoul			
Forest Harvesting Within Last 15 Years	Lfor	≥ 3 buffer stressors = 9	≥ 3 buffer stressors = 3	≥ 3 buffer stressors = 12
Golf Course	Lgolf			
Mowed Area	Lmow			
Sand/Gravel Operation	Lmine			
Intercept/Base Value		95	91	82
Flats IWCrapid= 95 -(∑weights(Habitat+Hydro+Buffer))				
Riverine IWCrapid= 91 -(∑weights(Habitat+Hydro+Buffer))				
Depression IWCrapid= 82 -(∑weights(Habitat+Hydro+Buffer))				

*** Stressors with weights in boxes were combined during calibration analysis and are counted only once, even if more than one stressor is present.*

APPENDIX D: MidTRAM Raw Data and Metric Scores from Estuarine Sites in the Christina River Watershed

Blue columns indicate raw variable values; orange columns indicate corresponding metric scores

Buffer Metrics:

Site Number*	QDR	B1: % of AA with 5m-buffer	B2: Average Buffer Width	B3: Percent Develop-ment	B5: % of Landward Edge Obstructed	B1 Score	B2 Score	B3 Score	B4 Score	B5 Score
RMDTCH11X000	3	100	235	10	10	12	12	6	6	6
RMDTCH11X001	2	100	216	18	100	12	12	3	6	3
RMDTCH11X002	6	100	205	5	100	12	12	9	3	3
RMDTCH11X003	6	100	147	40	100	12	9	3	3	3
RMDTCH11X004	4	100	177	25	10	12	9	3	6	6
RMDTCH11X005	3	100	242	0	0	12	12	12	6	12
RMDTCH11X007	5	100	187	22	100	12	9	3	3	3
RMDTCH11X008	2	100	250	0	0	12	12	12	9	12
RMDTCH11X009	6	100	168	15	100	12	9	6	3	3
RMDTCH11X010	6	100	142	40	100	12	9	3	3	3
RMDTCH11X011	2	100	154	1	0	12	9	9	9	12
RMDTCH11X012	5	100	123	20	60	12	6	3	3	3
RMDTCH11X015	6	80	132	45	100	9	9	3	3	3
RMDTCH11X016	5	100	75	20	100	12	6	3	3	3
RMDTCH11X018	2	100	189	0	0	12	9	12	12	12
RMDTCH11X019	6	80	166	30	50	9	9	3	3	3
RMDTCH11X020	3	100	248	15	0	12	12	6	3	12
RMDTCH11X022	2	100	250	10	100	12	12	6	9	3
RMDTCH11X023	5	100	172	35	100	12	9	3	3	3
RMDTCH11X024	1	100	250	0	0	12	12	12	9	12
RMDTCH11X025	6	100	117	25	100	12	6	3	3	3
RMDTCH11X027	2	100	119	5	100	12	6	9	9	3
RMDTCH11X029	6	100	141	25	100	12	9	3	3	3
RMDTCH11X030	5	100	151	40	30	12	9	3	3	3
RMDTCH11X032	5	85	159	12	100	9	9	6	3	3
RMDTCH11X033	4	100	233	1	0	12	12	9	6	12
RMDTCH11X036	6	100	195	17	50	12	12	3	3	3
RMDTCH11X037	5	100	93	20	100	12	6	3	3	3
RMDTCH11X038	6	100	218	12	100	12	12	6	3	3
RMDTCH11X039	6	75	83	50	100	9	6	3	3	3

* Site numbers are coded by condition categories (green are minimally stressed, yellow are moderately stressed, red are severely stressed)

APPENDIX D continued

Orange columns indicate corresponding metric scores

Hydrology Metrics:

Site Number*	H1 Score	H2 Score	H3 Score	H4 Score
RMDTCH11X000	12	12	12	12
RMDTCH11X001	12	12	12	12
RMDTCH11X002	12	12	3	3
RMDTCH11X003	12	3	3	3
RMDTCH11X004	12	12	12	12
RMDTCH11X005	12	12	12	12
RMDTCH11X007	12	12	3	12
RMDTCH11X008	12	12	3	12
RMDTCH11X009	12	12	3	3
RMDTCH11X010	12	9	12	12
RMDTCH11X011	12	12	12	12
RMDTCH11X012	12	12	12	12
RMDTCH11X015	12	3	3	3
RMDTCH11X016	12	6	12	12
RMDTCH11X018	12	12	3	12
RMDTCH11X019	12	6	6	3
RMDTCH11X020	12	12	3	12
RMDTCH11X022	12	12	12	12
RMDTCH11X023	12	3	3	6
RMDTCH11X024	12	12	3	12
RMDTCH11X025	12	12	12	12
RMDTCH11X027	12	12	12	12
RMDTCH11X029	12	3	12	3
RMDTCH11X030	12	12	3	3
RMDTCH11X032	12	3	3	12
RMDTCH11X033	12	12	3	12
RMDTCH11X036	12	3	3	9
RMDTCH11X037	12	12	9	6
RMDTCH11X038	9	12	3	3
RMDTCH11X039	9	3	3	3

* Site numbers are coded by condition categories (green are minimally stressed, yellow are moderately stressed, red are severely stressed)

Blue columns indicate raw variable values; orange columns indicate corresponding metric scores

Habitat Metrics:

Site Number*	HAB1: Bearing Capacity	HAB2: Veg Obstruc-tion	HAB3: # of Plant Layers	HAB4: Percent Co-dom Invasive spp.	HAB5: Percent Invasive Cover	HAB1 Score	HAB2 Score	HAB3 Score	HAB4 Score	HAB5 Score	Mid-TRAM Score
RMDTCH11X000	9.41	3.25	2	0	0	3	9	6	12	12	73.3
RMDTCH11X001	5.94	8.75	3	0	0	6	6	9	12	12	71.1
RMDTCH11X002	3.28	11.75	1	100	94	9	3	3	3	3	38.9
RMDTCH11X003	1.84	0	3	29	45	12	12	9	6	6	41.7
RMDTCH11X004	5.5	6.75	3	0	0	6	6	9	12	12	71.1
RMDTCH11X005	5.19	0.75	3	14	35	6	12	9	9	6	82.2
RMDTCH11X007	2.91	10.75	3	28.6	15	12	6	9	6	9	56.1
RMDTCH11X008	5.78	2.25	4	0	0	6	9	12	12	12	82.8
RMDTCH11X009	2.13	6	1	100	95	12	6	3	3	3	38.9
RMDTCH11X010	1.5	4	3	0	0	12	9	9	12	12	70.6
RMDTCH11X011	9.28	0.5	3	0	0	3	12	9	12	12	84.4
RMDTCH11X012	5.09	6.75	1	100	96	6	6	3	3	3	46.7
RMDTCH11X015	2.78	11	3	33	20	12	3	9	6	9	35.0
RMDTCH11X016	6.19	4.25	3	12.5	12.5	6	9	9	9	9	56.7
RMDTCH11X018	7.47	0	3	0	0	3	12	9	12	12	80.6
RMDTCH11X019	3.88	8.5	4	20	45	9	6	12	9	6	42.8
RMDTCH11X020	5.75	15	3	0	0	6	3	9	12	12	67.2
RMDTCH11X022	6.19	0.25	3	0	0	6	12	9	12	12	80.0
RMDTCH11X023	6.47	7	3	14	20	6	6	9	9	9	40.0
RMDTCH11X024	4.31	13.5	2	0	0	9	3	6	12	12	76.1
RMDTCH11X025	4.66	5.5	3	17	55	9	9	9	9	3	60.0
RMDTCH11X027	7.06	1	3	0	0	3	12	9	12	12	75.6
RMDTCH11X029	3.03	3.75	4	50	80	12	9	12	6	3	47.8
RMDTCH11X030	3.13	2.5	4	40	60	9	9	12	6	3	45.6
RMDTCH11X032	4.22	7.25	3	0.33	24	9	6	9	12	6	47.8
RMDTCH11X033	6.94	9.75	3	33	60	3	6	9	6	3	60.6
RMDTCH11X036	3.41	8.25	3	50	30	9	6	9	6	6	42.8
RMDTCH11X037	5.16	3.5	3	25	45	6	9	9	6	6	49.4
RMDTCH11X038	2.69	7.25	1	100	95	12	6	3	3	3	38.3
RMDTCH11X039	5.06	5.5	1	100	85	6	9	3	3	3	18.9

APPENDIX E: DERAP Wetland Assessment Stressor Checklist for Non-tidal Flat Wetlands in the Christina River Watershed

Stressor descriptions are listed in Appendix B. ‘1’ indicates stressor presence; ‘0’ indicates stressor absence.

Habitat and Plant Community Stressors

Site Number*	QDR	DERAP Score	Hfor31	Hfor16	Hfor3	Hfor2	Hcc10	Hcc50	Hcc100	Hforsc	Hpine	Hchem	Hmow	Hfarm	Hgraz	Hhorecov	Hinv1	Hinv5	Hinv50	Hinv100	Hherb	Halgae	Hnis50	Hnis100	Htrail	Hroad	Hpave
CH0124	2	91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
CH0013	2	89	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0030	2	89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
CH0060	3	89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0068	2	88	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
CH0021	3	86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0015	3	85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
CH0019	3	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0029	3	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
CH0063	3	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0071	3	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0046	4	80	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0009	4	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
CH0027	3	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
CH0107	2	78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
CH0001	4	76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
CH0079	5	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
CH0075	4	71	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
CH0004	5	65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
CH0003	4	61	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0091	4	61	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0081	4	58	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0
CH0131	5	58	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
CH0022	5	56	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
CH0038	4	55	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
CH0100	5	55	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0065	5	52	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
CH0007	6	51	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0076	3	51	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
CH0121	6	46	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0055	6	45	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
CH0017	5	43	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0

* Site numbers are coded by condition categories (green are minimally stressed, yellow are moderately stressed, red are severely stressed)

APPENDIX E continued

Stressor descriptions are listed in Appendix B. ‘1’ indicates stressor presence; ‘0’ indicates stressor absence.

Hydrology Stressors

Site Number*	QDR	DERAP Score	Wditchs	Wditchm	Wditchx	Wchanm	Wchan1	Wchan2	Wincision	Wdamdec	Wimp10	Wimp75	Wimp100	Wstorm	Wpoint	Wsed	Wfill10	Wfill75	Wfill100	Wmic10	Wmic75	Wmic100	Wsubsid
CH0124	2	91	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0013	2	89	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0030	2	89	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0060	3	89	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0068	2	88	0	0	0	-	-	-	-	0	0	0	0	0	0	0	1	0	0	0	0	0	0
CH0021	3	86	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0015	3	85	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	1
CH0019	3	84	0	0	0	-	-	-	-	0	0	0	0	0	0	0	1	0	0	0	0	0	0
CH0029	3	84	0	0	0	-	-	-	-	0	0	0	0	0	0	0	1	0	0	0	0	0	0
CH0063	3	82	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	1	0	0	0
CH0071	3	82	1	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0046	4	80	0	0	0	-	-	-	-	0	0	0	0	1	0	0	0	0	0	1	0	0	0
CH0009	4	79	0	1	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0027	3	79	0	1	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0107	2	78	1	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0001	4	76	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	1	0	1	0	0	0
CH0079	5	75	0	1	0	-	-	-	-	0	0	0	0	0	0	0	0	1	0	0	0	0	0
CH0075	4	71	0	0	0	-	-	-	-	0	0	0	0	1	0	0	1	0	0	1	0	0	0
CH0004	5	65	0	0	1	-	-	-	-	0	0	0	0	0	0	0	0	1	0	0	0	0	0
CH0003	4	61	1	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0091	4	61	0	0	0	-	-	-	-	0	0	0	0	0	0	0	1	0	0	1	0	0	0
CH0081	4	58	0	0	0	-	-	-	-	0	0	0	0	1	0	0	1	0	0	0	0	0	0
CH0131	5	58	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	1	1	0	0	0
CH0022	5	56	1	0	0	-	-	-	-	0	0	0	0	0	0	0	1	0	0	0	1	0	0
CH0038	4	55	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	1	0	0
CH0100	5	55	1	0	0	-	-	-	-	0	0	0	0	0	0	0	0	1	0	0	0	0	0
CH0065	5	52	0	0	1	-	-	-	-	0	0	0	0	0	0	0	0	1	0	0	1	0	0
CH0007	6	51	0	0	0	-	-	-	-	0	0	0	0	0	0	0	0	0	1	0	0	0	0
CH0076	3	51	0	1	0	-	-	-	-	0	0	0	0	0	0	0	1	0	0	1	0	0	0
CH0121	6	46	0	0	1	-	-	-	-	0	0	0	0	0	0	0	0	0	1	0	0	0	0
CH0055	6	45	0	1	0	-	-	-	-	1	0	0	0	0	0	0	0	1	0	0	1	0	0
CH0017	5	43	1	0	0	-	-	-	-	0	0	0	0	0	0	0	1	0	0	1	0	0	0

* Site numbers are coded by condition categories (green are minimally stressed, yellow are moderately stressed, red are severely stressed)

APPENDIX E continued

Stressor descriptions are listed in Appendix B. ‘1’ indicates stressor presence; ‘0’ indicates stressor absence.

Buffer Stressors

Site Number*	QDR	DERAP Score	Ldevcom	Ldevres3	Ldevres2	Ldevred1	Lrdgrav	Lrd2pav	Lrd4pav	Llndfil	Lchan	Lag	Lagpoul	Lfor	Lgolf	Lmow	Lmine
CH0124	2	91	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
CH0013	2	89	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
CH0030	2	89	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
CH0060	3	89	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
CH0068	2	88	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
CH0021	3	86	0	0	0	1	1	0	0	0	1	0	0	0	0	1	0
CH0015	3	85	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0019	3	84	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0
CH0029	3	84	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0
CH0063	3	82	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
CH0071	3	82	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0046	4	80	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
CH0009	4	79	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
CH0027	3	79	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
CH0107	2	78	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
CH0001	4	76	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
CH0079	5	75	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
CH0075	4	71	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0
CH0004	5	65	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0
CH0003	4	61	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0
CH0091	4	61	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
CH0081	4	58	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0
CH0131	5	58	1	0	0	0	0	0	1	0	0	0	0	1	0	1	0
CH0022	5	56	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0
CH0038	4	55	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
CH0100	5	55	0	0	0	0	0	0	1	0	1	0	0	1	0	1	0
CH0065	5	52	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
CH0007	6	51	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
CH0076	3	51	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
CH0121	6	46	1	0	0	0	0	0	1	0	1	0	0	1	0	1	0
CH0055	6	45	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
CH0017	5	43	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0

* Site numbers are coded by condition categories (green are minimally stressed, yellow are moderately stressed, red are severely stressed)

APPENDIX F: DERAP Wetland Assessment Stressor Checklist for Non-tidal Riverine Wetlands in the Christina River Watershed

Stressor descriptions are listed in Appendix B. ‘1’ indicates stressor presence; ‘0’ indicates stressor absence.

Habitat and Plant Community Stressors

Site Number*	QDR	DERAP Score	Hfor31	Hfor16	Hfor3	Hfor2	Hcc10	Hcc50	Hcc100	Hforsc	Hpine	Hchem	Hmow	Hfarm	Hgraz	Hhorecov	Hinv1	Hinv5	Hinv50	Hinv100	Hherb	Algae	Hnis50	Hnis100	Htrail	Hroad	Hpave
CH0028	3	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0092	3	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
CH0002	2	85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
CH0047	3	84	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0016	4	83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0125	3	83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
CH0104	3	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
CH0066	5	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0050	3	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0072	3	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0032	4	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0036	5	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0054	4	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0037	3	63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0044	4	62	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0051	3	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
CH0114	4	62	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0062	3	59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
CH0010	4	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
CH0058	6	55	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0136	4	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0064	4	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0098	5	49	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0101	5	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
CH0005	4	46	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0113	5	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0134	4	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
CH0096	6	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
CH0126	4	38	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0
CH0014	4	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0025	5	37	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
CH0052	5	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0082	5	36	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CH0049	4	31	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0006	5	24	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0
CH0031	5	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
CH0020	5	20	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
CH0069	5	16	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
CH0033	5	13	1	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1
CH0067	6	6	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

* Site numbers are coded by condition categories (green are minimally stressed, yellow are moderately stressed, red are severely stressed)

APPENDIX F continued

Stressor descriptions are listed in Appendix B. ‘1’ indicates stressor presence; ‘0’ indicates stressor absence.

Hydrology Stressors

Site Number*	QDR	DERAP Score	Wditchs	Wditchm	Wditchx	Wchannm	Wchan1	Wchan2	Wincision	Wdamdec	Wimp10	Wimp75	Wimp100	Wstorm	Wpoint	Wsed	Wfill10	Wfill75	Wfill100	Wmic10	Wmic75	Wmic100	Wsubsid
CH0028	3	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0092	3	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
CH0002	2	85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0047	3	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
CH0016	4	83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
CH0125	3	83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
CH0104	3	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0066	5	71	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
CH0050	3	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0072	3	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0032	4	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0036	5	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0054	4	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0037	3	63	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
CH0044	4	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0051	3	62	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0114	4	62	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0062	3	59	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CH0010	4	57	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
CH0058	6	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
CH0136	4	51	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
CH0064	4	49	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0098	5	49	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	1	0	0	0
CH0101	5	48	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0
CH0005	4	46	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
CH0113	5	45	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
CH0134	4	45	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0096	6	39	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0
CH0126	4	38	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0
CH0014	4	37	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
CH0025	5	37	0	0	0	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0
CH0052	5	36	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0
CH0082	5	36	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
CH0049	4	31	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0
CH0006	5	24	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0
CH0031	5	21	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
CH0020	5	20	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	1	0	0	0
CH0069	5	16	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0
CH0033	5	13	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
CH0067	6	6	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0

* Site numbers are coded by condition categories (green are minimally stressed, yellow are moderately stressed, red are severely stressed)

APPENDIX F continued

Stressor descriptions are listed in Appendix B. ‘1’ indicates stressor presence; ‘0’ indicates stressor absence.

Buffer Stressors

Site Number	QDR	DERAP Score	Ldevcom	Ldevres3	Ldevres2	Ldevred1	Lrdgrav	Lrd2pav	Lrd4pav	Llndfil	Lchan	Lag	Lagpoul	Lfor	Lgolf	Lmow	Lmine
CH0028	3	88	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0
CH0092	3	87	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
CH0002	2	85	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
CH0047	3	84	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
CH0016	4	83	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0
CH0125	3	83	1	0	0	0	0	1	0	0	1	0	0	0	0	1	0
CH0104	3	80	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0
CH0066	5	71	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0
CH0050	3	70	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
CH0072	3	69	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
CH0032	4	68	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0
CH0036	5	68	1	0	0	0	0	0	0	0	1	0	0	1	0	1	0
CH0054	4	68	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0
CH0037	3	63	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
CH0044	4	62	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
CH0051	3	62	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0
CH0114	4	62	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0
CH0062	3	59	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
CH0010	4	57	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
CH0058	6	55	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
CH0136	4	51	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
CH0064	4	49	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0098	5	49	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
CH0101	5	48	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0
CH0005	4	46	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
CH0113	5	45	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
CH0134	4	45	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0
CH0096	6	39	0	0	0	1	0	0	1	0	1	1	0	0	0	1	0
CH0126	4	38	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CH0014	4	37	0	0	0	1	0	1	0	0	1	0	0	0	0	1	0
CH0025	5	37	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0
CH0052	5	36	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0
CH0082	5	36	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0
CH0049	4	31	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
CH0006	5	24	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
CH0031	5	21	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0
CH0020	5	20	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0
CH0069	5	16	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
CH0033	5	13	1	0	0	0	1	0	0	0	0	1	0	0	0	1	0
CH0067	6	6	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0

* Site numbers are coded by condition categories (green are minimally stressed, yellow are moderately stressed, red are severely stressed)

APPENDIX G: DERAP Wetland Assessment Stressor Checklist for Non-tidal Depression Wetlands in the Christina River Watershed

Stressor descriptions are listed in Appendix B. ‘1’ indicates stressor presence; ‘0’ indicates stressor absence.

Habitat and Plant Community Stressors

Site Number*	QDR	DERAP Score	Hfor31	Hfor16	Hfor3	Hfor2	Hcc10	Hcc50	Hcc100	Hforsc	Hpine	Hchem	Hmow	Hfarm	Hgraz	Hnorecov	Hinv1	Hinv5	Hinv50	Hinv100	Hherb	Algae	Hnis50	Hnis100	Htrail	Hroad	Hpave
CH0011	4	15	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
CH0080	5	48	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0

Hydrology Stressors

Site Number*	QDR	DERAP Score	Wditchs	Wditchm	Wditchx	Wchannm	Wchan1	Wchan2	Wincision	Wdamdec	Wimp10	Wimp75	Wimp100	Wstorm	Wpoint	Wsed	Wfill10	Wfill75	Wfill100	Wmic10	Wmic75	Wmic100	Wsubsid
CH0011	4	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
CH0080	5	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Buffer Stressors

Site Number*	QDR	DERAP Score	Ldevcom	Ldevres3	Ldevres2	Ldevred1	Lrdgrav	Lrd2pav	Lrd4pav	Llndfil	Lchan	Lag	Lagpoul	Lfor	Lgolf	Lmow	Lmine
CH0011	4	15	1	0	0	0	0	1	0	0	1	0	0	0	0	1	0
CH0080	5	48	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0

* Site numbers are coded by condition categories (green are minimally stressed, yellow are moderately stressed, red are severely stressed)

This report and other watershed condition reports, assessment methods, and scoring protocols can be found on the Delaware Wetlands and the Partnership for the Delaware Estuary website:

Delaware Wetlands

Purify Provide Protect

http://de.gov/delawarewetlands

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