ATTACHMENT V

Written Public Comments
VIA EMAIL

To: The North Carolina Department of Environmental Quality - Division of Waste Management

RE: Comments on the “Proposed Coal Combustion Residual (CCR) Rule”

October 15, 2018

On behalf of Blue Ridge Environmental Defense League (BREDL) I offer the following comments on the “Proposed Coal Combustion Residual (CCR) Rule. BREDL does not support the landfilling of coal ash. Transferring health and environmental risks and liabilities from one community to the next is not a solution and is not protective of public health or the environment. Coal ash should be stored above-ground on utility property—isolated from the environment.¹

¹ See BREDL Report: Coal Ash Disposition: The Alternative for North Carolina
Blue Ridge Environmental Defense League Chapters Impacted by Coal Ash Impoundments, Existing Landfills, Coal Ash Leachate or Sludge Disposal, Proposed Coal Ash Recycling Facilities and Clay Mines

Chatham Citizens Against Coal Ash Dump (CCACAD) Chatham County
EnvironmentaLEE (ELEE) Lee County
No Fracking in Stokes (NFIS) Stokes County
Northampton County Citizens Against Coal Ash (NCCACA) Northampton County
Pee Dee WALL (WALL) Anson County
Person County Pride (PCPRIDE) Person County
Sampson Citizens for a Safe Environment (SCSE) Sampson County

GENERAL COMMENTS

Climate Change Exposure Assessments

Considering the climate crisis which is resulting in chaotic weather and impacting coal ash disposal facilities including landfills, climate change exposure assessments should be required for currently permitted structural fills/landfills, as well as those considered in the future. It is important to evaluate the impacts that severe weather will have on leachate collection systems, cover integrity, the potential for run-off into surface water and the possibility of structural failure.

2 Some chapters have more than one- for Example CCACAD has five
Environmental Justice

The Department of Environmental Quality must make environmental justice a priority, not simply a box to check or a public relations exercise. The proposed Rule does not provide any meaningful provisions regarding environmental justice—no remedy, no enforcement. Any rule pertaining to waste disposal must include a rigorous examination of disproportionate impacts to low-income communities and communities of color and provide a strong regulatory framework to prevent discriminatory siting of polluting facilities.

Mine “Reclamation”

DEQ allowing the excavation of land which had never been used for mining and calling it “mine reclamation” and “beneficial reuse” for the purpose of coal ash disposal has cost the taxpayers many thousands of dollars. The scheme was hatched in 2014—resulting in coal ash landfills being permitted as “mine reclamation” in Chatham and Lee Counties. It was clearly concocted to provide a way for Duke Energy and their contractor Charah to get out from under stricter solid waste landfill regulations and local government approval. In Lee County, over 70% of the site has never been excavated, and the Chatham County site was in a similar state. EPA does not consider the Brickhaven and Colon sites “beneficial reuse”—in fact EPA considers them landfills. Using coal ash for “mine reclamation” should not be permitted.

Landfill Liners

Landfill liners do not protect groundwater. World renowned landfill expert Dr. G. Fred Lee has long been critical of the “dry tomb” approach for municipal solid waste landfills. His many studies and reports outline the certainty of liner failure, insufficient monitoring wells placed far
apart, inadequate post-closure care and financial assurance. In comments prepared for Blue Ridge Environmental Defense League regarding the Brickhaven and Colon coal ash landfills, Dr. Lee stated, “However, there is no doubt that eventually the liner will fail to prevent pollution of groundwater with waste-derived leachable components. Since landowners near a landfill should be entitled to groundwater free of hazardous and deleterious chemicals forever, wastes with leachable components such as coal combustion ash should not be permitted to be deposited in landfills that do not provide protection of the groundwater resources forever.”

The efficacy of using composite liner systems for containment of coal ash has not been demonstrated. Dr. Dennis Lemly, Research Associate Professor of Biology at Wake Forest University points out that there is no performance data to indicate that this design is suitable for coal ash disposal. In a report submitted to the United States Environmental Protection Agency, Dr. Lemly concluded, “Coal ash produces leachate with an exceptionally high anionic strength due to the presence of sulfate, chloride, and many other constituents. Sulfate concentrations alone can exceed 30,000 mg/L. Moreover, ammoniated coal ash, which is the predominant form produced today, enhances the leaching rate of elements that form anionic compounds in solution selenium, arsenic, molybdenum, fluoride, and vanadium. Collectively, these factors suggest that failure of HDPE liner material in a coal ash application is
very possible for chemical reasons unrelated to direct degradation of the membrane itself.”

**Characterization of Coal Ash Toxicity**

Coal ash contains toxic constituents and is not a benign waste stream. It contains heavy metals such as arsenic, selenium, mercury, and chromium, often present as hexavalent chromium, and radionuclides. Despite the most current research on appropriate test methods for coal combustion residuals, DEQ continues to support the use of the “Toxicity Characteristic Leaching Procedure” (TCLP) for the characterization of coal ash. The test was never intended for this use and may underestimate the toxicity of the CCR. The US Environmental Protection Agency (EPA) does not recommend that the test be used for the characterization of coal ash waste. In its final rule on the disposal of coal combustion residues EPA said that, “For landfills, EPA agrees that TCLP, SPLP and other single pH test methods may not be the most appropriate leachate extraction methods for all waste streams and all disposal scenarios.” Using the TCLP allows what could very likely be hazardous waste to be disposed of in less-regulated facilities. It is incumbent upon the DEQ to require the most sensitive and accurate analytical methods to protect public health and the environment.

- PCBs

Duke Energy coal ash co-contaminated with PCBs was disposed of at the Brickhaven coal ash landfill in Chatham County. Because Duke Energy was allowed to use the TCLP, which is unreliable and has severe limitations, the true level of PCBs in the coal ash is unknown. BREDL has raised the potential for this kind of event with the Department numerous times. The proposed
Rule should include testing protocols for PCBs and other possible coal ash co-contaminants, using the most accurate and sensitive analytical methods.

• Radioactivity

The TCLP does not measure radionuclides. Coal ash contains varying amounts of Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM). Recent research has shown that coal ash is more radioactive than previously understood; a study by Duke University revealed that the presence of radioactive contaminants in coal ash was up to five times higher than the parent coal. More recently, analysis of groundwater at Duke Energy coal ash impoundments found levels of radioactivity higher than would be expected from background sources. On-site monitoring of radioactivity should be required using methods approved by the Department. Additionally, protocols for testing the CCR should be established using the most accurate and sensitive analytical methods.

Municipal Solid Waste Landfills

Municipal solid waste landfills (MSWLF) are particularly unsuitable for the disposal of CCR. MSWLFs which accept CCR should be subject to any applicable proposed rule more stringent than current solid waste regulations.

Closure

The proposed 30-year post-closure monitoring requirement is totally inadequate. Monitoring of coal ash landfills must be required as long as the waste remains a threat - which is forever. Additionally, closure costs and bonding should be calculated on the real costs for “cleanup”.
Coal Ash “Recycling”

“Sham recycling” has long been a practice used by the waste industry. The permitting of the proposed STAR coal ash recycling facilities at the Buck Combined Cycle Plant in Rowan County and the HF Lee plant in Wayne County have underlined the need for inter-divisional cooperation within DEQ on this new industry. The Division of Air Quality has allowed Duke Energy to avoid a Commercial Solid Waste Incinerator (CISWI) permitting designation for this facility. However, there are no requirements as to how much coal ash must be “recycled” for them to be exempted from the CISWI regulations. The proposed CCR Rule should include guidance on such facilities, and Duke Energy should be required to provide documentation from existing STAR facilities so that a determination can be made regarding this practice.
Monitoring Wells

Lined landfills do not typically produce large plumes of contamination. Because of the standard design of a landfill monitoring system, it is unlikely that contamination will be detected before it is widespread. A monitoring well system should be designed with intersecting zones of capture to provide for a high likelihood of detection of groundwater contamination.

Workers

Former workers that were contracted to “clean up” the 2008 coal ash spill in Kingston, Tennessee are experiencing an alarming incidence of illness and death. The workers were not provided with masks or other protective equipment. According to media reports, workers at the Brickhaven coal ash landfill in Chatham County are not provided with masks or other protective equipment. It is doubtful that workers at other facilities have been provided with masks or gloves. The Department of Environmental Quality should coordinate with the Department of Health and Human Services and the Department of Labor to establish requirements to protect workers who are exposed to coal ash.

Air Quality

During transportation of coal ash by truck, air monitoring conducted near the Brickhaven coal ash landfill by consultants for Chatham County showed significant increases of heavy metals, particulates and silicon.³ Thousands of North Carolinians live in communities where coal ash is being excavated and transported. Thousands more live along transport routes. Additional

³ Above background
rulemaking should be undertaken to develop air quality regulations that protect workers and communities.

Rather than relying on technology that at best “kicks the can down the road” and that continues to victimize communities, North Carolina has an opportunity to lead the way on the disposition of coal ash.

Respectfully Submitted,

Therese Vick
North Carolina Healthy, Sustainable Communities/Coal Ash Campaign Coordinator
October 15, 2018

Ellen Lorscheider

Division of Waste Management

Dept of Environmental Quality

Dear Ms Lorscheider:

Clean Water for North Carolina is a statewide, science-based, Environmental Justice organization with members in over 60 counties. We have been involved in researching groundwater impacts of coal ash since 2007 and have worked with coal ash impacted communities around three Duke coal-fired plants: Asheville, Cliffside and Roxboro. Thanks for the opportunity to comment on the draft CCR rules.

We were pleased to read that DEQ did an extensive reviews of its proposed and existing CCR requirements to ensure that NC requirements would be at least as protective as federal requirements. One example that was discussed is the possibility of creating citizen suit provisions for these regulations, something that we heartily support, but I understand that is a proposal, not anything included in these draft rules.

Some definitions that we find very concerning as they present problems in their use as purporting to create a protective set of rules:

100 year flood—this is a gravely inadequate level of protection for all aspects of landfill construction, given climate changes already happening. Until the 100 year flood can be credibly re-defined, under current climate conditions, it is simply not reasonable to assume that previously defined 100 year storm events will only have a 1% chance of occurrence in any given year! Both Floyd and Florence have been described as 500 to 1,000 year flooding events, and yet they happened within 19 years of each other.

All of the “factors of safety” listed in these regulations, in regard to construction standards, dam safety and resistance to leaching of chemicals in CCR must be re-evaluated to be far more protective of human health, safety and the environment.
The term “structural fill” has been misused by the agency to imply a beneficial use for coal ash landfills that actually include filling significant newly excavated areas which did NOT need to be remediated or filled. DEQ must remove this definition or revise it to exclude disingenuous statements about benefits of these coal ash landfills.

"Coal combustion residuals surface impoundment" means a topographic depression, excavation, or diked area that is: primarily formed from earthen materials; without a base liner. Such impoundments must not be allowed. All residuals must be stored above ground surface, in dry landfills away from 500 year flood plain and separated by at least 10 feet from highest recorded groundwater level.

Application, Siting requirements

While we realize that some stronger requirements for siting and depth to groundwater are included in these rules for new coal ash storage sites, none of those requirements were in place at the time our state’s current coal ash basins were sited and constructed. The reasonably foreseeable consequences of locating basins in the flood plain, completely unlined and even immersed in groundwater have all come to pass, with flooding washing out ash into public waters, and leaching of toxic contaminants into the public’s groundwater.

A separation of only 5 feet between the seasonal high groundwater level and bottom of settled ash is far from adequate to protect groundwater from leaching of coal ash constituents. No matter how impervious the line system in place, unexpected rainfall and flooding events could result in shifting of this “seasonal high groundwater” level and resulting groundwater contamination.

Preventing siting a coal ash landfill within 200 feet of a known fault zone is insufficient to protect landfill structural integrity from instabilities. Siting requirement must include substantially greater distance to assure that seismic events do not cause damage to impervious liner, caps or shifting of ash.

Compliance boundaries for all coal ash storage sites must be set within 100 feet of the permitted boundary of deposited coal ash, rather than much larger distances--even the boundary of the landfill owner’s property as in the past-- in order to protect the public’s resources, and hold the landfill owner and operator accountable.

Public notice allowing 45 days for public comment is excellent. However, allowing notice of a permit hearing as little as 15 days before the hearing is inadequate; this must be increased to 30 days. Allowing for any member of public to request a public hearing at any time during the public comment period is also good, but when the decision to hold a hearing comes within 30 days of the end of the comment period, the comment period must be extended to allow comments at least 15 days after the hearing.

Application Requirements must include a bond sufficient to cover liability/cost of clean up associated with any damage to the environment, including groundwater, surface water and land, or any offsite property damage due to inadequate management of the landfill construction, operation, maintenance and compliance requirements, including closure and post-closure monitoring.

No landfill shall be sited in a 500 year floodplain, regardless of whether it restricts the flow of the flood. No CCR landfill shall be sited in an area including an identified wetland, whether or not a “feasible alternative” has been identified.
200 feet is a gravely inadequate distance from an identified fault zone to site any landfill, much less one containing coal combustion residuals. The back distance from a fault zone to the permitted boundary of a CRR unit must be at least ¼ mile.

Seismic impact areas—CCR landfills and any potential lateral extensions must not be sited within seismic impact areas or unstable location, no matter how confident the site engineers are of the stability of the landfill structure.

To aid in making a determination as to whether the property is of archeological or historical significance, the State’s Historic Preservation Office in the Department of Natural and Cultural Resources must require the owner and operator to perform a site-specific survey in consultation with any community or tribe within 2 miles, for inclusion in the Site Study.

No CCR waste storage shall be permitted within 2,000 feet of any critical water supply watershed, with no exceptions.

Each applicant for CCR storage site must assure that there will be no disproportionate and adverse impacts to Title VI communities. Greater rigor than current NC DOT protocol must be applied in evaluating whether a population within a census block neighboring a proposed facility is disproportionately impacted. That population must be compared to the statewide average for BOTH income and minority status. Currently that determination for minority communities only compares the percentage of a minority group/people of color only to the demographics of the county in which the facility would be located. For high minority counties, this results in a significant under assessment of disproportionate impact, essentially writing off entire counties as not able to produce evidence of disproportionate impact.

Horizontal separation: 300 feet is an inadequate buffer between permitted boundary for deposited residuals and neighboring property or body of water. This distance must be increased to at least 1,000 feet to minimize risks of blowing ash, runoff carrying ash to public waters in extreme weather, or spread of contaminated groundwater.

Vertical separation: The bottom of any coal combustion residual storage must be above the pre-construction grade of the site, and at least 10 feet above the highest known groundwater level.

**Closure and Post Closure Requirements**

The public must be notified of all closure plans at least 60 days before intended start of closure activities, and a public comment period and hearing announced.

While we know that some improved conditions for siting and depth to groundwater are included in these rules for new coal ash storage sites, none of those requirements were in place at the time our state’s current coal ash basins were sited and constructed. Each of the existing sites must be considered an ongoing regulatory failure, needing near-term remediation, with removal of all ash to above ground, dry storage away from bodies of water and at least 10 feet above the highest groundwater level in the past 100 years at that location, as well as remediation of impacted soils and groundwater.
“Cap in place” for current badly sited, poorly dammed and managed and contaminant-leaching landfills, must never be considered a permanent or acceptable solution. Furthermore, DEQ’s acceptance of such an outcome will perpetuate the injustice to communities around facilities such as Belews Creek and Roxboro Steam Station, predominantly African American and of modest means, and continue to allow dispersal of coal ash into cooling ponds and public waters, as occurred in recent flooding from tropical storm Florence. The only acceptable solution to the massive problems created by Duke Energy’s existing coal ash sites will be removal of ash to dry, above-ground storage within 2 years, out of a 1,000 year flood plain, and complete decontamination of the current location. Until reprocessing can substantially reduce the volume of coal combustion waste, this is the only responsible way to deal with conditions that should never have been allowed to develop.

Compliance boundaries for all coal ash storage sites must be within 100 feet of the deposited coal ash, rather than much larger distances or even the boundary of the landfill owner’s property as in the past, in order to protect the public’s resources, and hold the landfill owner and operator accountable.

Post closure monitoring must continue for a period of greater than 30 years, unless complete removal of CCR and decontamination have occurred. The landfill owner must maintain complete liability for the site, to be reflected in a bond posted guaranteeing the lack of movement of ash or any of its characteristic toxic contaminants from an area within 100 feet of the deposited ash. We greatly hope that the growing awareness of the harm of coal’s emissions and new regulatory requirements will prevent any new coal ash storage sites will be needed in the future, except for removal of ash from current, highly vulnerable and contaminating sites to fully lined, above ground storage, far from surface water and groundwater.
Dear Ms. Lorscheider,

Duke Energy hereby submits (attached to this e-mail) its comments on the North Carolina Department of Environmental Quality’s (NCDEQ) Proposed Rules Relating to the Disposal and Recycling of Coal Combustion Residuals (15A N.C.A.C. 13B .2001 et al.) and Additional Requirements for Dams that Impound Coal Combustion Residuals (15A N.C.A.C. 02K .0224). Duke Energy appreciates the opportunity to comment on NCDEQ’s proposed rules package. As reflected in our comments, we support implementation of the CCR rule through an enforceable state permit program, which allows for the consideration of site-specific factors in lieu of the current one-size-fits-all regulatory regime.

Sincerely,
Michael Kafka
COMMENTS OF DUKE ENERGY

on the

North Carolina Department of Environmental Quality’s Proposed Rules Relating to
The Disposal and Recycling of Coal Combustion Residuals
(15A N.C.A.C. 13B .2001 et al.)
&
Additional Requirements for Dams that Impound Coal Combustion Residuals
(15A N.C.A.C. 02K .0224)

Submitted to:

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October 15, 2018

Duke Energy has long supported the regulation of coal combustion residuals ("CCR") as nonhazardous waste under Subtitle D of the Resource Conservation and Recovery Act ("RCRA"), and welcomes the opportunity to provide comment on the Proposed Rules. Regulatory certainty is of utmost importance as we continue to make investments on behalf of our customers to comply with state and federal CCR regulations. To that end, Duke Energy has been diligently working to install the necessary systems to transition to dry ash management, further enhance the structural stability of dams, and dewater and safely close coal ash surface impoundments.

Headquartered in Charlotte, N.C., Duke Energy’s Electric Utilities and Infrastructure business unit serves approximately 3.4 million customers in North Carolina. At such time the Coal Ash Management Act of 2014 ("CAMA") was promulgated, Duke Energy had 31 CCR surface impoundments in its coal-fired fleet across North Carolina and eight operational CCR landfills. The Company is making significant investments in these facilities to comply with the CAMA and is irrevocably on the path toward closure of all ash basins in the state. In fact, two basins in the state (Asheville 1982 Basin and Cliffside Units 1-4 Basin) have already been completely excavated, and Duke Energy is nearing completion of the two ash basins at Riverbend. At the same time, we continue to move toward closure of the 1964 basin at Asheville, as well as the ash basins at our Dan River and Sutton plants.

The outcome of this rulemaking is extremely important to Duke Energy and its customers, and the Company appreciates DEQ’s efforts to amend North Carolina’s solid waste and dam rules to align the requirements with the authorities provided by the Water Infrastructure Improvements for the Nation Act ("WIIN Act"). The WIIN Act fundamentally changed the statutory authority underpinning the federal Disposal of Coal Combustion Residuals From Electric Utilities rule at 40 C.F.R. Part 257 ("CCR Rule") by giving states the authority to implement and enforce the CCR Rule through state permit programs. It is, therefore, logical to amend the state rules to incorporate the federal criteria and establish other criteria that EPA determines are at least as protective as the criteria in the CCR Rule. Although this rulemaking is only a first step for the state to align its CCR management program with the CCR Rule, the ultimate approval of a North Carolina CCR permit program by EPA will allow common-sense, site-specific solutions that protect the environment under a proven regulatory construct.
Definitions (15A N.C.A.C. 13B .2002)

1. Proposed Section .2002(3) would define “aquifer” as “a geological formation, group of formations, or portion of a formation capable of yielding groundwater.” Consistent with the CCR Rule, the words “usable quantities of” should be added between the words “yielding” and “groundwater” above.

2. Consistent with CAMA, proposed Section .2002(6) would define “beneficial” and “benefit.” In contrast, the CCR Rule has a definition of “beneficial use of CCR,” and the language at Section .2018(c) largely mirrors that definition. On page 2-11 of EPA’s interim final Coal Combustion Residuals State Permit Program Guidance Document (Aug. 2007), EPA explains as follows:

   EPA will not be reviewing (or approving) a State’s beneficial use program as part of evaluating whether to approve the State’s CCR permit program. However, EPA will need to evaluate whether the State’s CCR permit program regulates the same activities as the federal regulations in part 257. In that regard, EPA would need to evaluate the state’s beneficial use definition, to ensure that activities that are considered to be the disposal of CCR under the federal regulations are also regulated as such under a State’s CCR permit program.

   To align the final state rule with the CCR Rule and facilitate ultimate EPA approval of the state program, Duke Energy recommends that DEQ move the language from .2018(c) setting out the beneficial use criteria to .2002, and create a new definition for “beneficial use of CCP” while retaining the definitions of “beneficial” and “benefit” to be consistent with CAMA.

3. Proposed Section .2002(19) defines an impoundment as “without a base liner.” Although this proposed definition tracks the statutory definition in CAMA, it is inconsistent with the CCR Rule’s broader definition, which does not address the existence of a liner. These different definitions could cause a particular impoundment to meet the more expansive definition of “CCR surface impoundment” under the CCR Rule but not under the state rule. We propose adding a new term—“lined CCR surface impoundment” to refer to units constructed with a base liner approved for use by Article 9 of Chapter 130A of the General Statutes or rules adopted thereunder for a
combustion products landfill or coal combustion residuals landfill, industrial landfill, or municipal solid waste landfill and globally inserting this new definition throughout the entire rule as the context requires.

4. Proposed Section .2002(33) would define “groundwater” as “those waters occurring in the subsurface under saturated conditions.” This proposed definition does not clarify the groundwater definition sufficiently to conclude that water below a surface is not necessarily groundwater. “Subsurface” is vague and needs to be better defined. The subsurface of what? This vagueness in the proposed regulatory definition would leave Duke Energy at risk that groundwater could be defined as water under any surface. The definition should be clarified consistent with the CCR Rule (i.e., “water below the land surface in a zone of saturation”) to avoid an incorrect interpretation that pore water in a basin is “groundwater.”

5. Proposed Section .2002(46) would define “liquid waste” as “any waste material that is determined to contain ‘free liquids’ as defined by Method 9095 (Paint Filter Liquids Test), S.W. 846.” RCRA § 3004(c)(3) generally prohibits “the placement of any liquid which is not a hazardous waste in a [permitted hazardous waste] landfill.” EPA promulgated regulations regarding the disposal of nonhazardous liquid wastes at hazardous waste landfills in 40 C.F.R. § 264.314 (and § 265.314). Pursuant to § 264.314(b), Method 9095B (Paint Filter Liquids Test), as described in “Test Methods for Evaluating Solid Waste, Physical/Chemical Methods” (S.W.846), must be used “[t]o demonstrate the absence or presence of free liquids in either a containerized or a bulk waste.” However, it is important to note that, although the paint filter test was subsequently extended to apply to MSWLF under 40 C.F.R. Part 258, EPA guidance makes clear that there is no prohibition on the disposal of liquids in Part 257 nonhazardous waste landfills, provided such disposal does not cause the facility to fail to meet its performance standards and the accumulation of liquids is avoided. See letter from John H. Skinner, Dir., EPA Office of Solid Waste, to Kevin Bromberg, Small Business Administration, titled “Disposal of Nonhazardous Liquid Wastewaters and Sludges in Sanitary Landfills under RCRA and HSWA” (Jan. 22, 1985) (explaining EPA “has no specific regulations on the disposal of bulk or containerized nonhazardous liquids in sanitary (nonhazardous waste) landfills”). Duke Energy appreciates DEQ keeping this in mind as it considers Comment No. 3 under 15A N.C.A.C. 13B .2012 below.

6. Proposed Section .2002(56) would define “phase” to be “an area constructed that provides five years of operating capacity.” In addition, Section .2007(c)(1) and (d)(1)(D), Section .2009(c), and Section .2012(a) would define a “phase” of operation as an area
that contains “approximately” five years of disposal capacity. It is difficult to discern the relevance of five years. Rather than establishing an arbitrary capacity number, a “phase” should be defined as a landfill area built in a single construction event.

7. The proposed definition of “project engineer” under Section .2002(59) specifies “construction of the solid waste management unit.” Duke Energy recommends that the definition include language making clear that the project engineer may also be the person responsible for certifying modifications, repairs, etc., not only initial construction of the landfill.

8. In pertinent part, proposed Section .2002(63) would define “review boundary” as “a boundary around a permitted disposal facility.” (Emphasis added.) However, “disposal facility” is not defined, and “disposal” is defined as discharging or placing waste so that it enters the environment. The word “disposal” should be replaced with the word “waste,” so a “review boundary” is defined as “a boundary around a permitted waste facility, midway between a waste boundary and a compliance boundary at which groundwater monitoring is required.”

9. The proposed definition of “run-off” at Section .2002(65) is inconsistent with the definition under the CCR Rule, and the term “run-on” is not defined. Duke Energy suggests that these terms be defined consistent with the CCR Rule.

**General Application and Processing Requirements for CCR Facilities and Units**

*(15A N.C.A.C. 13B.2003)*

1. Proposed Section .2003(a)(1)(A) and (B): The words “or unit” should be added after each reference to “CCR facility.”

2. Proposed Section .2003(a)(3)(A) would require a substantial permit amendment when “an increase in waste tonnage per year of greater than 10 percent occurs.” Given the inconsistent nature of CCR landfill operations supporting generating stations, which can be affected by weather, operation of the generating unit, and excavation activities, it is not practical to submit a substantial amendment to the permit for a 10 percent increase in the waste tonnage per year. This provision is a remnant of the MSW rules, and it would be difficult for Duke Energy to quantify or define. Is it a 10 percent increase from actual disposal or planned? How does Duke Energy capture harvesting activities? If Duke Energy sees an increase, must it stop operations until an amendment is issued? Because this requirement makes no sense in the context of CCR landfills, Duke Energy proposes that it be deleted in its entirety.
3. Proposed Section .2003(a)(5) would require existing CCR surface impoundments that close in accordance with G.S. 130A-309.214(a)(3)(c) to prepare an application in accordance with Section .2005(e). However, Section .2005 refers to Section .2014, which, by its terms, “does not apply to CCR surface impoundments.” See Section .2014(a). Duke Energy suggests bringing CCR surface impoundment post-closure monitoring requirements into the final state rule.

4. Proposed Section .2003(b)(3)(A)'s scale requirement for engineering drawings (1” = 100') should be removed. Duke Energy suggests the final state rule only note that 22 x 34 is a desired sheet size because there is no way engineering drawings can all be at the defined scale.

5. Proposed Section .2003(c)(3)(C): The word” shall” should be added between the words “Division” and “make.”

6. Proposed Section 2003(c)(4)(B) should not be included in the final state rule because it repeats the text found in Proposed Section .2003(c)(2)(B) and is misleading.

General Requirements for CCR Facilities and Units (15A N.C.A.C. 13B .2004)

1. Proposed Section .2004(b)(2)(J) would provide that the Division may “sample or monitor, at any location. . . .” Duke Energy suggest this instead read “may sample or monitor, at any location in the Water Quality Monitoring Plan.”

Application Requirements for CCR Facilities and Units (15A N.C.A.C. 13B .2005)

1. Proposed Section .2005(a)(1)(F) would require submission of monitoring plans prepared in accordance with Section .2014(a). However, by its terms, Section .2014 “does not apply to CCR surface impoundments.” See Section .2014(a). To be consistent with the CCR Rule, Duke Energy suggests bringing CCR surface impoundment monitoring requirements into the final state rule.

2. Proposed Section .2005(e)(4) would require a closure and post-closure care plan prepared in accordance with Section .2013, which incorporates requirements of Section 2014. By its terms, Section .2014 “does not apply to CCR surface impoundments.” See Section .2014(a).
1. Proposed Section .2006(c)(13) would require local government approvals of the site study prepared for a CCR facility. However, some counties do not require local government approval (i.e., a Special Use Permit) for CCR landfills. Therefore, Duke Energy suggests that the words “If applicable” be added to the beginning of the sentence.

2. Proposed Section .2006(c)(14) requires consideration of the cumulative impacts of a proposed new CCR facility or lateral expansions of a CCR facility, “when considered in relation to other similar impacts of facilities located or proposed in the community, would have a disproportionate adverse impact on a minority or low-income community protected by Title VI of the federal Civil Rights Act of 1964.”

Duke Energy appreciates and supports DEQ’s efforts to ensure equal access to the decision-making process and to ensure the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Duke Energy is committed to engaging with and supporting the communities in which the Company has or will have facilities and recognizes the importance of involving local citizens in major permitting activities.

As Duke Energy continues its work to safely close ash basins pursuant to the requirements of CAMA and the CCR Rule, we try to minimize community impacts as much as possible. At every facility, our focus is on closing ash basins in ways that are protective of people and the environment and that minimize the impact on the communities we serve while effectively managing costs.

With this in mind, the statutory authority for Proposed Section .2006(c)(14) is unclear. North Carolina General Statutes Section 130A-294 establishes the statutory authority for North Carolina’s Solid Waste Management Program. The statute requires DEQ to develop a permitting program that governs the establishment and operation of solid waste management facilities. See § 130A-294(a)(4)a. The statute was amended on August 2, 2007 to add a list of circumstances under which DEQ must deny permits for solid waste management facilities. For example, Section 130-294(a)(4)c.9. provides as follows:
The Department shall deny an application for a permit for a solid waste management facility if the Department finds that . . . [t]he cumulative impact of the proposed facility, when considered in relation to other similar impacts of facilities located or proposed in the community, would have a disproportionate adverse impact on a minority or low-income community protected by Title VI of the federal Civil Rights Act of 1964. This subdivision shall apply only to the extent required by federal law.

(Emphasis added.)

The final underlined sentence indicates that the subdivision only applies “to the extent required by federal law,” which limits its application considerably. With respect to proposed Section .2006(c)(14), there is nothing in the CCR Rule or federal law generally that requires owners and operators of CCR units to undertake the kind of analysis proposed in the Proposed Rules. Accordingly, DEQ lacks the authority to require same. As an executive agency of the state, DEQ may not exceed the limited statutory authority granted by the legislature and require a cumulative impacts analysis for each of Duke Energy’s applications.

Moreover, proposed Section .2006(c)(14) is inconsistent with the policy behind N.C.G.S. § 150B-19.3(a), which provides that “[a]n agency authorized to implement and enforce State and federal environmental laws may not adopt a rule for the protection of the environment or natural resources that imposes a more restrictive standard, limitation, or requirement than those imposed by federal law or rule. . . .”

Finally, it is not constitutionally permissible for DEQ to require the type of cumulative impacts analysis proposed in Section .2006(c)(14) for Duke Energy’s CCR landfill permit applications and not for other applicants. Section 130A-294(a)(4)a. applies to all applications for all solid waste management facilities, not just CCR facilities.

In any event, proposed Section .2006(c)(14) is impermissibly vague in that it does not specify what elements should be included in the study to fulfill this requirement, does not define what is meant by “cumulative impact” and whether that refers to multimedia impacts, and does not define “disproportionate” in terms of study metrics. Since the statute was adopted over 10 years ago, DEQ has not promulgated any rule provisions to specifically implement Subdivision (c)(9). Without details regarding the contents of the required cumulative impacts analysis, Duke Energy is left guessing what should be included, which introduces significant regulatory uncertainty.
Facility Requirements for CCR Landfills and Units (15A N.C.A.C. 13B .2007)

1. Proposed Section .2007(e)(1)(B) would require the facility plan to include the average yearly disposal rate and representative daily rate for the wastestreams. However, an application that includes these rates would be purely speculative at the time the application is submitted. Because the volumes fluctuate significantly, Duke Energy is not in a position to know what volume of wastestreams, which is affected by re-use markets, capacity factor, coal type, etc., will be produced from year to year. Accordingly, Duke Energy proposes that this requirement be deleted.

2. Proposed Section .2007(e)(1)(D) would require facility-specific management plans to incorporate “procedures for segregated management at different on-site facilities.” Because most facilities do not have segregated management, this requirement would end with language in every permit noting “it is not a part of this application or intended at this facility.” Accordingly, Duke Energy suggests adding the phrase “if segregated management is intended,” at the beginning of the sentence.

Geologic and Hydrogeologic Investigation Requirements for CCR Facilities and Units (15A N.C.A.C. 13B .2008)

1. Proposed Section .2008(a)(3) would require that “[a]ll borings intersecting the water table shall be converted to piezometers or monitoring wells,” but proposed Section .2008(b)(2)(J) contemplates that they may be abandoned. Duke Energy performs borings in many locations as a part of field investigation for landfills. Some locations would have no value associated with being monitored long term or could have structures being designed in the area. There is no compelling reason to convert any boring that reaches water to a monitoring well. Accordingly, Section .2008(a)(3) should be changed to read as follows: “All borings intersecting the water table shall be converted to piezometers or monitoring wells in accordance with 15A NCAC 02C .0108, or be properly abandoned in accordance with the procedures for permanent abandonment of wells as delineated in 15A NCAC 02C .0113.”

2. Proposed Section .2008(a)(11)(B) should include the word “available” before the word “construction.” Some wells in the 2000’ perimeter study area could be old with no records available. The Company would not want to have to contact property owners or investigate their wells for construction information. Duke Energy would review records with the local health department to obtain whatever information is publicly available.
1. Proposed Section .2009(c): As discussed above, the operating nature of CCR facilities precludes the accurate development of a time-phased development. As such, requirements for a five-year phase outlined in Proposed Section .2009(c) should not be included in the final state rule.

2. Proposed Section .2009(d)(1) and (3) appear redundant in requiring the engineering plan to contain a summary of the facility plan (.2009(d)(1)) and a copy of the Design Hydrogeologic Report (.2009(d)(3)). Instead, Duke Energy recommends a statement to the effect that “the engineering plan shall be consistent with the facility plan and Design Hydrogeologic Report.”

3. To promote clarity and completeness of the design, final Section .2009 should address all design and engineering elements required for the proper design of the unit. As such, design-specific references found elsewhere in the rule (especially Section .2010 (Construction Requirements for CCR Facilities and Units) should be consolidated into Section .2009. Specific references to design elements include:

   - .2010(b)(1) (Base liner system description) – These are design elements. The construction of these components is covered later in the section.

   - .2010(b)(2) (Leachate collection system design and operation) – This section exclusively covers leachate collection system design. The operation of these systems should be covered in Section .2011 (Operating Requirements for CCR Facilities and Units).

   - .2010(b)(2)(J)(3) and (4) (Horizontal and Vertical separation requirements, respectively) – These criteria are design elements and may be verified (with the exception of the vertical separation) during construction. These elements are identified in Section .2006 (Site Study Requirements), applied to the design, and may be field verified during construction.

4. Proposed Section .2009(d) is inconsistent with the CCR Rule with respect to chemical compatibility of elements of the design with CCR materials. This is particularly important when considering geosynthetic clay liner designs, which have specific design compatibility considerations that are not outlined elsewhere in the rule.
Construction Requirements for CCR Facilities and Units (15A N.C.A.C. 13B .2010)

1. Proposed Section .2010 in its entirety outlines construction requirements for CCR Facilities and Units, but it does not address implementation of these elements. One could construe it to imply that when the final state rule goes into effect, all construction elements must also be in place. It is impractical to require the upgrade of all existing systems to comply with these new rules. Duke Energy suggests either a grandfathering of some existing systems or an implementation schedule for system upgrades be included in this section.

2. Proposed Section .2010(b)(1) outlines five prescriptive liner sections for CCR landfills; however, it does not address liner sections for other types of CCR units. In addition, this language does not allow flexibility for liner equivalency evaluations as outlined in 40 C.F.R. § 257.70(c). This flexibility is important when considering alternate liners for surface impoundments and should be included in the final state rule.

3. Proposed Section .2010(b)(2) extensively outlines Leachate Collection System (LCS) design and operation. As noted above, for purposes of clarity, the design and operational elements should be located in the respective rule sections dedicated to that topic. Specifically, Section .2010(b)(2)(A) through(E) should be relocated to their respective sections.

4. Proposed Section .2010(b)(2)(A) refers to specific system components, such as chimney drains and side slope drains. This is confusing as used in this section because chimney drains do not remove leachate from the unit, and side slope drains are not used for leachate, only stormwater. Duke Energy recommends that the section be rewritten as follows: “The LCS shall be hydraulically designed to remove leachate from the CCR unit(s). . . .” (i.e., the phrase “...including all contributing appurtenances such as chimney drains or side slope drains if specified,” should be deleted from the first sentence).

5. Proposed Section .2010(b)(2)(J) addresses leachate pumping stations. This term should be better defined to more clearly delineate the reach of this requirement. As written, it is unclear if every location with a pump, even if it is not used for leachate, is a pumping station that would require duplicate pumps and provisions for temporary or permanent back-up power.

6. Proposed Section .2010(b)(3)(D) would require establishment of a monitoring zone between a new CCR unit and an existing landfill. However, Section .2014(m) expressly
contemplates multiunit systems, thereby directly conflicting with the language in .2010(b)(3)(D) requiring monitoring between units. Moreover, proposed Section .2010(b)(3)(D) would conflict with the CCR Rule, which expressly allows for multiunit groundwater monitoring systems at 40 C.F.R. § 257.91(d). Duke Energy suggests that the final state rule align with the CCR Rule.

7. Proposed Section .2010(b)(11)(C)(i) would require all leachate piping installed to transmit leachate to have dual containment outside of the disposal unit. However, this requirement would conflict with Section .2010(b)(2)(G), which would require dual containment only “at road and stream crossings.” More fundamental, however, the dual requirements contained in the Proposed Rules directly conflict with Senate Bill 1492, § 9.(b)(5), which provides as follows:

To the extent that G.S. 130A-295.6, as enacted by this section, imposes requirements that are more stringent than those in effect prior to 1 August 2007, the more stringent requirements do not apply to . . . [a] permit for a sanitary landfill used only to dispose of waste generated by a coal-fired generating unit that is owned or operated by an investor-owned utility subject to the requirements of G.S. 143-215.107D.

(Emphasis added.)

Operating Requirements for CCR Facilities and Units (15A N.C.A.C. 13B .2012)

1. Proposed Section .2012(a) refers to five-year operational phases. As discussed above, the reference to a time-phase program should be removed.

2. Proposed Section .2012(b)(1)(C) and (b)(3)(C) refer to yearly operational contours. As discussed elsewhere in these comments, there is little value in producing time-sequenced plans. These would be more useful as volume-based plans.

3. Proposed Section .2012(c)(1) would provide that no waste that has not been properly dewatered may be placed in the CCR unit. This provision should explicitly allow for the placement of any CCR material in CCR landfills, provided the placement method results in satisfactory engineering stability requirements and complies with the DEQ-approved Operations Plan. For example, paste—a slurry mixture that may consist of a specialized mix of fly ash, FGD filter cake, FGD filtrate, and lime—can be pumped and placed in a landfill. After placement, paste cures through chemical hydration into an engineered
solid material. Because the unit weight of paste is similar to the unit weight of compacted ash, a landfill designed for CCR material can accommodate paste without altering the liner design.

As another example, Duke Energy has approved plans for handling liquid vacuum waste at all of its operating landfills in North Carolina. It is critical that the Company be allowed to continue this practice in accordance with the approved procedures that were developed along with DWM. The landfills regularly utilize water or leachate for dust suppression, so a limited amount of liquid waste would not affect operations of the facility. Moreover, there are approved handling plans already in place at the operational facilities and included in the existing Operations Plans. Accordingly, Duke Energy suggests that the phrase “Unless otherwise approved by the Division,” be added to the beginning of the second sentence.

4. Proposed Section .2012(d)(3), which addresses alternate cover materials approved for use at an individual CCR landfill facility, conflicts with G.S. 130A 295.6(h1), which provides that once an alternate cover is approved at one sanitary landfill, it shall be approved for all sanitary landfills in the state.

5. Proposed Section .2012(i) addresses drainage control and surface water protection requirements. Requirements (1) and (2) of this section conflict with the use of chimney drains on CCR landfills and should be removed if chimney drains are required as the preferred method for managing water on the operational surface of the landfill.

Closure and Post-Closure Care (15A N.C.A.C. 13B .2013)

1. Proposed Section .2013(c)(1)(A)(vi) makes reference to time frames specified in Part (6)(A) and time extensions specified in Part (6)(B). These are incorrect section references. Consistent with Comment No. 9 below, the final state rule should track the language of 40 C.F. R. § 257.102(f) respecting closure time frames and extensions. Section .2013(c)(1)(A)(vi) should then refer to those sections in the final state rule.

2. Proposed Section .2013(c)(1)(B)(i) would include a reference to “existing surface impoundments.” However, this section pertains to preparation of initial closure plans and would require that such a plan be prepared “[n]o later than the date of initial receipt of CCR.” It is not possible to comply with this rule for “existing CCR surface impoundments” because these impoundments already have CCR in place. The corresponding language in the CCR Rule only applies to new CCR units and lateral
expansions. Duke Energy has already prepared initial closure plans for its existing units subject to the CCR Rule. Accordingly, the rule needs to be modified to not include existing CCR surface impoundments. Comment No. 3. under 15A N.C.A.C. 13B .2002 (Definitions) above proposes a new definition for a “lined CCR surface impoundment.” To the extent DEQ elects to create this new defined term, we suggest including a reference to new lined CCR surface impoundment in Section .2013(c)(1)(B)(i).

3. Proposed Section .2013(c)(2): In the third from last line, the word “for” should be inserted between the words “Section” and “assessment.”

4. Proposed Section .2005(e)(4) would require permits for closure and post-closure care of surface impoundments, in accordance with Section .2013. However, requirements for closure by removal in .2013(c)(2) references requirements to meet groundwater standards under Sections .2014 and .2015, which expressly do not apply to surface impoundments (see Sections .2014(a), .2015(a)). Under 40 C.F. R. § 257.102(c), for units undergoing closure by removal, closure cannot be certified until the unit meets the groundwater protection standards. Thus, provisions from Sections .2014 and .2015 need to apply to CCR units undergoing closure by removal. Duke Energy proposes two potential approaches to address this: (1) amend Sections .2014 and .2015 to apply to impoundments that have commenced or completed closure; or (2) reproduce the applicable language from these sections under Section .2013(c)(2).

5. Proposed Section .2013(c)(3)(A) sets out the closure performance standards when closing CCR in place. Subsection (i) of that section would require the owner or operator to ensure that the unit is closed in a manner that will “[c]ontrol, minimize or eliminate, to the maximum extent feasible, post-closure infiltration of liquids into the waste and releases of CCR, leachate, or contaminated runoff to the ground or surface waters or to the atmosphere.” Duke Energy proposes that the words “through the final cover system” be added between the words “liquids” and “waste.” In addition, Duke Energy proposes that DEQ add the phrase “on top of the final cover system” to the end of Subsection (ii) of Proposed Section .2013(c)(3)(A). Thus, these two subsections would read as follows:

   - (i) “In accordance with Section .2013(c)(3)(C), control, minimize, or eliminate, to the maximum extent feasible, post-closure infiltration of liquids through the final cover system into the waste and releases of CCR, leachate, or contaminated runoff to the ground or surface waters or to the atmosphere.”
(ii) “Preclude the probability of future impoundment of water, sediment, or slurry on top of the final cover system”

These changes would make explicit what is already clear from an analysis of the CCR Rule’s preamble—that the focus of 40 C.F.R. § 257.102(d) is on the prevention of infiltration of liquids through the cap and the integrity of the final cover system, not on groundwater conditions below the cap, which have nothing to do with the final cover system or unit closure generally. To the extent constituents in groundwater need to be addressed, this is accomplished pursuant to the CCR Rule’s post-closure care maintenance provisions at 40 C.F.R. § 257.104 (not its closure provisions under 40 C.F.R. § 257.102(d)), which require owners and operators to maintain the integrity and effectiveness of the final cover system, maintain the groundwater monitoring system, and monitor the groundwater for a minimum of 30 years, and, if appropriate, implement corrective action measures required under 40 C.F.R. § 257.96-.98.

On p. 21413, EPA states that

a facility must ensure that in designing a final cover for a CCR unit they account for any condition that may cause the final cover system not to perform as designed. This could include accounting for site conditions that may increase the likelihood that a cover would be susceptible to desiccation cracking or settlement cracking. Under this performance standard, if the cover system results in liquids infiltration or releases of leachate from the CCR unit, the final cover would not be an appropriate cover.

Thus, when referring to the standard concerning the post-closure infiltration of liquids into the waste, EPA speaks directly to site-specific conditions that could cause the final cover system to fail, thereby allowing liquids infiltration or releases of contaminated runoff. The fact that EPA describes these events as occurring in the context of a cracked cover makes clear that the performance standards are intended to address what is occurring on top of and through the cap, not underneath it.

Indeed, a review of EPA’s use of the term “infiltration” throughout the preamble reveals that the agency is consistently talking about the passage of liquids through the top of the cover when referring to this term. For example, on p. 21370, EPA explains that the soil component of a composite liner system “serves as a backup in the event of any leakage/infiltration from the geomembrane occurs,” while the geomembrane “provides
a highly impermeable layer that can . . . minimize infiltration of leachate in a CCR surface impoundment.” Similar usage appears on p. 21370, where EPA explains that uncontrolled storm water run-on “may have significant impacts on the . . . continued safe operation of the CCR landfill, due to such phenomena as erosion and infiltration.” And in describing “run-off,” EPA explains it is the “portion of rainwater, snowmelt, or other liquid which does not undergo abstraction, such as infiltration, and travels overland.” In these and in every other instance of the word “infiltration,” EPA is referring to the movement of liquids into the unit from above and never in terms of the horizontal migration of groundwater beneath the unit’s cover system.

Likewise, the requirement in Section 257.102(d)(1)(ii) that a closed unit “[p]reclude the probability of future impoundment of water, sediment, or slurry,” refers to the impoundment of water, sediment, and slurry on top of the final cover system, not underneath it. Although neither “sediment” nor “slurry” is defined under the CCR Rule, the common definition of “sediment” is “[f]inely divided solid material that settles to the bottom of a liquid,” and “[t]he deposition of such material onto the surface beneath this water or air.” And “slurry” is commonly defined as “[a] thin mixture of a liquid, esp[ecially] water, and any of several finely divided substances, [such] as cement, plaster of Paris, or clay particles.” EPA’s use of these terms along with the term “water” demonstrates that the standard is intended to preclude the deposition of materials on top of the cap of a closed unit, whether brought by water or other elements. The words indicate that the standard does not address the lateral migration of groundwater underneath the final cover system. Section VI.M.3.a. of the rule’s preamble, addressing closure in place, discusses the final cover system and explains the following:

To address the commenters’ concerns that the final cover system may not function effectively as designed over the long term under certain circumstances, the rule also includes a performance standard that any final cover system must meet. This standard is modeled after the closure performance standard applicable to interim status hazardous waste units under § 265.111. The final rule requires that any final cover system control, minimize or eliminate, to the maximum extent practicable, post-closure infiltration of liquids into the waste and releases of leachate (in addition to CCR or contaminated run-off) to the ground or surface waters.

(Emphasis added.)

6. Proposed Section .2013(c)(3)(C): In the second line, the letter “s” should be deleted from the word “meets.”
7. Proposed Sections .2013(c)(4)(B)(i) and .2013(c)(5)(D)(i): The references to Paragraph “(c)” should specifically refer to Subparagraph (c)(1).

8. Proposed Section .2013(c)(5)(B): The hyphen between the words “one” and “time” on the seventh line should be deleted.

9. Proposed Section .2013(c)(6)(A)(ii) fails to set out a time frame for closure of existing CCR surface impoundments that have commenced closure. The final state rule should track the language of 40 C.F.R. § 257.102(f)(1)(ii). With respect to the closure time frame for CCR surface impoundments greater than 40 acres, the CCR Rule allows up to 15 years to complete closure, provided the owner or operator demonstrates the need for additional time pursuant to 40 C.F.R. § 257.102(f)(2)(i). See 40 C.F.R. § 257.102(f)(2)(ii)(B). Pursuant to N.C.G.S. § 130A-309.216, Duke Energy is required to beneficiate the ash at three sites in North Carolina. Duke Energy selected Buck, Cape Fear, and H.F. Lee as the three beneficiation sites. The ash from these sites will be processed to specifications appropriate for cementitious products. EPA recognized on pp. 21327-28 of the CCR Rule’s preamble that encapsulated uses of CCR in concrete provide numerous environmental and economic benefits, and concluded that such uses do not raise health or environmental concerns in light of the fact that the CCR binds into a solid matrix that minimizes mobilization into the surrounding environment. Accordingly, amending the closure time frames in the final state rule to allow additional time for closure beyond 15 years in cases where CCR from the impoundment is being beneficiated would be at least as protective as the CCR Rule. Duke Energy proposes that under such circumstances, given the investment in these reprocessing units, the closure time frame be extended until the owner or operator removes the known final volume of CCR for the purpose of beneficiation.

10. Subsection (c)(6)(A)(iii) of proposed Section .2013 is out of place. It should be moved to .2013(c)(6)(B) below, which should read as follows:

   Extensions of closure timeframes. In order to obtain additional time extension(s) to complete closure of a CCR unit(s) beyond the times provided by Part (A) of this Subparagraph, the owner of the CCR unit(s) shall substantiate the factual circumstances demonstrating the need for extension. The demonstration shall include with the demonstration required by Subpart (A)(iii) of this Subparagraph the following statement signed by the owner or an authorized representative: “I certify under penalty of law that I have personally examined and am familiar with the information submitted in this demonstration and all attached documents, and that, based on my inquiry of those
individuals immediately responsible for obtaining the information, I believe that the
submitted information is true, accurate, and complete. I am aware that there are
significant penalties for submitting false information, including the possibility of fine and
imprisonment.”

11. Subsection (c)(11) of proposed Section .2013 does not contain a complete sentence. In
addition, this subsection would provide that annual progress reports are required during
implementation, but no initial and subsequent dates are defined. Duke Energy suggests
that these dates be defined in DEQ’s approval to close.

12. Proposed Section .2013(d)(1)(A) refers to “Part (c)(1)(B) or Part (c)(1)(C) of the Rule.”
The reference should instead be to Part (d)(1)(B). It should be noted that N.C.G.S. §
130A-309.214(a)(4)k. requires “[a] description of the plan for post-closure monitoring
and care for an impoundment for a minimum of 30 years.” This provision applies to
existing CCR surface impoundments at non-high-priority sites as defined by Section 3.(b)
of CAMA.

13. Similar to No. 4. above, Section .2005(e)(4) would require a permit for closure and post-
closure care of surface impoundments, in accordance with Section .2013. However, the
post-closure requirements in Sections 2013(d)(2)(C) and .2013(d)(3)(B) include a
requirement to meet the groundwater standards under Sections .2014 and .2015, which
expressly do not apply to surface impoundments (see Sections .2014(a), .2015(a)).
Sections .2014 and .2015 should be amended to include closed units (i.e., after the final
cover system has been installed) to conform to the requirements in 40 C.F.R. §
257.102(d). Duke Energy proposes two potential approaches to address this: (1) amend
Sections .2014 and .2015 to apply to impoundments that have commenced or
completed closure; or (2) reproduce the applicable language from these sections under
Sections .2013(c)(2). By not including surface impoundments in the monitoring program
(especially for post-closure), Duke Energy will be forced to follow multiple sampling and
analysis programs leading to greater confusion and forcing the Company to incur higher
costs to the detriment of its customers. The basins would fall under both CAMA and
EPA requirements, in addition to multiunit systems landing partly under these Proposed
Rules, CAMA, and the CCR Rule. Moreover, other closure requirements are based on
approval of post-closure sampling, analysis, and corrective action, such as financial
assurance requirements, CAMA closure plan submittal requirements, etc.

14. The words “the CCR unit(s)” should be deleted from the first line of proposed Section
15. By its terms, Section .2013 is applicable to CCR landfills, CCR impoundments, and new CCR landfills. Proposed Section .2013(d)(4)(B)(i) would establish a deadline for new landfills, but it is silent with respect to existing landfills and impoundments. Existing units must be addressed, so Duke Energy is not left trying to interpret the requirements.

16. Proposed Sections .2013(d)(5): The reference to Paragraph “(d)” on the fourth line should specifically refer to Subparagraph (d)(4).

17. The final state rule should explicitly provide for the use of CCR in completing the closure (grading and contouring of the final cover system, waste stabilization, etc.) of a unit. This is already allowed under the CCR Rule, provided the four beneficial use criteria set out in 40 C.F.R. § 257.53 are satisfied. Specifically, the CCR Rule provides that any use of CCR qualifies for the beneficial use exemption at 40 C.F.R. § 257.50(g), except for the placement of CCR in a sand and gravel pit or quarry, provided the relevant beneficial use criteria are met. See 80 Fed. Reg. at 21349. When discussing the kinds of unencapsulated uses of CCR required to comply with the fourth beneficial use criterion, EPA expressly acknowledges that such “[u]nencapsulated uses of CCR are numerous and range, in total use, from hundreds of thousands of tons to millions of tons per year.” 80 Fed. Reg. at 21353. Immediately following this statement, EPA provides as examples of such use the use of CCR for fill and waste stabilization/solidification. Id.

The use of CCR to facilitate closure furthers the goal of completing closure of the unit “in the shortest amount of time consistent with recognized and generally accepted good engineering practices.” 40 C.F.R. § 257.102(d)(1)(v). As EPA identified in the final CCR Rule, the process for procuring at specification earthen material in the volumes necessary for construction of the final cover system can complicate completion of closure requirements within the required time frames. 80 Fed. Reg. at 21420-23. Similarly, CCR can effectively be used as a stabilizing agent in many instances and thus expedite unit closure by avoiding the timing delays of mining and transporting materials from off-site to the unit undergoing closure. In fact, the closure process is likely to be significantly extended if an owner or operator is forced to mine and truck in borrow material for these activities.

In short, the use of CCR as fill and to stabilize waste for installation of the cover system will accelerate the closure process and correspondingly reduce risks to groundwater. Moreover, the beneficial use of CCR for grading and contouring and waste stabilization is consistent with RCRA’s goal of conserving natural resources using secondary materials. Failure to beneficially use CCR in this manner will result in the
need for significant quantities of virgin materials, which will not only delay the closure process, but be contrary to RCRA’s goals of resource conservation and recovery. Similar to other costs for environmental compliance that are traditionally paid by customers through electric rates, Duke Energy expects to seek permission to include costs associated with ash basin closures required by federal and state regulations. The beneficial use of ash for basin closure will help the Company manage costs for customers and avoid the needless use of native materials.

Detection Monitoring Requirements for CCR Facilities and Units (15A N.C.A.C. 13B .2014)

1. By its terms, proposed Section .2014 “does not apply to surface impoundments,” but it is important that a groundwater monitoring program be included in the final state rule. Consistent with other comments throughout this document, Duke Energy suggests that the final state rule’s groundwater monitoring requirements apply to surface impoundments, as is the case under the CCR Rule.

2. Proposed Section .2014(a)(1) is inconsistent with the CCR Rule. 40 C.F.R. § 257.94(b) requires eight independent samples from background wells within the first six months of sampling. In contrast, the Proposed Rules would require all the wells (background and downgradient) to have eight independent samples during the first year of operation. In addition, the 30-45-day period conflicts with DEQ’s April 2017 comments to the guidance titled “Statistical Methods for Developing Reference Background Concentration for Groundwater and Soil at Coal Ash Facilities,” which requires at least 60 days between sampling to use data in statistical analysis.

3. Proposed Subsection (b) of Section .2014 refers to a “Monitoring Plan,” Subsection (c) refers to a “Groundwater monitoring plan,” and Subsection (c)(1)(D) notes a “Water Quality Monitoring Plan.” Are all of these the same document, or are they intended to be different documents? Please use consistent terminology throughout the final state rule, and clearly identify the required components in such plans.

4. Proposed Section .2014(c)(1)(D) sets out the list of constituents for detection monitoring. Unlike under the CCR Rule, wherein EPA determined to use a phased approach by selecting Appendix III parameters that would rapidly move through the subsurface and would be used as indicators, the number of constituents in detection monitoring under the Proposed Rule includes the same list as under assessment monitoring. The CCR indicator parameters in Appendix III were determined by EPA to be adequate to determine if there is a need to sample for the additional parameters.
under Appendix IV. The final state rule should more closely track the well thought out federal rule in this regard.

In addition, detection monitoring would require monitoring for turbidity (field). Turbidity is an archaic, subjective test with questionable correlation to suspended solids. Because direct measurement of total suspended solids ("TSS") is possible and practical, Duke Energy recommends that TSS be substituted for turbidity.

5. Proposed Section 2014(c)(4) would provide Duke Energy with the option to perform statistical analysis. However, the CCR Rule requires statistical analysis. See 40 C.F.R. § 257.93(f). Not requiring a statistical analysis would be inconsistent with the CCR Rule and would risk the final state rule not being as protective as the CCR Rule.

6. Proposed Section 2014(c)(12) would require that the groundwater standards established under 15A NCAC 2L be at the compliance boundary. Although compliance under the CCR Rule is determined at the "waste boundary," Duke Energy believes that determining compliance at the compliance boundary is appropriate because it is as protective as the CCR Rule.

7. Proposed Section 2014(a)(4) would require an annual report by January 31 of each year. In contrast, proposed Section 2014(c)(6) would require a report 120 days after completing a sampling event. The Proposed Rules require additional water quality reporting, two semi-annual reports after monitoring events, and one annual report with all the data that is included in the semi-annual reports. Duke Energy will incur additional expenses and expend additional resources preparing these additional reports. The CCR Rule also requires an annual report. Accordingly, Duke Energy suggests that the semi-annual submissions DEQ proposes be data submittals rather than a full report that includes groundwater flow maps and analysis, which will be captured in the annual report.

8. Proposed Section 2014(d)(5) would provide that if a 2B standard is not established, "the owner or operator shall obtain a determination from the Division on establishing a surface water standard." Point source locations should have NPDES or stormwater requirements as opposed to DWM setting an alternative standard. Accordingly, Duke Energy proposes that these provisions not be included in the final state rule.

9. Proposed Section 2014(e) would establish gas monitoring requirements, which have no applicability to CCR landfills, which are monofills that contain only ash and are not used
to dispose of organics. Duke Energy performed gas monitoring in the past, and after many years of no indication of methane gas, the Division agreed that CCR facilities do not need gas monitoring. Such requirements are not contained in the CCR Rule, which makes sense given the characteristics of the material. Accordingly, Duke Energy proposes that these provisions not be included in the final state rule.

10. Proposed Section .2014(g) (regarding a waste acceptability program) should include the phrase “Unless otherwise approved,” prior to the word “Owners.” Duke Energy currently does not perform random inspections or develop contingency plans for excluded waste. Duke Energy notes in its Operations Plans that those items are not warranted because no waste outside of the Company is allowed on-site. The requirements should remain in light of the possibility of a private CCR facility, but language to afford an owner the opportunity not to perform the tasks should be included.

Assessment and Corrective Action Requirements for CCR Landfills (15A N.C.A.C. 13B .2015)

1. Similar to the title of Section .2014, the title to Section .2015 should be changed to: “ASSESSMENT MONITORING REQUIREMENTS FOR CCR LANDFILLS FACILITIES AND UNITS; CORRECTIVE ACTION REQUIREMENTS FOR CCR LANDFILLS FACILITIES AND UNITS”

2. Proposed Section .2015(a) expressly provides that it does not apply to CCR surface impoundments. However, CAMA includes corrective action requirements, and financial assurance for closure provides that corrective action must be included. Not including surface impoundments leaves them subject to multiple, and potentially inconsistent, programs for groundwater corrective action.

The WIIN Act authorizes states to establish permit programs under RCRA Subtitle D for implementing the CCR Rule. The central feature of the legislation is a state’s ability to submit an application to EPA requesting approval to administer the CCR Rule through a state permit program or other system of prior approval. EPA must approve a state’s application in whole or in part if EPA determines that the state CCR permit program requires each CCR unit in the state to comply with (1) criteria applicable to CCR units under 40 C.F.R. Part 257, or (2) such other criteria that EPA determines, after consultation with the state, are at least as protective as the criteria in the CCR Rule. Thus, the final state rule may contain criteria for individual CCR permits that differ from the criteria in the CCR Rule, if EPA determines, based on site-specific
conditions, that such different technical criteria are at least as protective as the federal rule.

On March 15, 2018, EPA promulgated the CCR Remand Rule Proposal, which proposed a number of alternative performance standards that would apply in states with approved state CCR permit programs. Among these are alternative groundwater protection standards and a modified corrective action remedy. However, without a state permit program that includes groundwater monitoring and corrective action requirements, these alternative, risk-based site-specific provisions will not be available to DEQ or Duke Energy. Accordingly, Duke Energy suggests that DEQ include the CCR Rule’s groundwater monitoring and corrective action programs in the final state rule to give North Carolina the ability to establish technical criteria that are at least as protective as the federal rule.

3. Proposed Section .2015(b) would require notification of persons who own land or reside on land that directly overlies any part of the plume within 14 days of determining contaminants have migrated off-site; however, the resampling and plume delineation does not occur until after the assessment monitoring work plan is submitted, which occurs 90 days after triggering the assessment program. The structure of this provision is confusing and not ordered correctly, and could lead one to believe that Duke Energy must make notifications 14 days after an exceedance, even though the plume has not yet been defined. Additionally, the proposed provision references exceedance of 2L or IMAC standards in any sampling event. An exceedance could be naturally occurring or potentially be the result of a data error. The results need to undergo validation and analysis prior to notifying landowners. Finally, the proposed provision fails to address the possibility of conducting an alternate source demonstration for Appendix III constituents.

4. The time frame to notify landowners under Proposed Section .2015(b) should be extended to 30 days. In addition, the phrase “If assessment monitoring is triggered,” should be added to the second sentence of this section so the sentence reads as follows: “If assessment monitoring is triggered, the owner or operator shall notify all persons within 14 30 days who own land or reside on land that directly overlies any part of the plume of contamination if contaminants have migrated off-site or are thought to have migrated off-site”

5. For the reasons discussed in Comment No. 9 under 15A N.C.A.C. 13B .2014, the phrase “or methane gas monitoring well” should not be included in Section .2015(c)(1) of the
final state rule. In addition, although Proposed Section .2015(c)(1) is consistent with the CCR Rule requirement that an additional well be installed at the facility boundary in the direction of contaminate migration, it is important to recall that the CCR Rule established a one-size-fits-all program without consideration for state requirements. With the advent of the WIIN Act and state CCR permit programs, state permitting authorities may consider site-specific factors when implementing the CCR Rule under a state permit program. Because CAMA required Duke Energy to install a network of groundwater monitoring wells at each site in North Carolina, to the extent such non-CCR Rule wells are available and meet the criteria in 40 C.F.R. § 257.95(g)(1)(iii), a new dedicated well should not have to be installed if a monitoring well installed for a separate program, at the facility boundary in the direction of contaminate migration, already exists.

6. Proposed Section .2015(c)(4) would allow the Division to establish a “stricter than background alternative groundwater protection standard” for constituents without an MCL or water quality standard. It is unclear why the Division would suggest remediating to lower than background levels. Remediating to such a level could have technical and economic challenges. Moreover, the legal basis for such a requirement is unsupported. Consistent with the CCR Rule, the groundwater protection standard for constituents for which the background level is higher than the MCL, water quality standard, or health-based levels, should be no lower than background.

7. Proposed Section .2015(d)(5) would allow the Division to approve a return to detection monitoring if criteria (A), (B), and (C) are met. However, 40 C.F.R. § 257.95(e) provides that “If the concentrations of all constituents listed in appendices III and IV to this part are shown to be at or below background values, using the statistical procedures in § 257.93(g), for two consecutive sampling events, the owner or operator may return to detection monitoring of the CCR unit.” Duke Energy suggests that the final state rule be consistent with the CCR Rule in this regard.

To the extent DEQ believes that Part (C) (i.e., “The plume has not exceeded the compliance boundary”) is required, Duke Energy proposes that it be changed to read as follows: “The monitored constituents do not exceed applicable limits at or beyond the compliance boundary.” If DEQ determines to adopt this proposed language, proposed Part (B) (i.e., “The plume is not migrating horizontally or vertically”) is not required. Moreover, the standard in proposed Part B would create an overly burdensome standard that would be extremely difficult to demonstrate.
8. Proposed Section .2015(d)(2) provides “[w]ithin 14 days, [Duke Energy shall] submit a report.” Please clarify within 14 days of what event. Is it within 14 days of obtaining the results of the initial and subsequent sampling events?

9. Proposed Section .2015(d)(3): The word “period” should be added between the words “care” and “of.”

10. Proposed Section .2015(d)(4) provides that only a Licensed Geologist may prepare the alternate source demonstration. This provision should be revised to include reference to a Professional Engineer, as is allowed under the CCR Rule. See 40 C.F.R. § 257.95(g)(3)(ii).

11. Proposed Section .2015(d)(5)(A): The words “the constituent levels in” should be added between the words “and” and “15A NCAC 02L.0202.”

12. Proposed Section .2015(e): In the first sentence, the word “days” should be added after the word “90.”

13. Proposed Section .2015(e)(2) would require a discussion of the results of the assessment of corrective measures prior to selection of the remedy. However, it does not provide how many days in advance of the remedy selection this should occur. Consistent with 40 C.F.R. § 257.96(e), we suggest that it be “at least 30 days.”

14. Proposed Sections 2015(f)(4)(B) and (m)(2) refer to “approved groundwater protection standards.” Should they also refer to IMAC?

15. Proposed Section 2015(h): The introductory sentence should be amended as follows: “Implementation of the Corrective Action Program. Based on the approved schedule for initiation, and completion of remedial activities, within 90 days after approval of the selected remedy or later, as approved by the Division, the owner and operator shall:”

16. Proposed Section 2015(j): The last sentence refers to Paragraph “(g).” This pertains to a determination by DEQ that additional measures are required. Therefore, should the reference instead be to Paragraph (k)?

17. Proposed Section 2015(l): Refers to Paragraph “(f).” Should it instead refer to Paragraph (h)(3)?
18. Proposed Section 2015(m)(2): Refers to Paragraph “(f)(2).” Should it instead refer to Section .2014(b)(4) and (5)? Also, the words “the applicable statistical procedures and” should be inserted between the words “with” and “performance.”

19. Proposed Section 2015(n): Refers to Paragraph “(n).” Should it instead refer to Paragraph (m)?

20. Proposed Section 2015(o): Refers to Paragraph “(n).” Should it instead refer to Paragraph (m)?


1. Proposed Section .2016(b) would establish financial assurance requirements for CCR Facilities and Units. Financial assurance would be required under this section for closure, post-closure, and corrective action. However, CCR surface impoundments are expressly not included in Sections .2014 and .2015, which address environmental monitoring and corrective action. If those units have no approval mechanism in line with closure plan approval, Duke Energy is uncertain of how appropriate financial assurance will be approved/obtained?

2. The meaning of the phrase “when the extent and manner of its operation would make closure the most expensive” in Proposed Section .2016(c)(1)(A) is unclear. Please clarify.

3. In Proposed Section .2016(c)(1)(B) we recommend deleting the sentence “For owners and operators using the local government financial test, the closure cost estimate shall be updated for inflation within 30 days after the close of the local government's fiscal year and before submission of updated information to the Division.” It is not applicable to the Proposed Rules. For the same reason, this same reference should be deleted from Proposed Section .2016(c)(3)(B).

4. Proposed Sections .2016(c)(1)(D), (c)(3)(D), and (c)(5)(C): In the second from last line, the word “Facility” should be added after “CCR.”

5. Proposed Section .2016(c)(4): The reference to Paragraph “(c)(2)” should be changed to “(c)(3).”

6. Proposed Section .2016(c)(6): The reference to Rule “.2015(l)” should be changed to .2015(m).
Recordkeeping, Notification, and Publicly Accessible Internet Site Requirements
(15A N.C.A.C. 13B .2017)

1. Proposed Section .2017(f)(4) would require that “Documentation recording the results of the weekly inspection in accordance with Rule .2012(l) of this Section” be placed in the facility’s operating record and posted on the publicly accessible Internet site. 40 C.F.R. §§ 257.83(a) and 257.84(a) set out the inspection requirements for CCR surface impoundments and landfills, respectively. 40 C.F.R. § 257.105(g)(5) and (8) provide that the documentation recording the results of the weekly inspections be placed in the facility’s operating record. Critically, however, 40 C.F.R. § 257.107(g) does not require that each weekly inspection be posted on the facility’s Internet site. Instead, only the periodic inspection reports required under 40 C.F.R. §§ 257.83(b)(2) and 257.84(b)(2) need be posted to the Web site. See 40 C.F.R. § 257.107(g)(6) and (9). In light of these federal requirements, the comprehensive periodic inspection report that must be posted annually, and the administrative burden that would be associated with posting the weekly inspection results for every CCR surface impoundment and landfill throughout the state, Duke Energy recommends that this requirement not be included in the final state rule.

CCR to CCP Treatment and Processing Facilities and Transportation Requirements
(15A N.C.A.C. 13B .2018)

1. Proposed Section .2018 pertains to CCR to CCP treatment and processing facilities and transportation of CCR (on- or off-site). Please clarify what activities are intended to fall under this section. Is it intended to apply to only the three beneficial reuse sites at Buck, Cape Fear, and H.F. Lee, which are being construct pursuant to N.C.G.S. § 130A-309.216? Or is it also intended to apply to the ash recycling operations being undertaken at Weatherspoon, which do not require ash reprocessing for use in cement kilns? Or is intended to be even broader in scope by capturing other activities, such as separation at Roxboro or trucking fly ash for off-site beneficial use? Which facilities and activities are the Division seeking to regulate with this section? What is the intent of the requirement?

2. In proposed Section .2018(c), the introductory sentence, which reads as follows, is legally incorrect: “, CCR does not have a beneficial use.” If the beneficial use criteria in 40 C.F.R. § 257.53 have been met, the CCR has a beneficial use. Because CCR is a federal regulatory definition that encompasses materials—a useful product—and not solid
waste, this statement is incongruous with the CCR Rule. Accordingly, this sentence, which is not needed, should be removed.

3. Proposed Section.2018(c)(3) would trigger a requirement for an environmental demonstration even in cases where unencapsulated CCR is being beneficially used in roadway applications. In addition, unlike under the CCR Rule, there would be no threshold below which the demonstration would not be required. The final state rule should be consistent with the four beneficial use criteria set out in the CCR Rule, which creates an exception for roadway applications and sets out a use threshold of 12,400 tons.

4. Proposed Section .2018(f)(3) would require Duke Energy to annually report CCR transported to another state. Is this paragraph also intended to cover CCP transported to another state, or CCR destined to be CCP for beneficial use? What is the Division seeking to regulate with this section? What is the intent of the requirement?
Additional Requirements for Dams that Impound Coal Combustion Residuals
(15A N.C.A.C. 02K .0224)

1. Proposed Section .0224(a)(2): The proposed definition of “CCR unit” does not include an exemption for basins that have been closed, including those that have been closed by leaving CCR in place. Duke Energy suggests that the final state rule expressly exempt closed CCR surface impoundments from the definition of “CCR unit” under this section.

2. Proposed Section .0224(b)(2) would provide that the additional dam requirements will apply to a CCR unit that “contains residuals to an elevation of five feet or more above the downstream toe of the structure and that has a storage volume of 20 acre-feet or more. . . .” This would require Duke Energy to send structural stability assessments to DEQ for the 1978 and 1985 basins at Cape Fear, which are currently exempt from the CCR Rule. As a result of the United States Court of Appeals for the District of Columbia Circuit’s decision in Utility Solid Waste Activities Group v. EPA (No. 15-1219), EPA must undertake a rulemaking to make changes to the CCR Rule to implement the court’s judgment regarding the regulation of legacy impoundments. In light of the fact that the Company must close these impoundments pursuant to CAMA, combined with the uncertainty of how they ultimately will be regulated under the CCR Rule, Duke Energy suggests exempting inactive impoundments at closed power plants and incorporating EPA’s new standards regulating these units once EPA promulgates a final rule regulating legacy ponds.

3. Proposed Section .0224(c)(2) would provide that “a qualified engineer, or person under his or her responsible charge, shall conduct monitoring of all instrumentation supporting the operation of the CCR unit no less than once per month according to the standards listed under 40 CFR 257.83(a). . . .” Duke Energy suggests defining “instrumentation” and explicitly delineating what equipment must be monitored on a monthly basis.

4. Proposed Section .0224(d) would provide that all CCR dams shall have a spillway system with capacity to pass a flow resulting from a design flood as specified in the Minimum Spillway Design Flood for CCR Units Table. The hazard categories in the table are based on 15A NCAC 02K .0105, which notes that high hazard dams are “located where failure will likely cause loss of life or serious damage to homes, industrial and commercial buildings, important public utilities, primary highways, or major railroads.” DEQ takes the position that a dam is classified as high hazard if it has the potential to cause economic damage greater than $200,000. See Documents related to HAZARD
CLASSIFICATION, DEQ (Feb. 14, 2018). If the $200,000 damage threshold is the basis for classification, then all CCR basins will be classified as high hazard and subject to Probable Maximum Flood (“PMF”) rather than fractional PMF, to which Duke Energy’s CCR units are currently subject. Duke Energy suggests distinguishing between an existing impoundment and a closed, capped impoundment when determining the hazard classification.

5. Proposed Section .0224(e)(4) would require stability assessments for CCR units with downstream slopes that may be inundated by the pool of an adjacent water body. The assessments shall include conditions for maximum pool loading, minimum pool loading, and rapid drawdown of the adjacent waterbody. As written, this section will require structural stability assessments for closed impoundments, which would not have any pool loading. Duke Energy suggests exempting closed impoundments from this requirement.

In closing, Duke Energy appreciates the opportunity to comment on the Proposed Rules. The comments we have included herein are intended to highlight areas for additional clarification and specificity. We believe that implementing the CCR Rule through an enforceable permit program will provide regulatory certainty as we work toward safely closing all ash basins across our service territories and make critical investments on behalf of our customers.
October 15, 2018

VIA E-MAIL AND U.S. MAIL

Ellen Lorscheider
Deputy Director
Division of Waste Management
1646 Mail Service Center
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Dear Ms. Lorscheider:

On behalf of Appalachian Voices, Cape Fear River Watch, Catawba Riverkeeper Foundation, Dan River Basin Association, MountainTrue, Roanoke River Basin Association, Sierra Club, Sound Rivers, Waccamaw Riverkeeper, Waterkeeper Alliance, Winyah Rivers Foundation, and itself, the Southern Environmental Law Center submits the following comments to the North Carolina Department of Environmental Quality (“DEQ”) on its proposed coal combustion residual (“CCR”) rules. In response to an earlier draft of the proposed rules circulated in connection with public meetings held last winter, we submitted written comments in March and April 2018. We incorporate those comments here. Please find them attached for your reference (see Attachments 1 and 2).

I. Introduction

The proposed rules contain many good provisions, and we do not object to strong state rules for coal ash facilities. We agree, as DEQ highlights in its regulatory impact analysis, that strong, consistent state rules are necessary to protect the people and waters of North Carolina, particularly because the federal rule is in flux. For example, the water protection requirements set forth in Section .2013(i) are clear and strong—particularly subparagraph (3), which explicitly prohibits disposing of solid waste in water. We support many of the protections contained in these standards, and note in these comments gaps in protections and areas for improvement.

However strong the new state rules may be, two fundamental issues remain. First, the easiest and best way to protect the people and waters of North Carolina is to require Duke Energy to clean up its coal ash. By court order, criminal plea agreement, settlement agreement, and statute, Duke Energy is already required to excavate more than 50 million tons of coal ash at eight sites across North Carolina and every site in South Carolina. The communities around every leaking coal ash pond in the state deserve the same protections. Duke Energy must be
required to excavate its coal ash at every surface impoundment and move it to safe, dry, lined storage away from our waterways, or recycled for cement and concrete.

Second, North Carolina does not need, and DEQ should not establish, a DEQ permitting program for the federal CCR Rule. A DEQ permitting program exercising delegated authority from the federal CCR Rule would undercut the rights of North Carolina’s citizens to enforce the federal CCR Rule, would impose unnecessary and unsustainable costs and burdens on DEQ itself, and adds nothing to the ability of DEQ to regulate, monitor, and enforce as to coal ash sites in North Carolina.

With those two essential points in mind, we submit the following comments on the proposed rule.

II. Surface Impoundments

a. Performance standards for closure

We support DEQ’s decision to incorporate the federal CCR Rule closure performance standards into any state rules it creates, as it has done in Section .2013 of this draft version. These performance standards make clear that Duke Energy cannot close its ash ponds by leaving its coal ash sitting deep in groundwater and impounded behind the ash lagoon dams. Whatever regulations or permitting processes DEQ establishes, DEQ should require Duke Energy to remove the ash from the groundwater and store it safely in lined, dry landfill storage, or recycle it for use in cement or concrete. This is the message that the public has conveyed to DEQ repeatedly, and this is what the law requires.

The proposed state rules—like the federal CCR Rule—require that if a utility wishes to close its ash pond by capping in place, the closure plan must describe “how the final cover system will achieve the performance standards specified in paragraph (d) of this section.” 40 C.F.R. § 257.102(b)(1)(iii); see also 15A NCAC 13B .2013(c)(1)(A)(iii). The performance standards require, “at a minimum,” that closure will:

- “Control, minimize or eliminate, to the maximum extent feasible, post-closure infiltration of liquids into the waste and releases of CCR, leachate, or contaminated run-off to the ground or surface waters or to the atmosphere,” id. § 257.102(d)(1)(i); 15A NCAC 13B .2013(c)(3)(A)(i);

- “Preclude the probability of future impoundment of water, sediment, or slurry,” Id. § 257.102(d)(1)(ii); 15 NCAC 13B .2013(c)(3)(A)(ii); and that

- “Free liquids must be eliminated by removing liquid wastes or solidifying the remaining wastes and waste residues.” Id. § 257.102(d)(2)(i); 15 NCAC 13B .2013(c)(3)(B)(i).

It is important to realize that these standards do not deal with the cap itself, but what conditions must be satisfied at the impoundment for the lagoon to be capped in place.
Across North Carolina, Duke Energy’s coal ash is sitting stories deep in groundwater, leaching pollutants into the groundwater and discharging to surrounding surface waters. If Duke Energy wants to cap its ash ponds in place, the federal CCR Rule and these draft rules require it to show that groundwater and other waters will not continue to flow through the coal ash, to “control, minimize or eliminate ... post-closure infiltration of liquids into the waste.” If groundwater remains in an ash pond, saturating the ash, and if the ash pond dam would remain wholly or partially in place after closure, the ash pond remains an impoundment, and the closure would not “preclude the probability of future impoundment of water, sediment, or slurry.” And if groundwater continues to saturate coal ash within the capped ash basin footprint, then the closure plan cannot meet the requirement that “free liquids must be eliminated.” EPA has confirmed—both before and after the change in Administrations—that utilities must meet these CCR Rule performance standards when they close their ash ponds. If they cannot meet the performance standards, they cannot cap in place and must remove the ash.

To the extent the draft rules incorporate and build on these performance standards, we support them. But DEQ must recognize and act on the clear meaning of these performance standards: Duke Energy must excavate its ash sitting in the groundwater in impoundments across the state.

b. Public comment for surface impoundment closure permits

As drafted, the rules are silent on public participation on permits for surface impoundment closure. Section .2003(c)(1)(B) states applications for a permit to construct a new facility, a substantial amendment, or a modification involving corrective remedy selection are subject to the permitting and public information procedures laid out in Section .2003(c)(2)-(9), while amendments and modifications other than corrective remedy selection are not subject to these requirements. The rule fails to state whether the comment procedures apply to permits for closure. This may be because DEQ intends to rely on the CAMA public participation provisions for impoundment closure. But because the contents of a CAMA closure plan and a permit application under these rules are not identical, the public must be able to weigh in on the permit as well. The rules should not exempt surface impoundment closure permits from public comment. Instead they should state that impoundment closure permits must be subject to notice and comment under these rules, but that comment periods for the impoundment closure permit and the CAMA closure plan may be combined.

But the procedural and technical standards DEQ establishes in these rules are secondary to the one straightforward action DEQ can take to protect the people and environment of North Carolina: require Duke Energy to excavate the coal ash from every leaking pit in the state and move it to dry, lined storage away from waterways or recycle it for concrete.

III. State enforcement of state rules should not replace citizen enforcement of federal rules.

We support strong protections against coal ash pollution in North Carolina, but we object to a DEQ federal CCR Rule permitting program that would displace or weaken enforcement of the federal CCR Rule now in effect. As explained in greater detail in the attached comments submitted earlier this year, the federal CCR Rule establishes standards and requirements that
states and citizens alike can enforce right now in federal court (Attachments 1 and 2). There is no need to change the current framework. The maximum protection for North Carolina’s communities and clean water would be provided by a strong state permitting program of state rules by DEQ and direct enforcement of the federal CCR Rule by citizens and DEQ if and when necessary. We would hope that strong enforcement by DEQ of North Carolina’s state rules and permits, along with direct enforcement of the federal CCR Rule by citizens or DEQ in federal court as needed, would ensure that Duke Energy obeys the law and does not further pollute North Carolina’s water resources or put communities at risk.

It is disturbing that in its Regulatory Impact Analysis, DEQ cites the elimination of federal citizen suits as a benefit of a state permitting program for the federal rule. Under the “Environment and Public Safety” section of its uncertainties analysis, DEQ states: “[i]ncorporating federal requirements into state rules would provide enhanced opportunities to ensure compliance. If the state agency were to be delegated federal responsibilities, state enforcement of the rules would supersede federal enforcement that relies on citizen suits in federal court.”

DEQ’s rationale is divorced from reality. Eliminating federal citizen suits guts, rather than enhances, enforcement. Citizen suits long have been a hallmark of United States environmental law. When it enacted its landmark environmental laws in the 1970s and ‘80s, Congress included explicit provisions for citizens to enforce the law. See Resource Conservation and Recovery Act, 42 U.S.C. § 6972; Clean Air Act, 42 U.S.C. § 7604; Clean Water Act, 33 U.S.C. § 1365; Safe Drinking Water Act, 42 U.S.C. § 300j-8; Surface Mining Control and Reclamation Act, 30 U.S.C. § 1270; Endangered Species Act, 16 U.S.C. § 1540(g). Congress recognized state agencies sometimes lack the resources or the political will to bring enforcement actions against industrial polluters, so it enabled citizens “to abate pollution when the government cannot or will not command compliance.” Gwaltney of Smithfield, Ltd. v. Chesapeake Bay Found., Inc., 484 U.S. 49, 62 (1987).

As EPA explained when the federal CCR Rule was published, citizen enforcement is particularly important for the federal CCR Rule. See Final Rule, 80 Fed. Reg. 21,302, 21,399 (Apr. 17, 2015) (the rule “relies on citizen enforcement.”). EPA explains that “citizens perform a crucial role in the implementation and enforcement of this rule. EPA designed certain requirements, including Internet posting requirements, as part of the final rule to help ensure transparency and to assist those charged with playing this role.” EPA, Final Rule: Disposal of Coal Combustion Residuals from Electric Utilities, https://www.epa.gov/coalash/coal-ash-rule (last accessed October 5, 2018). The Rule’s Preamble states that these public disclosure requirements are needed to “minimize the danger of owners or operators abusing the self-implementing system being established in this rule through increased transparency and by facilitating the citizen suit enforcement provisions applicable to the rule.” 80 Fed. Reg. 21,427 (emphasis added).

Based on DEQ’s budget cuts and history of reluctant coal ash enforcement, the idea that these rules increase efficiency, and that DEQ could robustly enforce the proposed state rules, is not credible. Without citing anything in support, DEQ baldly claims delegation of federal responsibilities to DEQ “will result in a more efficient program delivery, a reduction in taxpayer
resources applied to the coal combustion residual program, and more thorough and consistent enforcement.” This statement is simply not true.

In fact, all the cleanups of coal ash lagoons in North Carolina have resulted from the advocacy of local conservation groups and citizen enforcement actions. Citizens initiated the enforcement of clean water laws against Duke Energy’s coal ash pollution. DEQ filed an enforcement action only in response to citizen enforcement of the Clean Water Act in federal proceedings, and DEQ first tried to stop all enforcement through a settlement agreement with Duke Energy that DEQ ultimately abandoned. DEQ has never vigorously pursued that enforcement action, and never filed an action to enforce the Clean Water Act against Duke Energy. Duke Energy pleaded guilty to federal coal ash crimes at sites across North Carolina for activities which DEQ had failed to stop. Every requirement that Duke Energy excavate a coal ash lagoon has come as a result of citizen enforcement and advocacy.

DEQ’s regulatory impact analysis fails to acknowledge the benefits of citizen enforcement. The only group benefitted by the elimination or hindrance of federal citizen suits would be Duke Energy and other industrial polluters.

IV. **The rules must adequately protect against extreme weather and emergencies.**

a. **New CCR facilities never should be sited in floodplains.**

Nearly five years after the Dan River spill, Duke Energy coal ash sites continue to pollute the state’s lakes and rivers. Duke Energy’s coal ash sites continue to threaten disaster each time a flood or hurricane strikes, as Hurricane Florence demonstrated by overtopping coal ash dams and breaching a landfill at Duke Energy’s Sutton facility, and by flooding old coal ash ponds at Duke Energy’s H.F. Lee facility.

At the Lee plant, which is located within the 100-year floodplain of the Neuse River,\(^1\) flooding after Florence caused the release of enough coal ash to fill 180 dump trucks. Water samples around the site after the breach tested over the state standard for arsenic, with elevated levels of many other heavy metals present in the samples.\(^2\) After the flood, these toxins settle into and linger in the river sediment.

The coal ash flooding in the past month demonstrates that it is crucial to forbid the disposal of coal ash in flood-prone areas next to rivers. Yet the proposed rules would allow new facilities to be sited in floodplains under certain circumstances. *See Section .2006(c)(4).*

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The proposed rules rely on inadequate definitions of floodplain and the 100-year flood. The statistical definition of a 100-year flood has not been updated in North Carolina since 2006.\textsuperscript{3} Since that time, the state has seen many large floods. With hurricanes Matthew in 2016 and Florence in 2018, the state’s coastal plain has been dealt two so-called 1,000-year storms in only two years.\textsuperscript{4} There is a consensus among researchers that climate change will continue to make storms and the floods that follow more intense, as warmer air can hold more moisture and add more fuel to storm systems.\textsuperscript{5} We already have seen an increase in the number of Category 4 and 5 hurricanes since the 1980s.\textsuperscript{6}

North Carolina ranks second among US states for the number of tropical storms and hurricanes that have affected its shores.\textsuperscript{7} Atlantic coast geography and currents make Eastern North Carolina especially exposed and prone to tropical storm and hurricane strikes.\textsuperscript{8} Along the coast, the footprint of storm surge is expanding as sea levels rise, and more powerful storms are able to produce larger storm surges. Tide gauge observations already show worsening storm surges since the 1920s.\textsuperscript{9}

Even non-tropical storms are already releasing more water—the Southeast is the only region in the U.S. that has experienced a significant increase in extreme rainfall from 2-day storms, which are happening 50 percent more often than they did last century.\textsuperscript{10} Over the next 12 years throughout the Southeast, extreme summer thunderstorms that are typically 100-year floods events are expected to drop between 40 percent and 80 percent more rain than they do today.\textsuperscript{11}


\textsuperscript{6} See Webster, P.J., et al., \textit{Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment}, 309 SCIENCE 1844-1846 (2005) (attached as Attachment 3).


\textsuperscript{9} See Ning Lin, et al., \textit{Physically Based Assessment of Hurricane Surge Threat Under Climate Change}, NATURE CLIMATE CHANGE, DOI: 10.1038/NCLIMATE1389 (2012) (attached as Attachment 5).


\textsuperscript{11} See Andreas F. Prein, et al., \textit{Increased Rainfall Volume From Future Convective Storms in the US}, 7 NATURE CLIMATE CHANGE 880-884 (2017) (attached as Attachment 6); see also Zhe Feng, \textit{Near Doubling of Storm Rainfall}, 7 NATURE CLIMATE CHANGE 854-856 (2017) (attached as Attachment 7); Somini Sengupta, \textit{Why the Wilder Storms?}
With the extreme rainfall the state has seen, the floodplain delineations of the 2006 flood probabilities are now too conservative to capture the full risk, and therefore a larger flood event should be chosen to most effectively manage the danger posed by these chemicals. Based on the recent experiences during Hurricane Florence, new coal ash storage should not be permitted in the 500-year floodplain, let alone the 100-year floodplain.

Floodplain lines were not drawn by nature—storms and floods do not obey these restrictions. The concept of the “100-year” storm is deceptive, as storms of this magnitude happen far more often than once every 100 years. Rather, these storms have a 1 in 100 chance of occurring in a given year, and a 100 year storm one year does not prevent another from hitting in even a few months. As the climate continues to change, any infrastructure placed in North Carolina floodplains is increasingly at risk to flood. By planning for these changes proactively and placing new sources of hazardous materials safely in uplands, the state can mitigate future disasters and protect the health of both its people and environment.

Proper siting standards can prevent the problems seen at Lee and Sutton. There is no reason why any new CCR facility in North Carolina should be located in a floodplain. Accordingly, Section .2006(c)(4) should be revised to remove the entire phrase beginning with “unless,” so the provision simply states: “CCR unit(s) or constructed embankments used to construct a CCR unit shall not be located in floodplains.” Additionally, we recommend revising the definition of floodplain in Section .2002 to be more protective by using the 500-year—or better yet, 1,000-year—floodplain as the benchmark.

b. Emergency Action Plans

The proposed rules leave out the federal requirement that Duke Energy and other utilities post online Emergency Action Plans and maps showing what would happen if one of these unlined, leaking, earthen coal ash lagoons were to fail and spill coal ash into our waters. Duke Energy has already tried to keep the public in the dark in violation of a federal disclosure requirement, before conservation groups enforced the law against the violation. North Carolina needs to hold Duke Energy accountable going forward. Incorporating this requirement into state rules underscores the importance of transparency and public information regarding the dangerous storage of coal ash near waterways. This transparency should be a part of North Carolina’s rules, apart from and in addition to the requirement currently present in the federal rule.

Under 40 C.F.R. § 257.107, Duke Energy and other owners or operators of coal ash lagoons “must maintain a publicly accessible Internet site (CCR Web site)” containing information specified in the Rule. On this website, utilities must publish an Emergency Action Plan for high hazard and significant hazard coal ash lagoon dams. Id. § 257.105 (f)(5). At a minimum the Emergency Action Plan must “include a map which delineates the downstream area which would be affected in the event of a CCR unit failure and a physical description of the CCR unit”; “define responsible persons, their respective responsibilities, and notification procedures in the event of a safety emergency involving the CCR unit”; and “provide contact information of emergency responders.” Id. § 257.73.

Although the draft rules incorporate the basic requirement to have a public website (Section .2017(c)), there is no mention of an emergency action plan. DEQ must make clear that North Carolina’s rules include the requirement to create, maintain, and make public an emergency action plan showing the downstream areas that would be flooded in the event of a dam failure catastrophe. Access to information is a key part of the federal CCR Rule and must also be a key part of North Carolina’s rules. As EPA has explained in the Preamble to the Rule, “the establishment and maintenance of this information . . . on a publicly accessible Internet site” is important because citizens need “access to all of the information necessary to show that the rule has been implemented in accordance with the regulatory requirements.” 80 Fed. Reg. 21,302, 21,426. Any regulations DEQ adopts must recognize the public’s need to know the coal ash risks in their communities.

These public information requirements are all the more important in North Carolina, where Duke Energy has already violated the federal requirements to post complete and public Emergency Action Plans. Instead of complying with the requirement like every other major utility in the country, Duke Energy posted plans with blacked-out maps of the inundation risks. It also redacted contact information for responsible personnel in the event of a safety emergency. Only after conservation groups discovered Duke Energy’s illegal hiding of this critical information and notified Duke Energy that they intended to sue, Duke Energy gave in and posted unredacted maps and information. DEQ must make sure that this dam safety information remains up to date and available to the communities around and downstream of Duke Energy’s coal ash ponds.

V. Certain provisions of the proposed rules require strengthening and further clarification.

a. Section .2002 (Definitions):

- **Section .2002(21):** “Contaminate” or “Contamination” is defined only as the introduction of foreign materials into groundwaters—this definition should be revised to be broader, including contamination of surface waters, as well as soil.

- **Section .2002(54):** “Overfills”—the construction of a coal ash landfill over a closed impoundment—should be banned. Duke Energy has tried this in the past, and there is no need to have this practice repeated in the future. Overfills make it more difficult to reach the coal ash in the unlined pit when the ash needs to be removed due to pollution, leaching, and seeping; and this practice will make it more difficult to access ponded ash for recycling into concrete and cement.

b. Section .2003 (General Application and Processing Requirements for CCR Facilities and Units):

Section .2003 sets forth various rules for applications by owners and operators of CCR facilities and units, including procedures for permitting and public information. As described in
the introduction above, this Section unambiguously requires owners or operators of existing CCR surface impoundments that close in accordance with CAMA, to apply for a permit for closure. See Section .2003(a)(5). However, the other application requirements and procedures are confusing and should be clarified as follows:

- **Permitting and public information procedures.** Because the terminology is so muddled, it is unclear which applications are subject to permitting and public information procedures. Per Section .2003(c)(1)(B), applications for new facilities, substantial amendments, or modifications involving corrective remedy selection are subject to the permitting and public procedures. But then in the very next sentence, applications submitted under subparagraphs (a)(2) (“amendments”) and (a)(4) (“modifications”) are not, even though the previous sentence states certain amendments and some modifications are. There is no mention of requirements for closure permits required under subparagraph (a)(5).

  This subparagraph must be revised to clearly state which applications are subject to permitting and public information procedures—including applications for closure permits. All new permits and all amendments to existing permits (whether styled as amendments, substantial amendments or modifications), should be available for public notice and comment. But at the very least 1) closure permits for impoundments must be for the reasons explained above; 2) and modifications involving amendments to closure plans for all units under .2013, rather than just selection of corrective remedy under .2015 must receive comment, so the public knows if an owner is changing their long-term plan for the CCR unit. Such clarifications must be made throughout Section .2003(c)—for example, Section .2003(c)(4)(A) should be revised to say the Division must give public notice of all draft permits and all draft amendments to existing permits (whether styled as amendments, substantial amendments, or modifications).

- **Public review.** Section .2003 should be revised to include clear requirements for DEQ to post online for public review all draft permits, draft fact sheets, and draft permit amendments (including amendments, substantial amendments, and modifications). As drafted, Section .2003 only requires posting of fact sheets. See Section .2003(c)(3)(C).12

**c. Section .2006 (Site Study Requirements for CCR Facilities and Units):**

In addition to the revisions to Section .2006(c)(4) suggested above, Section .2006 also should be revised as follows:

- **Section .2006(c)(5)(G).** The comparable provision of the original federal CCR Rule required certification from a qualified professional engineer that the siting requirements of the rule have been met. 40 C.F.R. § 257.61(b). That requirement

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12 **Missing word.** The word “shall” should be inserted in Section .2003(c)(3)(C) so that it reads: “The Division **shall** make it available to the public for review or copying on the Division website.”
has been removed from DEQ’s proposed rules. The elimination of certification by a qualified professional engineer is one of the so-called “flexibilities” proposed by former Administrator Pruitt. This approach takes away any professional certification of technical determinations and leaves them to approval by Duke Energy and agency officials. DEQ should retain requirements that qualified professional engineers certify determinations. Furthermore, the certification requirement by a “qualified person” in Section .2006(b) is insufficient because it is not clear from the definition what those qualifications are.

- **Section .2006(c)(8).** This section deals with siting of new CCR units in unstable areas and omits a number of the protections in the original version of 40 C.F.R. § 257.64, including certification by a qualified professional engineer. This provision must be revised to include a professional certification to ensure accuracy and accountability.

- **Section .2006(c).** Included in the list of concerns when siting a new CCR unit should be the impact of the new unit’s site on any nearby properties that have been set aside previously to mitigate for wetlands impacts. A new CCR unit should not impair the functioning of mitigation properties. This Section should be revised by adding this as a requirement.

- **Section .2006(14).** This subparagraph appears to be missing words. In order for the provision to make sense, the bold underlined words should be inserted: “The cumulative impact of the proposed facility, when considered in relation to other similar impacts of facilities located or proposed in the community, shall not have a disproportionate adverse impact on a minority or low-income community protected by Title VI of the federal Civil Rights Act of 1964.”

d. **Section .2009 (Engineering Requirements for CCR Facilities and Units):**

Section .2009 describes engineering requirements for “CCR facilities and units.” Inasmuch as the definition of CCR facilities and units includes surface impoundments, and pursuant to Section .2005(e)(1), applicants for closure permits are required to submit engineering plans prepared in accordance with Section .2009, this Section must be clarified to include engineering details for all closure options—not just cap-in-place, as suggested by subparagraph (e)(4). Subparagraph (e) could be revised to clarify such drawings are required “as applicable” (“Engineering drawings shall illustrate, as applicable:”) and to add required drawings for an excavation scenario.

e. **Section .2012 (Operating Requirements for CCR Facilities and Units):**

Section .2012(k) requires the permittee to cause a survey of portions of the facility to determine whether operations are conducted “in accordance with the approved design and operational plans.” Strangely, the rules require a “registered land surveyor” to conduct the “survey,” which does not appear to be a traditional land survey but instead an inspection of whether the facility is operating in compliance with the permit. A land surveyor lacks the
qualifications to make such a determination. Section .2012(k)(2) should be revised to require an
engineer to assess the operations of the facility; part of that assessment may include causing a
land surveyor to determine whether the facility’s operations are properly located according to the
plan and the permit. Additionally, Section .2012 should be further revised so that DEQ either
performs or causes a qualified person to perform the evaluation and produces the report. A
polluter should not be allowed to self-evaluate and report on its own operations to determine
compliance with the permit.

f. Section .2013 (Closure and Post-Closure Requirements for CCR Facilities
and Units)

This section describes the requirements for closing CCR facilities and units, which
include surface impoundments. As DEQ explains in its regulatory impact analysis, we
understand these rules to establish a permitting requirement and procedure for closure of surface
impoundments, but “[t]his rule will not change the way in which the regulated community or
regulators manage basin closure activities” and “does not change the performance standards set
forth by the federal rules and CAMA.” See DEQ Regulatory Impact Analysis, at PDF page 11-12.13 Accordingly when the rules indicate the facility owner “may elect” the closure method, we
understand that to mean the owner may choose the method within the parameters set forth by
CAMA and the federal CCR rule. If the facility can not meet the performance standards
established by CAMA, these rules, or the federal CCR rule, then it must be closed by excavation.
Section .2013 should be revised to reflect this point.

With respect to the closure plans described in this section, DEQ should revise section
.2013(c)(1)(C) and .2013(d)(4)(C) to make clear that, as stated elsewhere in the rules, an owner
must obtain DEQ approval before amending a closure plan or post-closure plan. The provision
that the owner may amend closure or post-closure plans at any time is confusing unless it
includes “by seeking a modification under Section .2003(a)(4).”

g. Section .2014 (Detection Monitoring Requirements for CCR Facilities and
Units) and Section .2015 (Assessment and Corrective Action Requirements
for CCR Landfills):

In the attached comments submitted in April 2018, we identified several issues with
sections .2014 and .2015, which set forth detection, assessment, and corrective action
requirements (see Attachment 2). In the proposed rules and regulatory impact analysis, DEQ has
stated that sections .2014 and .2015 do not apply to surface impoundments. This may be because
the CAMA and federal CCR rule performance standards apply, as DEQ explains in its
Regulatory Impact Analysis (on page 11 of the PDF: “The proposed ruleset adds a permitting
process, permit and state oversight to basin closure activities, but does not change the
performance standards set forth by the federal rules and CAMA.”). If so, and this exclusion is
intended, DEQ should clarify what standards apply to surface impoundments. For example,
sections .2014(a) and .2015(a) could be revised as follows: “All CCR units(s) are subject to the
assessment and corrective action requirements under Rule .2014 of this Section except that Rule
.2015 does not apply to CCR surface impoundments. CCR surface impoundments are subject

to the performance standards and requirements set forth in the North Carolina Coal Ash Management Act (G.S. 130A-309.200 through G.S. 130A-309.231), the federal CCR rule (40 C.F.R. 257 and 40 C.F.R. 261), as may be amended, and any other applicable laws.” If this exclusion is inadvertent, DEQ must remove it to avoid creating a gap in protections for coal ash ponds.

Although some changes were made to sections .2014 and .2015 in line with our previous comments, further revision is required for the rules to adequately protect health and the environment, as explained in detail in the attached April 2018 comments (see Attachment 2).14

For example, bromides and hexavalent chromium should be added to the list of constituents in sections .2014(c)(1)(D) and .2015(c)(2). Bromides from Duke Energy’s coal ash sites have caused spikes in carcinogens in public drinking water supplies. Duke Energy’s bromide pollution is a topic of its criminal plea agreement with the United States Department of Justice and its criminal probation. After a citizen challenge, bromides were recently removed from a Duke Energy air permit that DEQ had proposed. These rules must protect against Duke Energy’s bromide pollution.

In addition, hexavalent chromium also has plagued drinking water wells near Duke Energy’s coal ash sites and poses a significant public health risk. Given their notorious histories, bromide and hexavalent chromium are conspicuous in their absence from the list of constituents DEQ will require to be monitored and assessed.

Other provisions should be made stronger. Section .2014(d)(3) should be strengthened by including maximum distances upstream and downstream from the source for sampling to avoid dilution of the sample.

Finally, what is the Corrective Action Evaluation Report, mentioned in Section .2015(i), and why is it submitted so infrequently, only every five years? We recommend corrective actions be evaluated more frequently so that their progress would be known and any lessons learned could be applied going forward.

VI. Conclusion

We commend DEQ for taking seriously public input and eliminating many of the weaknesses in the early drafts of the rules. We urge DEQ to consider these further comments and make additional changes to the draft rules. DEQ must hold Duke Energy accountable for its coal ash pollution and obligate Duke Energy to clean it up by excavating the ash from the groundwater and safely recycling it for concrete or storing it in a lined landfill.

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14 *Typo*: The last phrase in Section .2015(j) should be revised to read: “unless the Division makes the determination under Paragraph (g) of this Rule.”
Thank you for your consideration.

Sincerely,

[Signature]

Frank S. Holleman III  
Senior Attorney

cc: Bill Lane, DEQ General Counsel (via email)
Attachment 1

Comments from Southern Environmental Law Center, to North Carolina Department of Environmental Quality, dated March 14, 2018, regarding CCR Rules
March 14, 2018

Via email: publiccomments@ncdenr.gov

The Hon. Michael S. Regan
North Carolina Department of Environmental Quality
217 West Jones Street
Raleigh, North Carolina 27603

Re: CCR Rules

Dear Secretary Regan:

The Southern Environmental Law Center, on behalf of itself and Appalachian Voices, Cape Fear River Watch, Catawba River Keeper Foundation, Dan River Basin Association, MountainTrue, Roanoke River Basin Association, Sierra Club, Sound Rivers, Southern Alliance for Clean Energy, Waterkeeper Alliance, Waccamaw Riverkeeper, Winyah Rivers Foundation, and Yadkin Riverkeeper, submits these preliminary comments on the draft proposed rules of the North Carolina Department of Environmental Quality (“DEQ”) regarding coal combustion residuals (“CCRs”). The agency’s roll-out of these rules has been hasty and confusing, depriving the public of the opportunity to meaningfully review them and comment. We support strong protections against coal ash pollution in North Carolina, but we object to a DEQ federal CCR Rule permitting program that would displace or weaken the federal CCR Rule now in effect. The federal CCR Rule establishes standards and requirements that states and citizens alike can enforce in federal court. DEQ has not explained why it would risk undermining this federal rule with a state permitting program for the federal CCR Rule.

We may provide additional technical comments on later versions of the draft rules to make sure that the provisions regarding landfills and dams are as protective as possible of the environment and public health. We are submitting these initial comments now with the hope that DEQ thoughtfully chooses its next steps and more fully involves the public in its decision making.

DEQ’s Public Involvement Process Has Been Ineffective.

On February 8, 2018, DEQ released 90 pages of draft rules for public comment and announced three public hearings within the two weeks that followed. The first public hearing – held just four days after the release (including a weekend) – was in Roxboro, a community with serious coal ash concerns and where two federal suits are pending under the federal CCR Rule concerning Duke Energy’s coal ash disposal at Mayo and Roxboro. With one weekend to prepare and the limited advertisement of the meeting, residents and community groups could not possibly review and provide meaningful input on the dense draft rules, much less the scientific and technical comments DEQ claimed it preferred.
While two previous coal ash hearings in Roxboro attracted standing-room-only crowds of hundreds of citizens, almost nobody attended this one. However, citizens at the prior two hearings and citizens who have submitted comments on DEQ’s prior coal proposals have made one thing extremely clear: They want Duke Energy’s coal ash in Person County removed from unlined pits where it contaminates groundwater, streams, lakes, and rivers. They oppose cap in place because it would allow Duke Energy to continue to pollute in place.

Citizens had little more time to learn about DEQ’s proposed rules and give comments at the Dallas and Wilmington hearings. As with Roxboro, prior coal ash hearings in these areas attracted large crowds, and the local citizens urged DEQ to insist upon the maximum protections against Duke Energy’s coal ash pollution and to require Duke Energy to move its coal ash from unlined disposal in groundwater to dry, lined facilities or to recycle it for cement and concrete.

At all three hastily-arranged meetings, the citizens who did attend objected to the way that these hearings were scheduled and announced and urged DEQ to require Duke Energy to move its coal ash from unlined pits to dry, lined disposal areas. They also expressed frustration about DEQ repeatedly holding meetings and asking for comments, repeatedly being told the same thing by North Carolinians – require Duke Energy to remove its coal ash from unlined pits and put in place the maximum additional protections against coal ash pollution – and DEQ repeatedly ignoring their voices. Despite the clear response from citizens, DEQ has yet to require Duke Energy to remove its coal ash from unlined pits in these areas and continues to propose permits and rules that do not provide adequate protections from coal ash pollution. In some instances, DEQ’s proposals actually try to weaken some existing proposals and protections.

The haste and rush of DEQ is hard to understand because there is no legal deadline for adopting state CCR rules, and in fact there is no requirement to do so at all. One explanation given by DEQ for its rush is the priorities of EPA Administrator Pruitt. This rationale is particularly disturbing because Administrator Pruitt and the EPA leadership under his direction have worked to reduce many environmental protections and are trying to weaken federal protections against coal ash pollution. DEQ’s own statements at the meetings indicate that it is a partner in Administrator Pruitt’s efforts – efforts that put the interests of polluters ahead of those of North Carolina’s families and clean water.

DEQ’s failure to meaningfully engage with the public at this early stage is an unacceptable foundation for the rulemaking process. Before formally proposing rules, DEQ should start the public involvement process over. It should begin by consulting with community groups that have worked on coal ash pollution for years and with the communities directly affected by coal ash. North Carolinians have already told DEQ, over and over again, what they expect from their state environmental agency. But DEQ has yet to act on what North Carolinians have told them. Before drafting extensive rules, DEQ should confer with North Carolina’s communities and the community organizations that have been working on coal ash for years to determine what the goals of new rules should be.

We note that DEQ has recently extended the comment period for an additional fifteen days and scheduled another meeting. However, as set out below, once more the announcement
does not address the purpose of the rules and the plan to adopt a state federal CCR Rule permitting program. The subsequent formal notice and comment period will not make up for the failed introduction of the draft rules. There needs to be an open and free discussion between DEQ and the communities and organizations that have worked on coal ash pollution about what are the aims for these Rules and whether those aims are wise ones.

In Announcing These Proposed Rules, DEQ Did Not Tell the Public the Purpose of the Proposed Rules.

The notice and the press release accompanying these proposed rules do not set out that the rules are intended to be the basis for a DEQ permitting program for the federal CCR Rule. Yet, contained in the dense wording of the PowerPoint slides at the hearings is the fact that this is what DEQ is trying to do. And DEQ says that this project is designed to carry out the priorities of EPA Administrator Pruitt. But to the overwhelming majority of the public who are not deeply immersed in the technicalities of the federal CCR Rule, this intent would not be readily apparent.

At the hearings there have been indications that these rules apply to landfills and dams, but not impoundments. But a reading of the proposed rule demonstrates that this statement is not true, and at least one of the meetings, DEQ staff corrected this statement.

The text of the draft rules indicates that DEQ intends to create a permit program for closing at least some existing CCR surface impoundments. Section .2003(a)(5) states:

Permit for Closure and Post-Closure of a CCR surface impoundment- An existing CCR surface impoundment that closes in accordance with 130A-309.214(a)(3)(c) shall prepare an application in accordance with Paragraph (c) of Rule .2005 of this Section.

This section indicates that coal ash ponds deemed “low-risk” under the N.C. Coal Ash Management Act that close by complying with the closure requirements of the federal CCR Rule must obtain a permit under these draft rules. N.C. Gen. Stat. § 130A-309.214(a)(3)(c). The draft rules at Section .2005(e) require permits for “closure/post closure of a CCR surface impoundment” to include an engineering plan, a construction quality assurance plan, and an operation plan, and a closure and post-closure plan under Section .2013 that meets performance standards taken from the federal CCR Rule.

At the hearings, there have been confusing statements about this language. At the meetings, there has been indication that the rules apply only to the cap used in a cap-in-place closure for ash ponds. But the CCR Rule standards for a cap in place system require that free liquids be removed and that all impoundments be eliminated before a cap can be placed on a coal ash impoundment.

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1 Section .2003(a)(5) appears to contain an incorrect cross-reference to .2005(c), which refers to substantial amendments to permits, not impoundment closure.
North Carolinians cannot give meaningful feedback on a rule when its purpose is not made clear and there is confusion about what it provides.

North Carolina Does Not Need a DEQ Federal CCR Rule Permitting Program.

We support robust state protections for public health and the environment around existing and future coal ash landfills. We support robust state measures to make sure the earthen dams holding back coal ash do not collapse in catastrophic failure, harming communities downstream. And we welcome additional state protections against pollution from unlined, leaking coal ash ponds that would supplement or go beyond federal requirements.

However, North Carolina does not need a state permitting program for the federal CCR Rule. The federal CCR Rule already establishes performance standards that these surface impoundments must meet when they close. Citizens and DEQ itself can enforce this rule now. Adopting a state permitting program for the federal CCR Rule creates barriers to citizen enforcement of the federal CCR Rule standards and undermines the federal protections EPA put in place in 2015.

EPA Administrator Pruitt made clear on March 1 what we already knew – his push for state federal CCR Rule permitting programs is merely a means to reduce the protections against coal ash pollution and serve the interests of coal ash polluters like Duke Energy. Late on March 1 just before the release data showing utility coal ash groundwater contamination across North Carolina and America, Administrator Pruitt announced an effort to allow state agencies to reduce the protections against coal ash groundwater pollution, to allow malfunctioning coal ash lagoons to continue to receive waste, and to extend the lives of dangerous unlined coal ash lagoons. DEQ’s rush to carry out Administrator’s Pruitt’s priorities reinforces our concerns about these proposed state rules and a proposed DEQ federal CCR Rule permitting program.

Our concerns about a DEQ federal CCR Rule permitting program are many. First, DEQ does not need a state CCR Rule permitting program in order to enforce the Rule. Like citizens, DEQ and the state can enforce the Rule in federal court at any time. Yet, DEQ has not enforced the federal CCR Rule in the face of Duke Energy’s violations. Citizen groups enforced the Rule against Duke Energy when Duke Energy was the only major utility in America that did not publish coal ash inundation maps as the Rule clearly required. Upon enforcement, Duke Energy quickly retreated and published the maps. And citizen groups now are enforcing the Rule against inadequate proposed CCR Rule closure plans for Mayo and Roxboro, which fail to ensure that Duke Energy will remove the coal ash from groundwater and eliminate impoundments before putting a cap on top. But DEQ has taken no action to force Duke Energy to put forward compliant federal CCR Rule closure plans at these or any other sites.

DEQ’s actions under another major federal program applicable to Duke Energy’s coal ash sites – the Clean Water Act – indicate that a DEQ federal CCR Rule permitting program would be a step backwards. DEQ operates a state permitting program for the federal Clean

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Water Act. However, in the past DEQ has not taken action to force Duke Energy to stop violating that federal Clean Water Act at its coal ash sites across North Carolina. For example, for years Duke Energy openly violated the Clean Water Act and its permits at Riverbend, Asheville, and Lee by directing unpermitted flows of coal ash polluted water into the French Broad and Neuse Rivers and Charlotte’s principal drinking water reservoir. Even though DEQ was aware of these clear violations, it did not take action. Ultimately, Duke Energy companies pleaded guilty to crimes for these open violations of the Clean Water Act. Across North Carolina, Duke Energy’s coal ash has been contaminating groundwater, rivers, streams, and lakes, yet DEQ never took action to require Duke Energy to remove its coal ash from these leaking pits or to clean up this contamination. Duke Energy was forced to take action only after citizen groups enforced the law.

DEQ can show its interest in enforcing the federal CCR Rule by vigorously and effectively enforcing the federal CCR Rule against Duke Energy now, as it is empowered to do by the federal CCR Rule, without going through the unnecessary process of creating a state permitting program for the federal Rule.

Nor do we have reason to believe that federal CCR Rule permits issued by DEQ will be effective or will fully carry out the terms of the Rule. Under the Clean Water Act, DEQ has repeatedly proposed permits with provisions that did not comply with the Act. In 2013, DEQ went so far as to propose a permit for Duke Energy’s Lee facility that found that the leaking, polluting, unlined, dangerous Lee coal ash lagoons – which sit in a floodplain – were the best available technology for dealing with coal ash pollution. Subsequently, Duke Energy itself conceded that the Lee coal ash lagoons were unacceptable; a state court ordered their excavation; and the legislature mandated their excavation also. And, Duke Energy companies pleaded guilty to Clean Water Act crimes at Lee. And to date we have not seen DEQ effectively enforcing the Clean Water Act permits it has issued for Duke Energy.

Just this year, DEQ has proposed a permit for the Marshall facility that promises to give Duke Energy a pass on controlling its arsenic, mercury, and selenium pollution of Lake Norman, even though the Clean Water Act clearly requires otherwise – because of what EPA Administrator Pruitt might do in the future.

And DEQ has never effectively examined the best available technology for dealing with Duke Energy’s coal ash pollution across North Carolina, but instead has allowed dangerous, leaking, unlined lagoons to operate for decades with very lax limits, despite knowing that they continue to pollute North Carolina’s water resources.

Also, this proposed federal CCR permitting program is contrary to the challenges DEQ faces about its capacity. DEQ has needed more resources, been subject to budget cuts, and does not have the resources to handle the laws and permitting programs it already oversees. Yet, here DEQ proposes to create a new DEQ permitting program that it does not have to undertake. At the same time, there is already an enforcement mechanism in place – the federal CCR Rule itself – that DEQ can use at any time. Why go to the time and expense of a labor-intensive and resource-consuming permitting process when that is unnecessary?
On the other hand, a DEQ federal CCR Rule permitting program will hinder citizen enforcement of the federal CCR Rule. If DEQ adopts an inadequate permit, then citizens must contest that permit through the expensive and time-consuming process of the Office of Administrative Hearings and the state court appeal system. This process can take years, and meanwhile pollution and dangerous coal ash disposal continues. At the end of that process, with Duke Energy and DEQ working together to fight the citizen appeal, if the citizens lose, they will face an approved permit with inadequate protections.

Today, no such cumbersome, expensive, and difficult process exists for enforcement of the federal CCR Rule against Duke Energy. Citizens, just like DEQ and the state, can go into federal court and enforce the federal CCR Rule according to its terms. The federal Rule is enforced by a federal judge and ultimately a federal appeals court. There is no process available for Duke Energy to try to fudge, weaken, or avoid the terms of the Rule itself. And the enforcement of the Rule will occur much more quickly than through a time-consuming and expensive permitting process.

It is important to emphasize that we must look at the implementation of a DEQ federal CCR Rule permitting program in the future. The next election is just over two years away. We have no way of knowing who will lead North Carolina’s government or DEQ in the future and who will be making decisions concerning DEQ federal CCR Rule permits or their enforcement.

In short, we see no reason for an expensive and resource-consuming DEQ federal CCR Rule permit program which will make citizen enforcement of the law more difficult and help Duke Energy avoid steps required to clean up its coal ash pollution.

The Federal CCR Rule Requires Removing Coal Ash From Groundwater and Eliminating Impoundments.

Although we maintain that a DEQ federal CCR Rule permitting program for North Carolina ash ponds is not necessary or desirable, we support DEQ’s decision to incorporate the federal CCR Rule closure performance standards into any state rules it creates, as it has done in Section .2013 of this draft version. These performance standards make clear that Duke Energy cannot close its ash ponds by leaving its coal ash sitting deep in groundwater and impounded behind the ash lagoon dams. DEQ should require Duke Energy to remove the ash from the groundwater and store it safely in lined, dry landfill storage, or recycle it for use in cement or concrete. This is the message that the public has conveyed to DEQ repeatedly, and this is what the law requires.

The federal CCR Rule requires that if a utility wishes to close its ash pond by capping in place, their closure plan must describe “how the final cover system will achieve the performance standards specified in paragraph (d) of this section.” 40 C.F.R. § 257.102(b)(1)(iii). The performance standards require, “at a minimum,” that closure will:

- “Control, minimize or eliminate, to the maximum extent feasible, post-closure infiltration of liquids into the waste and releases of CCR, leachate, or contaminated run-off to the ground or surface waters or to the atmosphere,” Id. § 257.102(d)(1)(i);
• “Preclude the probability of future impoundment of water, sediment, or slurry,” Id. § 257.102(d)(1)(ii); and that

• “Free liquids must be eliminated by removing liquid wastes or solidifying the remaining wastes and waste residues.” Id. § 257.102(d)(2)(i).

It is important to realize that these standards do not deal with the cap itself, but what must be accomplished as to the impoundment in order for the lagoon to be capped in place. We are concerned that DEQ staff may have indicated in conversations at the meetings that the requirements in this proposed rule apply only to the cap itself. That is not correct.

Across North Carolina, Duke Energy’s coal ash is sitting stories deep in groundwater, leaching pollutants into the groundwater and discharging to surrounding surface waters. If Duke Energy wants to cap its ash ponds in place, the federal CCR Rule requires it to show that groundwater and other waters will not continue to flow through the coal ash, to “control, minimize or eliminate ... post-closure infiltration of liquids into the waste.” If groundwater remains in an ash pond, saturating the ash, and if the ash pond dam would remain wholly or partially in place after closure, the ash pond remains an impoundment and the closure would not “preclude the probability of future impoundment of water, sediment, or slurry.” And if groundwater continues to saturate coal ash within the capped ash basin footprint, then the closure plan cannot meet the requirement that “free liquids must be eliminated.” EPA has confirmed—both before and after the change in Administrations—that utilities must meet these CCR Rule performance standards when they close their ash ponds. If they cannot meet the performance standards, they cannot cap in place and must remove the ash.

Any CCR regulations DEQ puts in place must preserve or build on these performance standards and the requirement to separate coal ash from the groundwater and eliminate impoundments.

The Draft Rules Leave Out Key Public Information and Public Safety Requirements.

These rules leave out the federal requirement that Duke Energy and other utilities post online Emergency Action Plans and maps showing what would happen if one of these unlined, leaking, earthen coal ash lagoons were to fail and spill coal ash into our waters. Duke Energy has already tried to keep the public in the dark in violation of a federal disclosure requirement, before conservation groups enforced the law against the violation – so North Carolina needs to hold Duke Energy accountable going forward.

Under 40 C.F.R. § 257.107, Duke Energy and other owners or operators of coal ash lagoons “must maintain a publicly accessible Internet site (CCR Web site)” containing information specified in the Rule. On this website, utilities must publish an Emergency Action Plan for high hazard and significant hazard coal ash lagoon dams. Id. § 257.105 (f)(5). At a minimum the Emergency Action Plan must “include a map which delineates the downstream area which would be affected in the event of a CCR unit failure and a physical description of the CCR unit”; “define responsible persons, their respective responsibilities, and notification
procedures in the event of a safety emergency involving the CCR unit”; and “provide contact information of emergency responders.” Id. § 257.73.

Although the draft rules incorporate the basic requirement to have a public website (Section .2017(c)), there is no mention of an emergency action plan. DEQ must make clear that the federal requirement applies to create, maintain, and make public an emergency action plan showing the downstream areas that would be flooded in the event of a dam failure catastrophe. Access to information is a key part of the federal CCR Rule. As EPA has explained in the Preamble to the Rule, “the establishment and maintenance of this information . . . on a publicly accessible Internet site” is important because citizens need “access to all of the information necessary to show that the rule has been implemented in accordance with the regulatory requirements.” 80 Fed. Reg. 21,302, 21,426. Any regulations DEQ adopts need to prioritize public information and transparency.

These public information requirements are all the more important in North Carolina, where Duke Energy has already violated the federal requirements to post complete and public Emergency Action Plans. Instead of complying with the requirement like every other major utility in the country, Duke Energy posted plans with blacked-out maps of the inundation risks. It also redacted contact information for responsible personnel in the event of a safety emergency. Only after conservation groups discovered Duke Energy’s illegal hiding of this critical information and notified Duke Energy that they intended to sue, Duke Energy gave in and posted unredacted maps and information. DEQ must make sure that this dam safety information remains up to date and available to the communities around and downstream of Duke Energy’s coal ash ponds.

For all these reasons, we ask that DEQ withdraw these proposed rules and start the process over from the beginning,

Sincerely,

Frank S. Holleman III
Senior Attorney

cc: Bill Lane, Esq.
Attachment 2

Comments from Southern Environmental Law Center, to North Carolina Department of Environmental Quality, dated April 4, 2018, regarding CCR Rules
April 4, 2018

Via email: publiccomments@ncdenr.gov

The Hon. Michael S. Regan  
North Carolina Department of Environmental Quality  
217 West Jones Street  
Raleigh, North Carolina  27603

Re:   CCR Rules

Dear Secretary Regan:

The Southern Environmental Law Center submits these additional comments on the Department’s proposed coal ash rules, on behalf of itself and Appalachian Voices, Catawba Riverkeeper Foundation, Dan River Basin Association, MountainTrue, Roanoke River Basin Association, Sierra Club, Southern Alliance for Clean Energy, Sound Rivers, and Winyah Rivers Foundation.

As we previously set out at meetings and in comments, our principal concern about these proposed rules is that DEQ not establish a DEQ permitting program for the federal CCR Rule. A DEQ permitting program for the federal CCR Rule would undercut the rights of North Carolina’s citizens to enforce the federal CCR Rule, would impose unnecessary and unsustainable costs and burdens on DEQ itself, and adds nothing to the ability of DEQ to regulate, monitor, and enforce as to coal ash sites in North Carolina. The maximum protection for North Carolina’s communities and clean water would be provided by a strong state permitting program of state rules by DEQ and direct enforcement of the federal CCR Rule by citizens and DEQ if and when necessary. We would hope that strong enforcement by DEQ of North Carolina’s state rules and permits, along with the deterrent effect of possible direct enforcement of the federal CCR Rule by citizens or DEQ in federal court, would ensure that Duke Energy obeys the law and does not repeat its pollution of North Carolina’s water resources.

The following comments are intended to strengthen DEQ’s proposed state coal ash rules. As we understand it, these rules were intended to include within North Carolina’s state coal ash rules the strongest protections contained in the federal CCR Rule.

However, as set out below, at critical points these proposed rules weaken the requirements of the federal CCR Rule when they are incorporated into North Carolina’s state rules. In fact, these proposed rules have been written to embrace EPA Administrator’s Pruitt’s
proposed “flexibilities,” which are designed to protect Duke Energy and other polluters from having to take action to deal with their coal ash pollution.

**The Proposed DEQ Rules Weaken Groundwater Protections**

The federal CCR Rule is very clear:

‘Within 90 days of finding that any constituent listed in appendix IV to this part has been detected at a statistically significant level exceeding the groundwater protection standard defined under § 257.95(h), or immediately upon detection of a release from a CCR unit, the owner or operator must initiate an assessment of corrective measures to prevent further releases, to remediate any releases and to restore affected area to original conditions.’

40 C.F.R. § 257.96 (a).

For groundwater contamination, this obligation to remediate and restore is triggered when a pollutant exceeds the maximum contaminant level (MCL) or the background concentration. 40 C.F.R. § 257.95 (h).

DEQ’s proposed rules appropriately set the trigger at the most protective of the MCL, the state water quality standard, the IMAC, or the background concentration of the pollutant. However, DEQ’s proposed rules go on to allow the Division to create “an alternative protection standard” when there is not an MCL or a water quality standard. 15A NCAC 13B .2015 (b) (4). In the absence of this “alternative” standard, the governing standard would appropriately be the background concentration. As written, this provision would allow groundwater pollution above background; in other words, it would allow Duke Energy to pollute North Carolina’s groundwater. And in setting the “alternative” standard, DEQ can consider the vague categories of “other site-specific exposure or potential exposure to ground water.” 15A NCAC 13B .2015 (b) (5).

Although the proposed rule is not written in this way, it may be that DEQ intended the “alternative” standard in (b) (4) to be stricter than background. If so, then the phrase “stricter than the standard set out in (b) (3)” should be inserted. But if DEQ intends that the standard will not be stricter than the background concentration, then there is no need for (b) (4) other than to set out a more lenient standard that would excuse Duke Energy from correcting its pollution of groundwater. In that case, (b) (4) should be deleted.

The DEQ proposed rule adds another set of ways for Duke Energy to avoid remediation of its groundwater pollution. First, the Division may determine that remediation is not necessary if the groundwater is polluted by multiple sources and the Division decides that Duke Energy’s remediation would not provide “significant reduction in risk to actual or potential receptor.” 15A NCAC 13B .2015 (f). This exemption allows DEQ to make a discretionary decision,
subject to political influence and the pressures of Duke Energy. It also abandons groundwater if it is polluted by multiple sources. Instead, in these rules DEQ should require Duke Energy to stop and remediate its pollution and require the same of other polluters; DEQ should not allow Duke Energy to escape responsibility for its pollution because others are polluting also. This section also inserts the vague notion of “risk” analysis, without any notion of how that would be measured.

In addition, this section allows Duke Energy to get a pass for its pollution if the groundwater is “not currently or reasonably expected to be a source of drinking water.” 15A NCAC 13B .2015 (f) (2). Groundwater has other uses, including agricultural use. Further, groundwater is a public resource for generations to come, and is not just a resource for immediate or foreseen use. Duke Energy should not be allowed to operate malfunctioning and polluting coal ash sites and to pollute groundwater, and North Carolina’s groundwater should not be a resource dedicated to Duke Energy’s coal ash pollution. This subsection ends with a phrase concerning hydraulic connection that is garbled and is not comprehensible. That phrase may be intended to allow Duke Energy the benefit of dilution of pollution as it moves to larger amounts of groundwater, an unacceptable outcome.

Then, this section allows Duke Energy to escape remediation if remediation is “technically impracticable.” 15A NCAC 13B .2015 (f) (3). The phrase is undefined and would be subject to manipulation by Duke Energy and indeterminate evaluation by DEQ. Presumably, this phrase means Duke Energy does not have to remediate its pollution if Duke Energy and the Division think the remediation is not worth the effort. Such decisions have been made poorly in the past and have exposed the state’s citizens and clean water to serious pollution and catastrophic events. This section should be deleted, or at least “impracticable” be replaced with “impossible.”

Finally, the section ends with the undefined and vague concept of “unacceptable cross-media impacts.” 15A NCAC 13B .2015 (f) (4).

In short, these excuses for Duke Energy’s pollution and malfunctioning coal ash sites are subject to expensive wrangling and litigation, battles over interpretation, Duke Energy’s pressure, and political decision making. This section should be deleted.

The DEQ proposed rules do not appear to have a firm deadline for the initiation of the remedial action. The federal CCR Rule provides that Duke Energy’s assessment for corrective action must be completed in 90 days and may be extended no more than 60 days upon certification by a professional engineer. 40 C.F.R. § 257.96. Then, as soon as feasible, a remedy must be selected; and, within 90 days of selection, the remedy must be implemented. 40 C.F.R. §§ 257. 97 &98.

In addition, the DEQ proposed rule delays Duke Energy’s obligation to implement the corrective action plan, by extending the 90-day deadline in 40 C.F.R. § 257.98 (a) to 120 days,
Since 2013, a consistent theme in public comments concerning coal ash proposals has been the need for firm deadlines for Duke Energy to take action and DEQ to make decisions. More than nine years have passed since the Kingston collapse, more than five years have passed since North Carolina citizens have been enforcing the law against Duke Energy’s coal ash pollution, and more than four years have passed since the Dan River catastrophe. For a decade or more, Duke Energy’s groundwater contamination has been documented. Yet, to date, DEQ has not required Duke Energy to take remedial action for groundwater contamination at any site in North Carolina.

These rules must have firm deadlines for action by both Duke Energy and DEQ for them to be meaningful. North Carolina has had groundwater rules in the law for years, but DEQ has yet to enforce them and Duke Energy has yet to live up to them.

In 15A NCAC 13B .2015 (h) (1) (B), DEQ’s proposed rules have weakened Duke Energy’s obligation to establish a corrective action groundwater monitoring program that “demonstrates” the effectiveness of the remedy, by requiring a program that only “indicates” the effectiveness. 40 C.F.R. § 257.98 (a) (1) (ii).

In 15A NCAC 13B .2015 (h) (1) (3) (E), DEQ’s proposed rules have further weakened Duke Energy’s obligations. Under the federal CCR Rule, in selecting interim measures, Duke Energy must consider weather conditions that may cause the migration or release of any constituents listed in Appendix IV. 40 C.F.R. § 257.98 (a) (3) (v). DEQ’s proposed rules limit that obligation to the release or migration of “hazardous” constituents – without explaining how they are different from the Appendix IV constituents.

In short, as written, the proposed DEQ rules are a significant step backwards in groundwater protection and create many opportunities for Duke Energy to continue and avoid remediating its coal ash pollution, to argue about and litigate its responsibility, and to delay fixing a release and cleaning it up.

Also, EPA has recognized now that boron should be included in Appendix IV, and it should be added to Appendix IV in the DEQ rules. EPA explained that boron presents unacceptable human and ecological risks, that it is present in many coal ash damage cases, and that it reaches receptors sooner than other coal ash pollutants. Consequently, boron should be included in Appendix IV. 83 Fed. Reg. 11589 (March 18, 2018).

Bromides should also be listed in Appendix IV. Bromides from Duke Energy’s coal ash sites have caused spikes in carcinogens in public drinking water supplies. Duke Energy’s
bromide pollution is a topic of its criminal plea agreement with the United States Department of Justice and its criminal probation. After a citizen suit, bromides were recently removed from a Duke Energy air permit that DEQ had proposed. It is important that Duke Energy’s bromide pollution be carefully watched, stopped, and cleaned up.

Finally, given the notorious history of hexavalent chromium and vanadium in North Carolina wells near coal ash sites, these constituents should be included in Appendix IV, also. These substances have plagued drinking water wells near Duke Energy’s coal ash sites, and they pose a significant public health risk. They are conspicuous in their absence.

**DEQ’s Proposed Rules Weaken Protections Against the Irresponsible Use of Coal Ash**

The concept of so-called “beneficial use” of coal ash is subject to abuse and can be used by coal ash owners to get rid of their problem by spreading it across the landscape and creating new coal ash pollution problems throughout North Carolina. The federal CCR Rule puts specific limits on “beneficial use,” requiring (1) a functional benefit; (2) substitution for the use of a virgin material that therefore conserves natural resources; (3) compliance with relevant product specifications, regulatory standards, and design standards, and that coal ash not be used in excess quantities; and (4) a limit of unencapsulated use to 12,400 tons, with protective limits on releases to air and water. 40 C.F.R. § 257.53

In contrast, DEQ’s proposed rules define “beneficial” and “benefit” minimally and generally, without the protections of the federal CCR Rule, to mean “projects promoting public health and environmental protection, offering equivalent success relative to other alternatives, and preserving natural resources.” 15A NCAC 13B .2002.

To our knowledge, Duke Energy is not currently allowing coal ash to be used for unlined fill; the settlement agreement between the Yadkin Riverkeeper and Duke Energy for the Buck site and the Superior Court Orders issued at seven other sites forbid it. However, there remains the possibility of misuse of coal ash in the future and from other sites and sources. DEQ’s rules should protect North Carolina at least as much as does the federal CCR Rule.

**DEQ Should Not Use Provisions from Municipal Solid Waste Landfill (MSWLF) Regulations to Weaken Coal Ash Disposal Protections**

From the presentations made at the hearings and meetings held so far, it appears that DEQ’s proposed coal ash rules have incorporated provisions from MSWLF regulations that weaken the coal ash rules. It is a mistake and inappropriate to use municipal landfill regulations to govern the disposal of an industrial waste, coal ash, containing toxic substances.

Regulation of municipal solid waste landfills falls under the Resource Conservation and Restoration Act (“RCRA”) § 4010, which states that the Administrator must promulgate criteria for MSWLFs that are “necessary to protect human health and the environment and may take
into account the practicable capabilities of such facilities.”¹ In addition, this section of RCRA specifically provides for some flexibility. For instance, section 4010(c) allows exemptions from the use of groundwater monitoring wells to detect releases, and section 4010(c)(4) allows suspension of groundwater requirements in certain circumstances.² EPA may consider costs under section 4010(c) in promulgating the MSWLF regulations.³

Regulation of coal ash is governed by a more protective standard than the MSWLF regulations. RCRA section 4004 states that “[t]he Administrator shall promulgate regulations containing criteria for determining which facilities shall be classified as sanitary landfills and which shall be classified as open dumps . . . . At a minimum, such criteria shall provide that a facility may be classified as a sanitary landfill and not an open dump only if there is no reasonable probability of adverse effects on health or the environment from disposal of solid waste at such facility.”⁴ Put simply, “EPA is charged with issuing regulations to address all ‘reasonable probabilities of adverse effects’ (i.e., all reasonably anticipated risks) to health and the environment from the disposal of solid waste.”⁵ This standard does not allow any consideration of “practicable capabilities” of facilities. The standard applied to CCR facilities must be those necessary to ensure “no reasonable probability of adverse effects on health or the environment.” In addition, the provisions governing CCR do not authorize any exemptions from groundwater monitoring requirements.

Unlike the MSWLF regulations, EPA cannot consider cost in regulating CCR: “Congress did not authorize the consideration of costs in establishing minimum national standards under RCRA section 4004(a).”⁶ In complying with RCRA sections 4004 and 4005, EPA’s 2018 proposed revisions state numerous times that cost cannot be a factor when it determines whether to grant a waiver from rule requirements.⁷

Furthermore, EPA agrees that the MSWLF and CCR regulations are governed by two different standards. In the 2018 proposed revisions, EPA states “the rulemaking record for some part 258 provisions may not fully support a determination that a particular provision meets the RCRA section 4004(a) standard or will be ‘at least as protective’ as EPA’s CCR regulations.”⁸

Furthermore, the storage in perpetuity of millions of tons of industrial waste, which contain toxic substances and even radioactivity, is substantially different from the storage of household garbage and other wastes placed in a municipal landfill. North Carolinians expect DEQ to provide them greater protection from coal ash than the protections built into a municipal landfill.

¹ RCRA § 4010(c) (emphasis added).
² Id.
³ See Solid Waste Disposal Facility Criteria, 56 Fed. Reg. 56,078, 50,983 (Oct. 9, 1991) (“[I]t would appear that Congress explicitly authorized EPA to consider costs under 4010(c) . . . .”).
⁴ RCRA § 4004(a) (emphasis added).
⁵ 80 Fed. Reg. at 21,310.
⁶ Id. at 21,406.
⁷ See, e.g., 83 Fed. Reg. at 11,601 (determination that no Remediation of a release is necessary cannot be made “on the grounds that the cost of treating the water to remove the contaminants is too high”); id. at 11,615 (“An increase in costs . . . is not sufficient” to demonstrate no alternative capacity for non-CCR wastestreams).
CCR and MSWLF are governed by two different standards for public health and environmental protection purposes. ADEM cannot apply standards for municipal solid waste landfills under Section 4010 and Part 258 to state permit programs because it is contrary to the more protective standards required by RCRA and the 2015 CCR Rule.

**DEQ Should Make Clear that Water Resources are Protected from Unlined Coal Ash Lagoons Upon Closure**

Like the federal CCR Rule, DEQ’s proposed rules make clear that Duke Energy can close a coal ash lagoon in place only if the closure will “control, minimize or eliminate, to the maximum extent feasible, post-closure infiltration of liquids into the waste” and “preclude the probability of future impoundment of water, sediment, or slurry”; and that closure in place can take place only if “prior to installing the final cover system,” “free liquids [are] eliminated by removing liquid wastes or solidifying the remaining waste and waste residues.” 15A NCAC 13B .2013 (c) (3) (A) & (B).

However, despite the plain language of the federal CCR Rule as repeated in DEQ’s proposed rules, Duke Energy persists in arguing that it can leave coal ash sitting in groundwater and leave in place an impoundment held back by a portion of the coal ash dam. To foreclose this baseless argument, DEQ should make clear in these rules that Duke Energy cannot leave coal ash sitting in groundwater when it closes a coal ash lagoon and cannot continue to impound coal ash.

**Other Comments**

1. Section 2002 (24) is garbled.

2. Section 2002 (50). “Overfills” – the construction of a coal ash landfill over a closed impoundment – should be banned. Duke Energy has tried this in the past, but there is no need to have this practice repeated in the future. Overfills make it more difficult to reach the coal ash in the unlined pit when the ash needs to be removed due to pollution, leaching, and seeping; and this practice will make it more difficult to access ponded ash for recycling into concrete and cement.

3. Section 2203 (c) (4) (A) is garbled.

4. Section 2006 (c) (4). This section allows new CCR landfills to be sited in floodplains in certain circumstances. There is no reason why any new CCR landfill in North Carolina should be placed in a floodplain.

5. Section 2006 (c) (5) (G). The comparable provision of the federal CCR Rule requires certification from a qualified professional engineer that the siting requirements of the rule have been met. 40 C.F.R. § 257.61 (b). That requirement has been removed.
from DEQ’s proposed rules. The elimination of certification by a qualified professional engineer is one of the so-called “flexibilities” proposed by Administrator Pruitt. This approach takes away any professional certification of technical determinations and leaves them to decision making by Duke Energy and political officials in the agency. In every instance, DEQ should retain requirements that qualified professional engineers certify determinations.

6. Section 2006 (c) (8). This section deals with siting of new CCR units in unstable areas and omits a number of the protections in 40 C.F.R. § 257.64, including certification by a qualified professional engineer.

7. Section 2006 (c). Included in the list of concerns when siting a new CCR unit should be the impact of the new unit’s site on any nearby properties that have been set aside previously to mitigate for wetlands impacts. A new CCR unit should not impair the functioning of mitigation properties.

8. Section 2013 (c) (1) (A) and (B) are garbled.

9. Section 2013 (c) (1) (C). The reference to “new surface impoundments” should be deleted. There will be no new surface impoundments in North Carolina.

Since 2013, in thousands upon thousands of comments and at public hearings and at a multitude of meetings and hearings across North Carolina, North Carolina’s communities have made it clear that they expect their government to provide them the maximum protection against Duke Energy’s coal ash pollution. DEQ can respond appropriately to the wishes of the citizens of the state only if it puts in place a set of strong state coal ash rules, without exceptions and outs for Duke Energy and with firm deadlines, and preserves the citizens’ right to go directly to federal court to enforce the federal CCR Rule.

Thank you for your consideration.

Sincerely,

Frank S. Holleman III
Senior Attorney

cc: Bill Lane, Esq. (via email)
Attachment 3

Webster, P.J., et al., Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment, 309 SCIENCE 1844-1846 (2005)
Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment

P. J. Webster, 1 G. J. Holland, 2 J. A. Curry, 1 H.-R. Chang 1

We examined the number of tropical cyclones and cyclone days as well as tropical cyclone intensity over the past 35 years, in an environment of increasing sea surface temperature. A large increase was seen in the number and proportion of hurricanes reaching categories 4 and 5. The largest increase occurred in the North Pacific, Indian, and Southwest Pacific Oceans, and the smallest percentage increase occurred in the North Atlantic Ocean. These increases have taken place while the number of cyclones and cyclone days has decreased in all basins except the North Atlantic during the past decade.

During the hurricane season of 2004, there were 14 named storms in the North Atlantic, of which 9 achieved hurricane intensity. Four of these hurricanes struck the southeast United States in rapid succession, causing considerable damage and disruption. Analysis of hurricane characteristics in the North Atlantic (1, 2) has shown an increase in hurricane frequency and intensity since 1995. Recently, a causal relationship between increasing hurricane frequency and intensity and increasing sea surface temperature (SST) has been posited (3), assuming an acceleration of the hydrological cycle arising from the nonlinear relation between saturation vapor pressure and temperature (4). The issue of attribution of increased hurricane frequency to increasing SST has resulted in a vigorous debate in the press and in academic circles (5).

Numerous studies have addressed the issue of changes in the global frequency and intensity of hurricanes in the warming world. Our basic conceptual understanding of hurricanes suggests that there could be a relationship between hurricane activity and SST. It is well established that SST > 26°C is a requirement for tropical cyclone formation in the current climate (6, 7). There is also a hypothesized relationship between SST and the maximum potential hurricane intensity (8, 9). However, strong interannual variability in hurricane statistics (10–14) and the possible influence of interannual variability associated with El Niño and the North Atlantic Oscillation (11, 12) make it difficult to discern any trend relative to background SST increases with statistical veracity (8). Factors other than SST have been cited for their role in regulating hurricane characteristics, including vertical shear and mid-tropospheric moisture (15). Global modeling results for doubled CO2 scenarios are contradictory (15–20), with simulations showing a lack of consistency in projecting an increase or decrease in the total number of hurricanes, although most simulations project an increase in hurricane intensity.

Tropical ocean SSTs increased by approximately 0.5°C between 1970 and 2004 (21). Figure 1 shows the SST trends for the tropical cyclone season in each ocean basin. If the Kendall trend analysis is used, trends in each of the ocean basins are significantly different from zero at the 95% confidence level or higher, except for the southwest Pacific Ocean. Here we examine the variations in hurricane characteristics for each ocean basin in the context of the basin SST variations. To this end, we conducted a comprehensive analysis of global tropical cyclone statistics for the satellite era (1970–2004). In each tropical ocean basin, we examined the numbers of tropical storms and hurricanes, the number of storm days, and the hurricane intensity distribution. The tropical cyclone data are derived from the best track archives supported by the Nordic Council of Ministers program Vestnordisk Okeanlæm; the Ocean Surface Topography Science Team of NASA; the Research Council of Norway through RegClim-NOCLIM; and the Program of Supercomputing; and the European Union DG-XII Climate and Environment Program through DYNAMITE (GOCE-009303) and NOCES (EVK-2001-00115).

Supporting Online Material
www.sciencemag.org/cgi/content/full/309/5742/1841/DC1
Materials and Methods
Figs. S1 to S6

12 May 2005; accepted 4 August 2005
10.1126/science.1114777

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of the Joint Typhoon Warning Center and of international warning centers, including special compilations and quality control (22).

Tropical cyclonic systems attaining surface wind speeds between 18 and 33 m s\(^{-1}\) are referred to as tropical storms. Although storms of intensity >33 m s\(^{-1}\) have different regional names, we will refer to these storms as hurricanes for simplicity. Hurricanes in categories 1 to 5, according to the Saffir-Simpson scale (23), are defined as storms with wind speeds of 33 to 43 m s\(^{-1}\), 43 to 50 m s\(^{-1}\), 50 to 56 m s\(^{-1}\), 56 to 67 m s\(^{-1}\), and >67 m s\(^{-1}\), respectively. We define the ocean basins that support tropical cyclone development as follows: North Atlantic (90\(^\circ\) to 20\(^\circ\)W, 5\(^\circ\) to 25\(^\circ\)N), western North Pacific (120\(^\circ\) to 180\(^\circ\)E, 5\(^\circ\) to 20\(^\circ\)N), eastern North Pacific (90\(^\circ\) to 120\(^\circ\)W, 5\(^\circ\) to 20\(^\circ\)N), South Indian (50\(^\circ\) to 115\(^\circ\)E, 5\(^\circ\)-20\(^\circ\)S), North Indian (55\(^\circ\) to 90\(^\circ\)E, 5\(^\circ\)-20\(^\circ\)N), and Southwest Pacific (155\(^\circ\) to 180\(^\circ\)E, 5\(^\circ\) to 20\(^\circ\)S). Within these basins, total tropical storm days are defined as the total number of days of systems that only reached tropical storm intensity. Total hurricane days refer to systems that attained hurricane status, including the period when a system was at tropical storm intensity. Total tropical cyclone number or days refers to the sum of the statistics for both tropical storms and hurricanes.

Figure 2 shows the time series for the global number of tropical cyclones and the number of tropical storm days for tropical cyclones (blue curves), hurricanes (red curves), and hurricanes (black curves). Contours indicate the year-by-year variability, and the bold curves show the 5-year running average.

Fig. 2. Global time series for 1970–2004 of (A) number of storms and (B) number of storm days for tropical cyclones (hurricanes plus tropical storms; black curves), hurricanes (red curves), and tropical storms (blue curves). Contours indicate the year-by-year variability, and the bold curves show the 5-year running average.

Fig. 3. Regional time series for 1970–2004 for the NATL, WPAC, EPAC, NIO, and Southern Hemisphere (SIO plus SPAC) for (A) total number of hurricanes and (B) total number of hurricane days. Thin lines indicate the year-by-year statistics. Heavy lines show the 5-year running averages.

In summary, careful analysis of global hurricane data shows that, against a background of increasing SST, no global trend has yet emerged in the number of tropical storms and hurricanes. Only one region, the North Atlantic, shows a statistically significant increase, which commenced in 1995. However, a simple attribution of the increase in numbers of storms to a warming SST environment is not supported, because of the lack of a comparable correlation in other ocean basins where SST is also increasing. The observation that increases in North Atlantic hurricane characteristics have occurred simultaneously with a statistically significant positive trend in SST has led to the speculation that the changes in both fields are the result of global warming (3).

It is instructive to analyze the relationship between the covariability of SST and hurricane characteristics in two other ocean basins, specifically the eastern and western North Pacific. Decadal variability is particularly evident in the eastern Pacific, where a maximum in the number of storms and the number of storm days in the mid-1980s (19 storms and 135 storm days) has been followed by a general decrease up to the present (15 storms and 100 storm days). This decrease accompanied a rising SST until the 1990–1994 pentad, followed by an SST decrease until the present. In the western North Pacific, where SSTs have risen steadily through the observation period, the number of storms and the number of storm days reach maxima in the mid-1990s before decreasing dramatically over the subsequent 15 years. The greatest change occurs in the number of cyclone days, decreasing by 40% from 1995 to 2003.

Examination of hurricane intensity (Fig. 4) shows a substantial change in the intensity distribution of hurricanes globally. The number of category 1 hurricanes has remained approxi-
R E P O R T S

Cyclone intensities around the world are estimated by pattern recognition of satellite features based on the Dvorak scheme (25). The exceptions are the North Atlantic, where there has been continuous aircraft reconnaissance; the eastern North Pacific, which has occasional aircraft reconnaissance; and the western North Pacific, which had aircraft reconnaissance up to the mid-1980s. There have been substantial changes in the manner in which the Dvorak technique has been applied (26). These changes may lead to a trend toward more intense cyclones, but in terms of central pressure (27) and not in terms of maximum winds that are used here. Furthermore, the consistent trends in the North Atlantic and eastern North Pacific, where the Dvorak scheme has been calibrated against aircraft penetrations, give credence to the trends noted here as being independent of the observational and analysis techniques used. In addition, in the Southern Hemisphere and the North Indian Ocean basins, where only satellite data have been used to determine intensity throughout the data period, the same trends are apparent in the Northern Hemisphere regions.

We deliberately limited this study to the satellite era because of the known biases before this period (28), which means that a comprehensive analysis of longer-period oscillations and trends has not been attempted. There is evidence of a minimum of intense cyclones occurring in the 1970s (11), which could indicate that our observed trend toward more intense cyclones is a reflection of a long-period oscillation. However, the sustained increase over a period of 30 years in the proportion of category 4 and 5 hurricanes indicates that the related oscillation would have to be on a period substantially longer than that observed in previous studies.

We conclude that global data indicate a 30-year trend toward more frequent and intense hurricanes, corroborated by the results of the recent regional assessment (29). This trend is not inconsistent with recent climate model simulations that a doubling of CO2 may increase the frequency of the most intense cyclones (18, 30), although attribution of the 30-year trends to global warming would require a longer global data record and, especially, a deeper understanding of the role of hurricanes in the general circulation of the atmosphere and ocean, even in the present climate state.

References and Notes

31. This research was supported by the Climate Dynamics Division of NSF under award NSF-ATM 0328842 and by the National Center for Atmospheric Research, which is funded by NSF.

Table 1. Change in the number and percentage of hurricanes in categories 4 and 5 for the 15-year periods 1975–1989 and 1990–2004 for the different ocean basins.

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<td>Number</td>
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<tr>
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<td>West Pacific Ocean</td>
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<tr>
<td>North Indian</td>
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<td>South Indian</td>
<td>23</td>
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Fig. 4. Intensity of hurricanes according to the Saffir-Simpson scale (categories 1 to 5). (A) The total number of category 1 storms (blue curve), the sum of categories 2 and 3 (green), and the sum of categories 4 and 5 (red) in 5-year periods. The bold curve is the maximum hurricane wind speed observed globally (measured in meters per second). The horizontal dashed lines show the 1970–2004 average numbers in each category. (B) Same as (A), except for the percent of the total number of hurricanes in each category class. Dashed lines show average percentages in each category over the 1970–2004 period.
Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment

P. J. Webster, G. J. Holland, J. A. Curry and H.-R. Chang

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Attachment 4

Spatial and temporal variability of coastal storms in the North Atlantic Basin

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Abstract

Over the past three to four decades, there has been a growing awareness of the important controls exerted by large-scale meteorological events on coastal systems. For example, definitive links are being established between short-term (timescales of 5–10 years) beach dynamics and storm frequency. This paper assesses temporal variability of coastal storms (both tropical and extratropical) and the wave climatology in the North Atlantic Basin (NAB), including the Gulf of Mexico. With both storm types, the empirical record shows decadal scale variability, but neither demonstrates highly significant trends that can be linked conclusively to natural or anthropogenic factors. Tropical storm frequencies have declined over the past two or three decades, which is perhaps related to recent intense and prolonged El Niños. Some forecasts predict higher frequencies of tropical storms like that experienced from the 1920s to the 1960s to occur in coming decades. Results from general circulation models (GCMs) suggest that overall frequencies of tropical storms could decrease slightly, but that there is potential for the generation of more intense hurricanes. These data have important implications for the short-term evolution of coastal systems.

There is strong suggestion that extratropical systems have declined overall over the past 50–100 years, but that there is an increase in frequency of very powerful storms, especially at higher latitudes. Both ENSO and the North Atlantic Oscillation (NAO) are shown to have associations with frequencies and tracking of these systems. These empirical results are in general agreement with GCM forecasts under global warming scenarios. Analyses of wave climatology in the NAB show that the last two to three decades have been rougher at high latitudes than several decades prior, but this more recent sea state is similar to conditions from about 100 years ago. The recent roughness at sea seems to be related to high NAO index values, which are also expected to increase with global warming. Thus, when coupled to an anticipated continued rise in global sea level, this trend will likely result in increasing loss of sediment from the beach-nearshore system resulting in widespread coastal erosion.

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Keywords: temporal variability; tropical storms; extratropical storms; wave climatology

1. Introduction

In recent years, there has been a concerted effort to establish definitive links between large-scale me-
teorological events and the short-term (decadal scale) evolution of coasts (Stone et al., 1997; Muller and Stone, 2001; Ranasinghe et al., 2004; Stone et al., 2004; Pepper and Stone, 2004). In terms of environmental and economic impacts, coastal storms are among the most significant on earth. Although wind speeds in coastal storms are less than the most severe tornadoes, the scale and duration of these events are much larger, which are compounded by the generation of damaging waves that propagate far beyond the region of wind stress. Along low-lying coastal zones, storm surges can extend damage even further inland. As a result, impacts of these storms are significant to both the coastal morphodynamics and the large population base that inhabit the coastal zone. This paper will assess the spatial and temporal variability of coastal storms in the North Atlantic Basin (NAB), including the Gulf of Mexico. It will include examination of tropical and extratropical storms, both of which occur in this region, as well as the wave climatology of the basin. Empirical studies over the past century, as well as recent modeled results of future climates, are both addressed. Implications for coastal systems are assessed for the areas under study.

2. Observed trends in tropical cyclones

Tropical cyclones are storms that generally form and intensify over warm tropical water surfaces and then frequently travel poleward. In the NAB, these events can occasionally have their origins traced back to the coast of northwestern Africa, where clusters of thunderstorms begin to take on cyclonic circulations. These thunderstorms initially become tropical waves, which can then intensify to tropical storm or hurricane strength under particular atmospheric and oceanic conditions. A tropical cyclone can be defined as a low-pressure, synoptic-scale system that is warm-cored and nonfrontal (Neumann et al., 1993), occurring from June to November, with a peak in September. During development in the NAB, these storms drift westward at tropical latitudes within the easterly trade winds, then often turn northward, tracking around the Atlantic Subtropical High (Davis et al., 1997) to affect the eastern United States and occasionally even western Europe (Fig. 1), e.g., Tropical Storm Andrew in 1986 and Hurricane Bob in 1991 (Neumann et al., 1993). Along this trajectory, it is common for tropical cyclones to transform into extratropical systems, especially north of 35°N latitude. Although these transformed cyclones rarely regain their former strength, over half of these systems undergo posttransition intensification and are most likely to impact the northeastern United States and Canadian Maritimes (one to two storms per year) and western Europe (once every 1–2 years) (Hart and Evans, 2001). Fig. 1 depicts all the tropical storm tracks from 1886 to 1992 during the latter part of August (August 21–31). The classic parabolic curved path is clearly evident here as storms drift from east to west in the trade winds, then drift poleward until steered by the westerlies, where they travel from west back to east at higher latitudes.

Empirical analyses of tropical storm and hurricane strikes along the coasts of the United States over the past century show that particular coastal segments are exposed to recurring strikes, e.g., southeastern Louisiana, southern Florida, and eastern North Carolina (14–17 events over the 100-year record), and that other coastal segments rarely experience direct hurricane strikes, e.g., the Sea Islands of Georgia (1 in 100 years) and the northeastern margin of the Gulf of Mexico in the vicinity of Cedar Keys, Florida (3 in 100 years) (Muller and Stone, 2001). For the NAB, multidecadal variability in frequencies is more characteristic than linear trends (Landsea et al., 1999). For example, Bove et al. (1998a,b) found no trends in hurricane frequencies and intensities in the Gulf of Mexico basin from 1886 to 1995. However, regarding total NAB hurricane activity, the early 1900s to the 1920s was a relatively quiet period, the late 1920s to the 1960s was active, and the 1970s through the early 1990s was relatively quiet again (Landsea et al., 1992). Muller and Stone (2001) also showed that the Cape Hatteras region, southern Florida, the northern Gulf Coast, and southern Texas all experienced different clusters of years and even decades with frequent or infrequent storm strikes. Gray (1990) attributed these decadal and geographical scale oscillations to shifts in sea surface temperatures (SSTs), where above-normal SSTs in the NAB, coupled with below-normal SSTs in the South Atlantic, are most conducive to intense hurricane formation in the NAB.
Zhang et al. (2000) analyzed storm surge data along the U.S. East Coast and also found similar decadal scale variability, but also reported that sea-level rise over the past century has exacerbated impacts of these events over time.

The El Niño Southern Oscillation is also linked to frequencies of NAB tropical cyclone activity. Goldenberg and Shapiro (1996) demonstrated that warm phase (El Niño) conditions in the eastern Pacific Ocean coupled with drought in the African Sahel operate together to increase potential for westerly vertical wind shear. This creates unfavorable conditions for hurricane formation in the NAB. Furthermore, Bove et al. (1998a,b) showed that the annual probability of a major hurricane landfall in the United States is 23% during a (warm phase) El Niño season, 58% during neutral conditions, and 63% during cold-phase (La Niña) conditions. Similarly, Pielke and Landsea (1999) found that hurricane-induced damage is associated with ENSO, with La Niña hurricane seasons exhibiting significantly more damage than during hurricane seasons occurring with an El Niño.

3. Model studies of tropical storms

Modeled studies of tropical cyclone activity may give us some indication as to how these storms may change in frequency and magnitude as the overall global climate changes. For example, Hobgood and Cerveny (1988) used the Goddard Institute for Space Studies general circulation model (GCM) run of the last glacial maximum conditions of 18,000 years BP. They concluded that this atmosphere had potential to support tropical cyclone development, but such tropical storms would have been weaker than modern tropical storms. Using this same concept of implementation of GCMs, there have been several studies that attempted to assess the impacts of potential global warming on tropical cyclone activity. Emanuel (1987) used a GCM to simulate global warming conditions in August and concluded that there may be up to a 40–50% increase in the destructive potential of hurricanes at that time of year. Bengtsson et al. (1996) concluded that a doubling of CO₂ on earth would not likely change the geographical patterns and seasonality of storms, but that the
overall number of events was significantly reduced in their model run. Despite this conclusion, they also suggested that more powerful storms could result, which is in general agreement with Emanuel (1987). Similarly, Haarsma et al. (1992) found an increase in the frequency and magnitude of the most intense tropical cyclones in their GCM run, although they did caution that GCMs do not resolve tropical cyclones adequately. They found that GCM-simulated tropical cyclones are generally weaker in intensity and have larger horizontal extent than modern storms, but the simulated storms do display the basic physics of tropical cyclones.

Broccoli and Manabe (1990) raised the question as to how useful GCM results are when used to predict future tropical cyclone activity. Although they admit that their model resolution is insufficient to reproduce the fine structures exhibited by tropical cyclones, they concluded that given the models’ ability to qualitatively simulate tropical storm climatologies, the answer is yes. However, Henderson-Sellers et al. (1998) argued that the coarse resolution of modern GCMs greatly limits their results. In lieu of GCMs, they instead analyzed recent thermodynamical estimation of tropical cyclone maximum potential intensities (MPI). The MPI is an estimation of the possible strength of a hurricane resulting from available energy from both atmosphere and ocean. Modern estimates are made from monthly mean atmospheric temperature soundings at radiosonde sites, combined with sea surface temperatures, whereas forecasts are informed with GCM input. Recent studies suggest that hurricane MPI will remain the same or increase modestly (up to 10–20%) with global warming (Henderson-Sellers et al., 1998).

4. Observed trends in extratropical cyclones

Whereas tropical cyclones develop over warm tropical oceans, extratropical cyclones, also called mid-latitude cyclones, evolve along the polar front, which is defined as a semicontinuous boundary in the mid-latitudes that separates cold polar air masses from warm subtropical air masses (Ahrens, 2000). Three-dimensional interactions between these contrasting air masses provide the needed dynamics for development of extratropical storms. Cyclogenesis takes place in regions of baroclinicity, where winds blow across isothermal patterns to produce temperature advection. In other words, a baroclinic zone has warm air transport into a region that is colder, while adjacent cold air is transported into a region that is warmer. The polar front resides below the baroclinic zone, separating cold polar air from warm tropical air at the surface, while the jet stream resides aloft. This type of atmospheric setting is conducive to the formation of extratropical cyclones (cyclogenesis) and occurs frequently during colder months on the lee side of the Rocky Mountains, over the northwestern Gulf of Mexico along the Texas Coast, and especially off Cape Hatteras, North Carolina where colder air from the continent meets much warmer air over the warmer ocean (Fig. 2). Along the East Coast of North America, there are noteworthy secondary points of cyclogenesis off of Cape Cod, Massachusetts, and Nova Scotia, Canada (Fig. 3) (Bradbury et al., 2003).

Mather et al. (1964) were the first to classify storms along the East Coast of the United States. They developed eight classes of storms, of which one represented tropical events, while the remaining seven classes were all extratropical cyclonic systems. Coastal storms of moderate intensity or greater should be expected once every 1.4 years in New York and New Jersey and once every 4.2 years in Georgia. Mather et al. (1967) also reported a high number of damaging storms along the East Coast of the United States in late 1950s and early 1960s as compared to the 1930s through early 1950s. Davis and Dolan (1993a) have also examined United States East Coast storm frequencies. They concluded that storm frequencies
declined from the mid-1960s to mid-1970s, then increased through 1984, but the frequency of the most severe damaging storms had increased throughout the period of record (1942–1992). The overall decrease in storm frequencies was also observed by Reitan (1979) and Zishka and Smith (1980), who reported a general trend toward decreasing cyclone frequencies over the continent of North America. However, somewhat contradictory results were reported by Agee (1991), who found that there was a positive correlation between northern hemisphere temperature and cyclone frequencies, citing higher frequencies during the warming period from 1905 to 1940 (at least in the United States) and reduced frequencies during the cooler period from 1940 to 1977.

Hirsch et al. (2001) reported that, on average, 12 East Coast winter storms occur per winter season, with a maximum in January. Significant trends (1951–1995) were not evident. However, a marginally significant (alpha = 0.10) decrease in average storm minimum pressure was noted. They also concluded that the average monthly winter storm frequency anomalies are significantly higher during El Niño months over the October–April storm season. Winter storms showed little or no change in frequencies during La Niña months. DeGaetano et al. (2002) took this research a step further and noted that United States East Coast storms are related to both El Niño and the North Atlantic Oscillation (NAO) phases, as heightened storm activity tends to occur during the positive phase of the NAO in conjunction with El Niño conditions. However, Joyce (2002) cautioned that the recent (post-1960) associations between the NAO and climate in the eastern United States may be overestimated because the relationship was not as robust earlier in the 20th century and was nonexistent in the latter portion of the 19th century.

McCabe et al. (2001) concluded that cyclones in the middle latitudes (30–60°N) in the northern hemisphere have significantly declined in frequency, but have increased significantly at higher latitudes (60–90°N), suggesting that extratropical cyclonic activity has shifted poleward due to hemispheric warming (Fig. 4). In addition, they reported that severe storm intensity has increased at both middle and high latitudes, which corroborated results of Davis and Dolan (1993a).

Schmith et al. (1998) studied winter storminess using mean sea level pressure data over the Northeast Atlantic. They reported decadal scale variations and large geographical variability in storms. They concluded that a modest increase in storminess over the

Fig. 3. Total cyclogenesis occurrences (1958–2000) along the northeastern coast of the United States. Adapted from Bradbury et al. (2003).

Fig. 4. Northern hemisphere standardized departures of winter (November–March) cyclone counts at (A) high latitudes and (B) mid-latitudes, as well as for intensity (C) high latitudes and (D) mid-latitudes. Adapted from McCabe et al. (2001).
past two to three decades occurred in the region of Scandinavia, but this was less detectable in and near the United Kingdom, supporting results of McCabe et al. (2001). Overall, they found modest increases in winter storminess over the Northeast Atlantic from 1875 to 1995. Andrade et al. (2004) examined storms in the Azores and found high frequencies of storms from about 1875 to 1905, very low frequencies in the 1920s to the early 1940s, then returning to a regime of higher frequencies, peaking around 1980.

Although a few studies have actually analyzed wind data, Siegismund and Schrum (2001) reported a substantial increase in average annual wind over the North Sea: about a 10% increase from 1958 to 1997. Pirazzoli et al. (2004) also examined wind data in western France and found increasing occurrences of strong winds in western Brittany, but decreasing trends in Normandy and Pays de Loire.

5. Model studies of extratropical cyclones

In agreement with Schmith et al. (1998), GCM simulations of increasing CO₂ indicated heightened storminess in the Northeast Atlantic, as well as in northwestern Europe because of a potential intensification and eastward extension of the North Atlantic storm track (Carnell et al., 1996). Schrum (2001) also demonstrated that a high North Atlantic Oscillation (NAO) Index results in an intensification of cyclonic circulation in both the Baltic and North Seas and that under a global warming scenario, the NAO index values are expected to rise. Furthermore, Lambert (1995) reported that in a 2 × CO₂ GCM simulation, there is a reduction in the total number of winter cyclones in both hemispheres, but the frequency of intense cyclones increases, especially in the Northern Hemisphere, which is clearly in general agreement with the empirical record. Lozano et al. (2004) further support these findings by reporting that the Ireland–Scotland region may experience fewer, but more powerful storms in a future dominated by global warming.

6. Wave climatology of the North Atlantic Basin

Most significant ocean waves are generated from wind stress, either from tropical or extratropical storms. There is a body of literature that places primary focus on the waves and may or may not address the storms that generated the waves. Dolan and Davis (1992), for example, devised a rating system for northeasters based on significant wave heights (SWH) and storm duration. The scale is similar to the Saffir/Simpson hurricane scale ranging from Dolan/Davis 1 (minor beach erosion) to a Dolan/Davis 5 (extreme beach erosion). Although their dataset ends in 1992, they concluded that Class 4 and 5 northeasters appeared to be increasing in frequency (Davis and Dolan, 1993a), though this result was not statistically significant (Keim and Cruise, 1998). Davis and Dolan (1993b) also classified northeasters into eight types based on the origins of the storms. Bahamas Lows and Florida Lows were found to be rare, but produced the greatest wave heights along the East Coast of the United States. Kushnir et al. (1997) reported an increasing trend in significant wave heights (SWH) at several Northeast Atlantic locations since 1960. They believe this trend is related to the systematic deepening of the Icelandic low and intensification of the Azores high over the last three decades, leading to high positive NAO values. The analysis suggests that wave height south of 40°N has decreased during the same period.

Wang and Swail (2001) concluded that over the past four decades, statistically significant changes in the seasonal extremes of SWH in the North Atlantic (NA) were evident, but only for the winter (January–March) season. The geographical pattern of these findings was that the northeastern North Atlantic had significant increases in SWH, while significant decreases were found in the subtropical North Atlantic. The temporal patterns were also associated with phases and intensity of the North Atlantic Oscillation (NAO). Wang and Swail (2002) confirmed their previous results and showed that the northeast North Atlantic Ocean has experienced significant multidecadal variations in wave height activity over the last century, and it has indeed roughened in winters of the last four decades. This detailed Atlantic hindcast shows more significant increases in wave heights in the region off the Canadian coast in summer and fall; and in winter, it shows higher rates of increases in the region northwest of Ireland, but less significant changes in the North Sea and in the region off the Scandinavian coast.
The WASA Group (1998) pointed out that inhomogeneities in the empirical data are a major methodological obstacle in wave hindcasting. However, their main conclusions in this research were that decadal scale variations are evident in the record, the northeastern Atlantic has indeed roughened in recent decades, but that recent wave climates are comparable to the climatology around the turn of the 20th century, and that at least part of this variability is associated with the NAO.

7. Discussion and summary

With both tropical and extratropical storms, the empirical record shows decadal scale variability, but data for both of these storm systems tend to lack highly significant trends that can be linked conclusively to natural or anthropogenic factors. Tropical storm frequencies have shown decadal variability, whereas the past two or three decades have had reduced frequencies. This is probably the result of recent intense and prolonged El Niños, which create environments that are not conducive to the formation of tropical systems in the NAB. However, there are signs that hurricanes may be increasing in frequency again, and some forecasts for the next few decades are predicting higher frequencies like that experienced from the 1920s to the 1960s (Gray, 1999). Results from GCMs about future tropical cyclone climatologies are mixed, but there is a suggestion that overall frequencies of tropical storms could decrease slightly, but that there is potential for the generation of more intense hurricanes. Broccoli and Manabe (1990) concluded that GCMs are qualitatively appropriate tools to assess anthropogenic changes in tropical systems, though there is no general agreement in the literature.

There is strong suggestion that extratropical systems in the NAB have declined overall over the past 50–100 years, but that there is an increase in frequency of really powerful storms. Some geographical variability is apparent in these trends, whereas higher latitudes in the northern hemisphere are experiencing upward trends in cyclone frequencies, including the regions off of the eastern Canadian coast, Iceland, and Scandinavia, while decreasing trends are more evident at middle latitudes. Both ENSO and the NAO have impacts on frequencies and tracking of these systems. These empirical results are in general agreement with GCM forecasts under global warming scenarios, as extratropical storms are expected to displace northward along with the jet stream and regions of baroclinicity. Analyses of wave climatology in the NAB show that the last two to three decades have been rougher at high latitudes than several decades prior, but this more recent sea state is similar to conditions about 100 years ago. The recent roughness at sea seems to be related to high NAO index values, which are also expected to increase with global warming.

These findings have important implications for the short-term evolution of coasts particularly if an increase in the frequency and/or intensity of hurricanes occurs. As an example, barrier and beach ridge coasts along the northeast Gulf of Mexico have demonstrated stability over periods approximating two decades when tropical cyclone activity was very low (from the 1970s to the mid-1990s). This sand-rich stretch of coast offsets rises in sea level during that period. However, with the onset of a pronounced period of storminess, which occurred post-1995 (Stone et al., 2004), a significant erosional trend was observed. The same response would be anticipated along the NAB where an increase in frequency of very powerful storms may occur. Over longer timescales (millennia), the incidence and intensity of storms will play an increasingly important role in the morphodynamic evolution of coasts during periods of ‘stillstands’ in sea level, particularly in the transgressive evolution and migration of coasts across the shelf.

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Attachment 5

Ning Lin, et al., *Physically Based Assessment of Hurricane Surge Threat Under Climate Change*, NATURE CLIMATE CHANGE, DOI: 10.1038/NCLIMATE1389 (2012)
Physically based assessment of hurricane surge threat under climate change

Ning Lin1*, Kerry Emanuel1, Michael Oppenheimer2 and Erik Vanmarcke3

Storm surges are responsible for much of the damage and loss of life associated with landfalling hurricanes. Understanding how global warming will affect hurricane surges thus holds great interest. As general circulation models (GCMs) cannot simulate hurricane surges directly, we couple a GCM-driven hurricane model with hydrodynamic models to simulate large numbers of synthetic surge events under projected climates and assess surge threat, as an example, for New York City (NYC). Struck by many intense hurricanes in recorded history, NYC is highly vulnerable to storm surges. We show that the change of storm climatology will probably increase the surge risk for NYC; results based on two GCMs show the distribution of surge levels shifting to higher values by a magnitude comparable to the projected sea-level rise (SLR). The combined effects of storm climatology change and a 1 m SLR may cause the present NYC 100-yr surge flooding to occur every 3–20 yr and the present 500-yr flooding to occur every 25–240 yr by the end of the century.

Associated with extreme winds, rainfall and storm surges, tropical cyclones present major hazards for coastal areas. Moreover, tropical cyclones respond to climate change1–3. Previous studies predicted an increase in the global mean of the maximum winds and rainfall rates of tropical cyclones in a warmer climate4; however, the effect of climate change on storm surges, the most damaging aspect of tropical cyclones, remains to be investigated5. Hurricane Katrina of 2005, the costliest natural disaster in US history, produced the greatest coastal flood heights ever recorded in the US, causing more than US$100 billion in losses and resulting in about 2,000 fatalities. On the eastern US coast, where tropical cyclones are less frequent than in the Gulf of Mexico and Florida regions, the Great Hurricane of 1938 produced record flood heights in Long Island and southern New England, killing 600–800 people. A question of increasing concern is whether such devastating surge events will become more frequent.

The storm surge is a rise of coastal shallow water driven by a storm’s surface wind and pressure gradient forces; its magnitude is determined, in a complex way, by the characteristics of the storm plus the geometry and bathymetry of the coast. As a result, the change of surge severity cannot be inferred directly from the change of storm intensity4–8. For example, Hurricane Camille of 1969 (category 5) made landfall in the same region of Mississippi as the less intense Hurricane Katrina (category 3), but produced lower surges owing to its smaller size5,6,8. Using only a storm’s landfall characteristics to predict surges is also inaccurate10,11, as the evolution of the storm before and during landfall affects the surge. Furthermore, similar storms can produce quite different surges at locations with different topological features4. Therefore, quantifying the impact of climate change on hurricane surges requires explicit modelling of the development of storms and induced surges at regional scales under projected climates.

Modelling hurricane surges under climate scenarios, however, is not straightforward, because tropical cyclones cannot be resolved in present GCMs owing to their relatively low resolution (∼100 km) when compared with the size of the storm core (∼5 km). Although high-resolution regional models (for example, refs 12 and 13) may be used to downscale the GCM simulations, these models are still limited in horizontal resolution and are too expensive to implement for risk assessment. This study takes a more practical approach, coupling a simpler GCM-driven statistical/deterministic hurricane model with hydrodynamic surge models to simulate cyclone surges for different climates.

Computationally efficient, this method can be used to generate large numbers of synthetic surge events at sites of interest, providing robust statistics to characterize surge climatology and extremes. We apply this method to investigate present and future hurricane surge threat for NYC, considering also the contribution of wave set-up, astronomical tides and SLR. The resulting surge flood return-level curves provide scientific bases for climate adaptation and sustainable development in rapidly developing coastal areas14–16.

Storm simulation

The statistical/deterministic hurricane model17,18, used in this study generates synthetic tropical cyclones under given large-scale atmospheric and ocean environments, which may be estimated from observations or climate modelling. This method does not rely on the limited historical track database, but rather generates synthetic storms that are in statistical agreement with observations17, and it compares well with various other methods used to study the effects of climate change on tropical cyclones4,18,19. In this study, we assume the cyclone-threatened area for NYC to be within a 200-km radius from the Battery (74.02 W, 40.9 N; chosen as the representative location for NYC), and we call it a NY-region storm if a storm ever passes within this area with a maximum wind speed greater than 20 m s⁻¹. To investigate the present surge probabilities, we generate a set of 5,000 NY-region storms under the observed climate (represented by 1981–2000 statistics) estimated from the National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis20. To study the impact of climate change, we apply each of four climate models, CNRM-CM3 (Centre National de Recherches Météorologiques, Météo-France), ECHAM5 (Max Planck Institute), GFDL-CM2.0 (National Oceanic
Figure 1 | Two worst-case surge events for the Battery, under the NCEP/NCAR climate. The contours and colours show the surge height (m). The black curve shows the storm track. The black star marks the location of the Battery. The storm parameters when the storm is closest to the Battery are as follows. a, Storm symmetrical maximum wind speed $V_m = 56.6 \text{ m s}^{-1}$, minimum sea-level pressure $P_c = 960.1 \text{ mb}$, radius of maximum wind $R_m = 39.4 \text{ km}$, translation speed $U_t = 15.3 \text{ m s}^{-1}$ and distance to the site $ds = 3.9 \text{ km}$. b, $V_m = 52.1 \text{ m s}^{-1}$, $P_c = 969.2 \text{ mb}$, $R_m = 58.9 \text{ km}$, $U_t = 9.7 \text{ m s}^{-1}$ and $ds = 21.1 \text{ km}$.

Surge modelling

This study uses two hydrodynamic models: the Advanced Circulation$^{34,23}$ (ADCIRC) model and the Sea, Lake, and Overland Surges from Hurricanes$^{26}$ (SLOSH) model, both of which have been validated and applied to simulate storm surges and make forecasts for various coastal regions (for example, refs 27–32). Storm surges are driven by storm surface wind and sea-level pressure fields. For the ADCIRC simulations, the surface wind is estimated by calculating the wind velocity at the gradient level with an analytical hurricane wind profile$^{28}$, translating the gradient wind to the surface level with a velocity reduction factor (0.85; ref. 34) and an empirical expression of inflow angle$^{35}$, and adding a fraction (0.5; based on observed statistics) of the storm translation velocity to account for the asymmetry of the wind field; the surface pressure is estimated from a parametric pressure model$^{36}$. For the SLOSH simulations, the wind and pressure are determined within the SLOSH model by a semi-parametric hurricane model$^{37}$. The two hydrodynamic models are applied with numerical grids of various resolutions (from $\sim1 \text{ km}$ to $\sim10 \text{ m}$ around NYC). The SLOSH simulation with a coarse-resolution grid is used to select the extreme surge events, which are further analysed with higher-resolution ADCIRC simulations to estimate the probability distributions of NYC surges (see Methods and Supplementary Figs S1 and S2).

As examples, Fig. 1 shows the spatial distribution of the storm surge around the NYC area for two worst-case scenarios for the Battery under the NCEP/NCAR climate. The storm that generates the highest surge ($4.75 \text{ m}$) at the Battery moves northeastward and close to the site with a high intensity (Fig. 1a). A relatively weaker storm that moves farther from the site also produces a comparable surge ($4.57 \text{ m}$) at the Battery, owing to its larger size and northwestward translation (Fig. 1b). Both storms induce high surges at the site with their largest wind forces to the right of the track, especially the northwestward-moving storm, which concentrates its strongest wind forces on pushing water into New York harbour and up to lower Manhattan. These two worst-case surges for the Battery have very low occurrence probabilities under the present climate condition. However, NYC has indeed been affected by numerous intense storm surges in recorded history and, on the basis of the local sedimentary evidence, prehistory$^{37}$. The highest water level at the Battery as inferred from historic archives

and Atmospheric Administration (NOAA) Geophysical Fluid Dynamics Laboratory) and MIROC3.2 (CCSR/NIES/FRCGC, Japan), to generate 5,000 NY-region storms under present climate conditions (1981–2000 statistics) and another 5,000 NY-region storms under future climate conditions (2081–2100 statistics) for the A1B emission scenario of the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report$^{11}$ (AR4). (Most of the climate data are obtained from the World Climate Research Program (WCRP) third Climate Model Intercomparison Project (CMIP3) multimodel data set.) We choose these four climate models because the predictions of the changes in storm frequency, intensity and power dissipation in the Atlantic basin due to global warming by these models span the range of predictions by all seven CMIP3 models from which the required model output is available$^{18}$.

The annual frequency of the historical NY-region storms is estimated from the best-track Atlantic hurricane data set (updated from ref. 22) to be 0.34; we assume this number to be the storm annual frequency under the present climate. As the hurricane model does not produce an absolute rate of genesis, the storm frequency derived from each climate model for the present climate is calibrated to the observed value (0.34), and the frequency for the future climate is then predicted$^{18}$. Estimated annual frequencies of future NY-region storms from the four climate models differ: CNRM is 0.70, ECHAM is 0.31, GFDL is 1.34 and MIROC is 0.29; the change of the storm frequency ranges from a decrease of 15% to an increase of 290%. The large variation among the model predictions reflects the general uncertainties in climate models’ projections of tropical cyclone frequency, due to systematic model differences and internal climate variability (which may not be averaged out over the 20-yr periods considered here). According to ref. 23, as much as half of the uncertainty may be due to the climate variability. Moreover, the variations in the storm frequency changes at global or basin scales, as projected by refs 4 and 18, are greatly amplified at regional scales, owing to the differences in the changes of the storm track and intensity predicted by the climate models. We also note that even larger variations in the storm frequency changes can be induced if more climate models are considered; for example, the Hadley Center UK Meteorological Office model UKMO-HadCM3 may predict a relatively large reduction in the storm frequency due to climate change$^{3}$.
In addition, we study the nonlinear effect on the surge from the SLR, by simulating the extreme surges for a range of projected SLRs for NYC. This SLR effect is found to be negligible (see Supplementary Fig. S6), and thus the projected SLR in future climates is accounted for linearly in the estimation of the flood height for NYC.

**Statistical analysis**

We assume the annual number of NY-region storms to be Poisson-distributed (Supplementary Fig. S7 and associated discussion), with the annual storm frequency as the mean. For each storm arrival, the probability density function (PDF) of the induced surge is estimated from the generated surge database. Our empirical data sets show that the surge PDF is characterized by a long tail, which determines the risk. We apply a peaks-over-threshold method to model this tail with a generalized Pareto distribution, using the maximum-likelihood method, and the rest of the distribution with non-parametric density estimation. The generalized Pareto distribution fits relatively well with the surge distribution for almost all storm sets in this study (Supplementary Figs S8 and S9). The estimated storm frequency and surge PDF are then combined to generate the surge return-level curve and associated statistical confidence interval (calculated with the Delta method\(^{39}\)). The storm frequency and surge PDF are further applied to estimate the storm tide and flood height return levels (see Methods).

**Present surge threat**

The estimated return levels of the storm surge at the Battery under the NCEP/NCAR climate are shown in Fig. 2. The estimated present 50-yr storm surge is about 1.24 m, the 100-yr surge is about 1.74 m and the 500-yr surge is about 2.78 m. A previous study\(^{39}\), using the SLOSH model with a relatively coarse mesh, predicted a higher surge (2.14 m) for the 100-yr return period but slightly lower surges for longer return periods for this site. These differences result mainly from the different wind profiles and grid resolutions applied in the ADCIRC and SLOSH simulations and the different storm sets (statistical samples) used. The estimated return level of the storm surge, shown also in Fig. 2, is about 0.3–0.5 m higher than the storm surge level. Thus, the estimated present 50-yr storm tide is about 1.61 m, the 100-yr storm tide is about 2.03 m and the 500-yr storm tide is about 2.78 m.

**Figure 3 | Estimated storm tide return levels for the Battery, predicted with each of the four climate models.** The black is for the present climate, the blue is for the IPCC A1B climate and the red is for the IPCC A1B climate with \(R_0\) increased by 10% and \(R_m\) increased by 21%. The shade shows the 90% confidence interval.
The storm tide is about 3.12 m. Considering that much of the sea wall protecting lower Manhattan is only about 1.5 m above the mean sea level\textsuperscript{39}, NYC is now highly vulnerable to extreme hurricane-surge flooding. For return periods under 50 yr, extratropical cyclones may also contribute to the coastal flooding risk and become the main source of 1–10 yr coastal floods for NYC\textsuperscript{40,41}.

**Impact of climate change**

The predictions of storm tide return levels for present and future IPCC A1B climates are presented in Fig. 3. (In the context of climate change, the return level at period $T$ may be understood as the level with an annual exceedance probability of 1/$T$.) The results from the four climate models differ: CNRM predicts an increase of the storm tide level, whereas ECHAM predicts a decrease; GFDL predicts that the storm tide level will increase for the main range of the return period but decrease for very long return periods, whereas MIROC predicts a decrease for low and moderate return periods but an increase for longer return periods. However, the magnitudes of the change (the ratio of A1B to the present-climate level) using CNRM (1.13–1.24) and GFDL (0.98–1.44) are more significant than those using ECHAM (0.89–0.96) and MIROC (0.89–1.08). The discrepancies among the model results can be attributed to the models’ different estimations of the change of the storm frequency and the surge severity. The storm frequency at a regional scale plays an important role in determining the surge risk; the prediction of the frequency change for NY-region storms by the four climate models varies greatly. Moreover, unlike the average storm intensity, which is predicted to increase by these and other climate models\textsuperscript{4}, the storm surge severity is predicted to increase by some models but decrease by others. This difference is the result of the surge magnitude depending on the storm’s intensity as well as other parameters, all of which may change differently in the different climate models.

We suspect that a main reason that the increase of storm intensity (in some models) does not translate to an increase in surge magnitude is that the storm’s radius of maximum wind ($R_m$) tends to decrease as the storm’s intensity increases, given the assumption made in the above simulations that the distribution of the storm’s outer radius ($R_o$, determined from observed statistics\textsuperscript{22}) remains the same under different climates. However, in theory the storm’s overall dimension scales linearly with the potential intensity\textsuperscript{43}; therefore, the increase of potential intensity in a warmer climate\textsuperscript{44} may induce an increase of $R_m$. Consequently, the reduction of $R_o$ due to the increase of storm intensity may be offset and even reversed. In such a case, climate change will probably increase storm intensity and size simultaneously, resulting in a significant intensification of storm surges. To test this hypothesis, we carry out the simulations as before but assume that $R_o$ increases by 10% and $R_m$ increases by 21% in the future climate. We base this assumption on the estimated change of the potential intensity (expected to increase by about 10% refer. 4) and on a theoretical scaling relationship between $R_o$ and $R_m$ ($R_m$ scales with $R_o^2$; refer. 33). The storm tide level thus predicted, shown also in Fig. 3, is higher or nearly unchanged in the future climate for the four models. The magnitude of the change also grows owing to the increase of the storm size; it becomes 1.23–1.36 for CNRM, 1.05–1.50 for GFDL, 0.95–1.02 for ECHAM and 0.97–1.11 for MIROC. At present, the effect of climate change on hurricane size has yet to be investigated; therefore, it is uncertain whether the surge will greatly increase owing to the simultaneous increase in storm intensity and size or only moderately change when one factor increases while the other decreases. Further study of the storm size distribution under different climates is needed to answer this question.

**Discussion**

As the climate warms, the global mean sea level is projected to rise, owing to thermal expansion and melting of land ice. Superimposed on the global SLR, regional sea levels may change owing to local land subsidence and ocean circulation changes, both of which are expected to significantly increase sea level in the NYC area\textsuperscript{45,46}. The total SLR for NYC is projected to be in the range of 0.5–1.5 m by the end of the century\textsuperscript{21,40,47}. The effect of SLR, rather than changes in storm characteristics, has been the focus of most studies on the impact of climate change on coastal flooding risk (for example, refs 45 and 48); some studies also account for the change of hurricane intensity due to the change of the sea surface temperature (for example, refs 49 and 50). To our knowledge, this paper is the first to explicitly simulate large numbers of hurricane surge events under projected climates to
assess surge probability distributions. Our study shows that some climate models predict the increase of the surge level due to the change of storm climatology to be comparable to the projected SLR for NYC. For example, the CNRM and GFDL models predict that, by the end of the century, the 100-yr and 500-yr storm tide levels will increase by about 0.7–1.2 m (Fig. 3a,c). More consequential, the combined effect of storm climatology change and SLR will greatly shorten the surge flooding return periods. As shown by the estimated flood return level in Fig. 4, if we assume the SLR in the NYC area to be 1 m, by the end of the century, the present NYC 100-yr surge flooding may occur every 20 yr or less (with CNRM, GFDL, ECHAM and MIROC yielding predictions of 4/4, 3/3, 21/20 and 14/13 yr, respectively, for observed/increased storm size) and the present 500-yr surge flooding may occur every 240 yr or less (with CNRM, GFDL, ECHAM and MIROC yielding predictions of 45/29, 28/24, 188/140 and 241/173 yr, respectively). These findings are dependent on the climate models used to generate the environmental conditions for the storm simulations, so other climate models may produce different results. Nevertheless, all four climate models used in this study predict significant increases in the surge flood level due to climate change, providing an additional rationale for a comprehensive approach to managing the risk of climate change, including long-term adaptation planning and greenhouse-gas emissions mitigation.

**Methods**

High-resolution surge simulations are computationally intensive; therefore, to make it possible to simulate surges with reasonable accuracy for the large synthetic storm sets, we apply the two hydrodynamic models with numerical grids of various resolutions in such a way that the main computational effort is concentrated on the storms that determine the risk of concern. First, the SLOSH simulation, using a polar grid with a resolution of about 1 km around NYC, is applied as a filter to select the storms that have return periods, in terms of the surge height at the Battery, greater than 10 yr, the typical range of hurricane surge periodicity relevant to design and policymaking. Second, the ADCIRC simulation, using an unstructured grid with a resolution of ~100 m around NYC (and up to 100 km over the deep ocean), is applied to each of the selected storms (see Supplementary Fig. S1, for a comparison between SLOSH and ADCIRC simulations). To determine whether the resolution of the ADCIRC simulation is sufficient, another ADCIRC mesh with a resolution as high as ~10 m around NYC is used to simulate over 200 most extreme events under the observed climate condition. The differences between the results from the two grids are very small, with our ~100-m mesh overestimating the surge at the Battery by about 2.5% (Supplementary Fig. S2). Thus, the ~100-m ADCIRC simulations are used, with a 2.5% reduction of the surge magnitude, to estimate the surge levels at the Battery for return periods of 10 yr and longer. (ADCIRC model control parameters follow refs 29 and 30, whose results have been validated against observations.)

To quantify tide-surge nonlinearity, we generate a database of the storm surge and storm tide as a function of the tidal phase $\phi$ when the (peak) surge arrives, the surge height $H$, tidal range $t_i$ and mean tidal level $t_m$. We define a non-dimensional nonlinearity factor $\gamma$ as

$$\gamma = \frac{L + t_m}{H + t_i}$$

so that, for a given value of $\gamma$, the higher the storm surge or the astronomical tide, the larger the nonlinearity relative to the negative mean tidal level ($-t_i$), considering that the nonlinearity and the tide are out of phase (Supplementary Fig. S4). We use the generated storm surge and storm tide database to estimate $\gamma$ by kernel regression as a function of the tidal phase (Supplementary Fig. S5). Then, the nonlinearity $L$, for a given tide and a surge corresponding to tidal phase $\phi$, is estimated from equation (1) as

$$L(\phi) = \gamma(H + t_i) - t_m$$

We assume the annual number of NY-region storms to be Poisson-distributed, with mean $\lambda$. The probability distribution of the surge height, $P(H < h)$, estimated from the generated surges for each storm set, is applied to estimate the PDF of the storm tide ($H'$),

$$P(H' < h) = \int_0^\infty \int_0^\infty \left\{ P[H < h - (\gamma(H + t_i) - t_m)\frac{1 + \gamma(\phi)}{1 + \gamma(\phi) + \Phi(\phi)}] \right\} d\phi$$

where $H'$ is the height of the astronomical tide and $\Phi$ is the (random) phase when the storm surge arrives. Making use of equation (2) and the estimated $\gamma$ function, equation (3) becomes

$$P(H' < h) = \int_0^\infty \int_0^\infty \left\{ P[H < h - (\gamma(H + t_i) - t_m)\frac{1 + \gamma(\phi)}{1 + \gamma(\phi) + \Phi(\phi)}] \right\} d\phi$$

It is reasonable to assume that the surge can happen at any time during a tidal cycle with equal likelihood, and equation (4) becomes

$$P(H' < h) = \int_0^\infty \int_0^\infty \left\{ P[H < h - (\gamma(H + t_i) - t_m)\frac{1 + \gamma(\phi)}{1 + \gamma(\phi) + \Phi(\phi)}] \right\} \frac{1}{2\pi} d\phi$$

(Note that equation (5) can be extended to include the effects of different tides during the hurricane season by taking a weighted average of $P[H' < h]$ for all types of tide considered, with weights equal to the fractions of time during the season when different types of tide occur.) Then, by definition, storm tide return period $T'$ is

$$T' = \frac{1}{1 - e^{-\lambda(T' - t_m)}}$$

No analytical expression for the return level ($\bar{h}$) is available in this case; the storm tide return levels in Figs 2 and 3 are calculated by solving equations (5) and (6) numerically. The astronomical tide cycle observed at the site during the period of 18–19 September 1995 (NOAA tides and currents) is used, with an assumption that the tidal variation at NYC during the hurricane season is relatively small.

The surge PDF is also applied to estimate the PDF of the flood height ($H' + h$),

$$P(H' + h < h) = \int_0^\infty \int_0^\infty \left\{ P[H < h - (\gamma(H + t_i) - t_m)\frac{1 + \gamma(\phi)}{1 + \gamma(\phi) + \Phi(\phi)}] \right\} \frac{1}{2\pi} d\phi$$

where $\bar{S}$ denotes the value of SLR, and the nonlinear effect of SLR on the surge is neglected. Then, on the basis of equation (5), equation (7) becomes

$$P(H' < h) = \int_0^\infty \int_0^\infty \left\{ P[H < h - (\gamma(H + t_i) - t_m)\frac{1 + \gamma(\phi)}{1 + \gamma(\phi) + \Phi(\phi)}] \right\} \frac{1}{2\pi} d\phi$$

The flood return period $T''$ is, similar to equation (6),

$$T'' = \frac{1}{1 - e^{-\lambda(T'' - t_m)}}$$

The flood return levels in Fig. 4 are calculated by solving equations (9) and (10) numerically, assuming a SLR of 1 m ($\lambda = 1$) for the future climate (and $s = 0$ for the present climate) and using the astronomical tide cycle observed during 18–19 September 1995. The statistical confidence interval of the estimated storm tide and surge flood return levels remains the same as the confidence interval of the estimated surge return level, as no new distribution parameters are introduced. The uncertainty in the estimation of the future return levels may be considered as the combination of the statistical confidence interval and the variation of predictions from different climate models.

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**References**


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Author contributions

All authors contributed extensively to the work presented in this paper, and all contributed to the writing, with N.L. being the lead author.

Additional information

The authors declare no competing financial interests. However, in the interests of transparency we confirm that one of us, Kerry Emanuel, is on the boards of two property and casualty companies: Homesite and Bunker Hill, and also on the board of the AlphaCat Fund, an investment fund dealing with re-insurance transactions. In all three cases, Dr Emanuel receives fixed fees but owns no stocks or shares. Dr Emanuel does not stand to make any personal financial gain through these directorships as a consequence of the reported findings.

Supplementary information accompanies this paper on www.nature.com/natureclimatechange. Reprints and permissions information is available online at www.nature.com/ reprints. Correspondence and requests for materials should be addressed to N.L.
Attachment 6

Increased rainfall volume from future convective storms in the US

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Mesoscale convective system (MCS)-organized convective storms with a size of ~100 km have increased in frequency and intensity in the USA over the past 35 years, causing fatalities and economic losses. However, their poor representation in traditional climate models hampers the understanding of their change in the future. Here, a North American-scale convection-permitting model which is able to realistically simulate MCSs is used to investigate their change by the end-of-century under RCP8.5 (ref. 5). A storm-tracking algorithm indicates that intense summertime MCS frequency will more than triple in North America. Furthermore, the combined effect of a 15–40% increase in maximum precipitation rates and a significant spreading of regions impacted by heavy precipitation results in up to 80% increases in the total MCS precipitation volume, focused in a 40 km radius around the storm centre. These typically neglected increases substantially raise future flood risk. Current investments in long-lived infrastructures, such as flood protection and water management systems, need to take these changes into account to improve climate-adaptation practices.

Economic losses from convective storms are steadily increasing in the USA and currently exceed US$20 billion annually. Many of these losses are caused by MCSs that produce flash floods, debris flows, landslides, high winds and hail. Flash floods alone cause 84 fatalities per year, which is more than any other weather hazard in the United States, except for heatwaves. A rising frequency and intensity of long-lasting MCSs was found in observations during spring in the Central United States, which led to an increase of subdaily convective rainfall extremes during the past 35 years. Australian observations confirm this trend and show that rainfall has become spatially more concentrated over a similar time period.

Observed extreme daily precipitation increased in all regions of the United States during the period from 1958 to 2012. Extreme rainfall intensity in the USA and currently exceed US$20 billion annually. Many of these losses are caused by MCSs that produce flash floods, debris flows, landslides, high winds and hail. Flash floods alone cause 84 fatalities per year, which is more than any other weather hazard in the United States, except for heatwaves. A rising frequency and intensity of long-lasting MCSs was found in observations during spring in the Central United States, which led to an increase of subdaily convective rainfall extremes during the past 35 years. Australian observations confirm this trend and show that rainfall has become spatially more concentrated over a similar time period.

Here we use a set of two continuous 13-year long 4 km horizontal grid spacing continental-scale convection-permitting climate model (CPCM) simulations to investigate climate change effects on MCSs during June, July and August (JJA) over North America. By using a storm-tracking algorithm we can identify and track MCSs in space and time according to their hourly precipitation fields. The detected MCSs are consistent with standard definitions of contiguous heavy precipitation for a minimum of 100 km in at least one direction and a minimum duration of four hours. Also, the frequency of ~60 MCSs per summer season in the Central United States is similar to that in previous studies. It cannot be ruled out that a small fraction of frontal precipitation is picked up by the tracking algorithm, but this is unlikely to affect the results systematically. A schematic on how MCSs are tracked and how they change in the future period is shown in Fig. 1. The CPCM is able to simulate realistic MCSs (Supplementary Fig. 1) and can reproduce the characteristics of observed MCSs, such as their maximum rain rate, size,
total rainfall and storm motion, within observational uncertainties. However, the frequency of MCSs is up to 50% underestimated in the Central United States and up to 50% overestimated along the Gulf and Atlantic Coast. The Central United States bias results from a systematic underestimation of MCS frequencies in situations with weak synoptic-scale gradients, which is related to a model warm bias during late summer caused by an overestimation of incoming solar radiation and biases in soil–atmosphere interactions. Note that these frequency biases could possibly affect the climate change signals of MCS occurrence.

All regions except for the Central United States experience an increase in MCS frequency in the future period (Supplementary Fig. 2), which is in agreement with previous studies that show an increase in convective extremes in future climates. In the Central United States, MCSs with maximum hourly precipitation \( P_{\text{max}} < 40 \text{ mm h}^{-1} \) reduce by 30%, but extreme MCSs with \( P_{\text{max}} > 90 \text{ mm h}^{-1} \) increase by 380%. Similar high increases in extreme MCSs can be found in other regions. The highest relative increases in MCS frequency occur in Canada and the US Northeast, where MCSs with \( P_{\text{max}} > 80 \text{ mm h}^{-1} \) are almost unrepresented in the current climate and become frequent in the future (Supplementary Table 1).

\( P_{\text{max}} \) of future MCSs shows relative increases of 25% to 40% in northern regions such as Canada, the US Northeast and the US Mid-Atlantic and −15 to −20% elsewhere (Supplementary Fig. 3), which is consistent with expectations from the CC relationship because of a greater temperature increase at high latitudes. Also, MCS sizes systematically increase in all regions with the largest increases in southern regions and smaller increases in mid and high latitudes. A significant increase in the convective available potential energy (CAPE) makes the future environment more favourable for convection and allows MCSs to grow larger. The combined effect of higher \( P_{\text{max}} \) and larger MCSs results in a significant increase in the MCS hourly total rainfall \( P_{\text{total}} \), which is the total volume of precipitation from a system within an hour. Increases in \( P_{\text{total}} \) range between 20% and 40% in the mid- and high-latitude regions and between 40% and 80% in lower latitudes.

The impact of future MCSs will strongly depend on the combined effect of these changes. MCSs that have high \( P_{\text{total}} \) relative to their size rapidly increase in frequency (Fig. 2a), which results in a higher flood potential because of the concentration of large precipitation volumes over small areas. Systems with a high \( P_{\text{total}} \) and a high \( P_{\text{max}} \) also significantly increase in the future climate; however, the largest MCSs are typically not those with the highest \( P_{\text{max}} \) (Fig. 2b). A large flood risk occurs from MCSs with a high \( P_{\text{total}} \) and slow storm motion. This category of MCSs shows the highest increase in all regions (Fig. 2c), but changes in storm speed are regionally variable. MCSs that move slower than 20 km h\(^{-1}\) reduce their speed by up to 20% in the US Midwest and Mid-Atlantic, and in Canada, but are faster in Mexico and the US Northeast (Supplementary Fig. 3). Changes in the MCS motion are consistent with changes in the steering level flow (~7 km wind speed\(^{-1}\)) (Supplementary Fig. 4) and changes in MCS internal processes such as cold pool dynamics.

Next, changes in the 40 MCSs with the highest \( P_{\text{total}} \) are investigated in the densely populated US Mid-Atlantic region. For statistical robustness, 40 MCSs were selected and the results do not change significantly for sample sizes between 20 and 100 MCSs. Future MCSs significantly increase their \( P_{\text{max}} \) and have substantially larger areas covered by high rain rates (Fig. 3a,b). Mean rain rates are exponentially decreasing with increasing distance from the location of \( P_{\text{max}} \) (Fig. 3c), which can be described by the statistical model

\[
P_x = P_{\text{max}} e^{-d/k} + d \text{ with } d \ll P_{\text{max}}.\]

Here, \( x \) (km) is the distance from the location of \( P_{\text{max}} \), \( d \) (mm h\(^{-1}\)) is the average rainfall at 80 km distance from \( P_{\text{max}} \) and \( k \) (km) is the horizontal length scale that denotes the distance from \( P_{\text{max}} \) at which \( P_x = P_{\text{max}}/2 \). On average, \( P_{\text{max}} \) increases by 30% from 95 ± 12 mm h\(^{-1}\) to 122 ± 14 mm h\(^{-1}\) (± 1 s.d.), in line with the CC relationship. \( d \) is approximately 2.5 ± 1.7 mm h\(^{-1}\) and stays constant in future climates, whereas \( k \) significantly increases from 8.1 ± 2.2 km to 9.8 ± 2.6 km. The larger \( k \) values cause rainfall to increase from 30% at the location of \( P_{\text{max}} \) to ~70% at a radius of 10–30 km around \( P_{\text{max}} \). This substantially increases \( P_{\text{total}} \) because MCS precipitation volume increases with the square of the distance (Fig. 3d). \( P_{\text{total}} \) increases are largest on the scale of major cities (O 1,000 km (Fig. 3d)). For example, \( P_{\text{total}} \) increases by 60% or 3,900 m\(^3\) s\(^{-1}\) on the area of New York City, which is equivalent to adding six times the Hudson River discharge to an extreme MCS of the current climate. One-third of the increase in \( P_{\text{total}} \) is related to...
to a larger $P_{\text{max}}$ and two-thirds to larger $k$ values. Similar changes are found in Mexico and the US Southeast, North-Atlantic and Midwest regions (Supplementary Fig. 5). Increases in $k$ are not significant and contribute less than 50% to the volume increase in the other regions (Supplementary Fig. 6). The increases in future MCS precipitation volume are consistent with previous studies that focus on individual MCS cases\(^{21,22}\).

To understand the processes that cause the intensification and broadening of heavy precipitation in future MCSs during IIJ, we analyse changes in the MCS environments and dynamics (Fig. 4). The future US Mid-Atlantic MCSs have, on average, a 1.8 km higher cloud top that is 3.8 °C colder than in the current climate (Fig. 4a,b and Supplementary Fig. 7). A 10 °C warmer equivalent potential temperature in the boundary layer combined with a higher tropopause lead to a significantly higher CAPE. However, these future environments have larger absolute values of convective inhibition (CIN) of the inflow air (Fig. 4c,f).

The increased CAPE is consistent with an increase of future maximum updraft velocities and mean updraft sizes above 2 km (Supplementary Fig. 7), which is roughly the height of the level of free convection. The stronger updrafts produce more graupel and hail in the core of future MCSs above the future freezing level (Fig. 4c). The fall speed of graupel and hail are at least twice those of snow and ice, which increases the downward fluxes of moisture in future MCSs (Fig. 4d). The downdrafts intensify and broaden, probably in response to enhanced cooling through melting in the warm cloud layer (between the lifting condensation level and the freezing level) because of an increased input of frozen particles from aloft (Supplementary Fig. 7) and a larger precipitation loading\(^{23}\).

Figure 4c,d shows that the increase in surface precipitation rates results from a more than 30% increase in downward moisture flux and constant hydrometeor mixing ratios below 2 km height. At higher levels, the largest changes occur for the snow mixing ratio with decreases below 7 km and increases above because of the increased upward moisture transport. The decreases are related to the higher freezing level that leads to an earlier melting of frozen particles and results in an increase of liquid particles of up to 5 kg kg\(^{-1}\) (300%) at ~4 km height (Fig. 4c and Supplementary Fig. 8). As raindrops fall ten times faster than ice and snow\(^{24}\), they reside for a shorter period in the atmosphere, which contributes to the enhance downward moisture flux\(^{25}\). Relative humidity is slightly decreased by 1.5% at all levels and the atmosphere becomes more stable because of a 3 °C larger temperature increase in the upper troposphere compared with the near-surface levels (Supplementary Fig. 7). Wind-shear changes are small and have minor effects on the changes in MCS dynamics (Supplementary Fig. 9). Changes in future MCSs in other regions are similar.

The increasing size of MCSs is in line with previous findings that show that large systems are related to high CAPE values\(^{11,12}\) and that CAPE is expected to increase because of climate change\(^{13,14}\) as a result of a boundary layer that is warmer with increased humidity throughout its depth. Future US Mid-Atlantic MCSs have a 70 m higher lifting condensation level (cloud base) and an 860 m higher...
Hydrometeors Moist fluxes

Fig. 4 | Current and future MCSs environments. a,b. Average cross-section of the equivalent potential temperature (filled contour), hydrometeor mixing ratios (blue, brown and red contours show rain and cloud, graupel and snow, and ice-mixing ratios, respectively), and wind field (streamlines) relative to the MCS movement for 807 current (a) and 1,207 future hourly time slices of mid-Atlantic MCSs (b). Black solid lines show isothermals and the black dashed line shows the lifting condensation level (LCL, that is, the cloud base). c,d. Average changes (future minus current) in hydrometeor mixing ratios (e) and vertical moisture flux (d) (upward/downward fluxes are shown as red/blue lines) at different heights above surface. Thick lines show significant changes (alpha is 0.01) according to 100 bootstrap samples. e–f. Probability density functions of CAPE (e), CIN (f) and warm cloud layer depth (g) for current (blue) and future (red) MCSs. Shaded areas show the 1–99 percentile range of 100 bootstrap samples. Changes in CAPE and CIN are calculated in the MCS inflow region.

Freezing level, which leads to a deepening of the warm cloud layer from 3.2 ± 0.4 km in the current to 4.0 ± 0.4 km in the future climate (Fig. 4g). The deeper layer allows for more precipitation particles to grow via collision and coalescence (warm rain process), which forms larger drops that fall faster and have a greater chance of reaching the surface and contribute to the increase in areas with high rainfall rates. Flash-flood situations are typically associated with warm cloud layers deeper than 3–4 km (ref. 35).

The results show that the relative increase of $P_{\text{max}}$ exceeds the relative increases of $P_{\text{out}}$ in all regions because of an expansion of the area with heavy precipitation in future MCSs. Most of today’s climate change assessments do not account for changes in MCS spatial patterns28, which suggests that future flood impacts may exceed current expectations. This study highlights that a process-based assessment is needed that takes different aspects of climate change into account to assess the full spectrum of related impacts.

The presented climate change signals are significantly larger than the natural variability in our current climate simulations that feature active summer seasons, such as 2001, and inactive seasons, such as the drought year of 2012. A remaining caveat is that we cannot assess the effect of climate internal variability and changing atmospheric circulation patterns on our results. Large-scale dynamics have a strong control on the genesis and development of MCSs. However, there is limited consensus among climate projections on how large-scale dynamics might change in future US summers, whereas there is higher confidence in changes controlled by thermodynamics30.

Methods

Methods, including statements of data availability and any associated accession codes and references, are available at https://doi.org/10.1038/s41558-017-0007-7.

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Author contributions
A.F.P designed the study, and collected and analysed the data. C.L. and K.I. performed and post-processed the climate simulations. All the authors contributed to the writing process and gave conceptual advice.

Competing interests
The authors declare no competing financial interests.

Additional information
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Methods

Climate model simulations. The weather research and forecasting model\(^2\) Version 3.4.1 was applied with convection-permitting grid spacing (4 km) over a North American domain (Supplementary Fig. 2). The model domain includes 3,160 × 1,616 grid points on a 31 stretched grid levels, which results in a spatial resolution of 93 km at its grid points. The main applied model physics schemes are the Thompson aerosol-aware microphysics\(^3\), the rapid radiative transfer model\(^4\), the Yonsei University planetary boundary layer\(^5\) and the improved Noah-MP land-surface model\(^6\). Additionally, weak spectral nudging\(^7\) of a large wavelength (~2,000 km) of the European Centre for Medium-Range Weather Forecasts (ECMWF) Interim Reanalysis (ERA-Interim) temperature, horizontal wind and geopotential height fields is applied above the planetary boundary layer every six hours. More information about the model setting and a basic evaluation of the model performance and climate change signals is given in Liu et al. (2017).\(^8\)

A horizontal grid spacing of 4 km is widely accepted as the upper limit for convection-permitting simulations that operate without a cumulus parameterization.\(^9\) However, this grid spacing is too coarse to resolve the full spectrum of turbulent motions and there is no established theory about how turbulence can be parameterized on such scales. Simulations in the European Alps showed that bulk properties, such as area average precipitation amounts and vertical fluxes, already converged in a 4 km simulation compared with a 500 m simulation; however, the structure of isolated convective cells did not converge.\(^10\) Simulations of squall lines in the United States showed that models with a 4 km or 1 km horizontal grid spacing underestimate the entrainment of mid-level air into the system, which leads to higher cloud tops, a slower development and more precipitation in the convective cores of the 250 m model than the 4 km model. The thickness of dry air was fairly similar between the 4 km and 250 m simulations. The studies also show that an intermediate grid spacing of 1 km does not necessarily improve the 4 km model results. The usage of a two-moment microphysics scheme, such as that used in this study, generally improves the simulation, but significant uncertainties in the convection-permitting model simulation of updraft intensities associated with microphysical parameterizations have been reported.\(^11\) Apart from these caveats, our 4 km simulation can reproduce many realistic features of MCSs (Supplementary Fig. 1).

Two 13-year long simulations were performed that consisted of a current climate simulation, in which the ERA-Interim\(^12\) data were downscaled for the period October 2000 to September 2013 and a future, high-end emission scenario (RCP 8.5) climate simulation. For the latter simulation, the pseudo-global warming (PGW) approach\(^13\) was applied, which is identical to the current climate simulations, but the ERA-Interim lateral boundary conditions and sea-surface temperatures were perturbed by a climate change signal. This signal is the average monthly mean climate change signal of 19 CMIP5 (ref. 41) global circulation models (GCMs) for the periods 1976–2005 and 2071–2100.\(^14\) The PGW approach allows the calculation of representative climate change signals that are related to thermodynamic processes, lapse rate and baroclinicity with the year-to-year variability and large-scale weather patterns largely unaffected. This has the advantage that climate change signals can be attributed to forced climate change processes because the internal climate variability is negligible. The drawbacks of the PGW approach is that systematic changes in the large-scale circulation are not considered. For instance, dynamic changes in the US nocturnal low-level jet, which is related to MCS intensities and frequency\(^15\), because of its transports of unstable warm and moist air from the Gulf of Mexico into the Great Plains, might not be fully captured by the PGW approach. A recent study\(^16\) attributes MCS properties to the PGW approach as it demonstrates that the full climate change signal from a GCM-driven RCM simulation can be decomposed in three additive terms: (1) a large-scale thermodynamic effect, (2) a lapse-rate effect and (3) a large-scale circulation change.

Tracking of convective systems. The storm tracking is performed using the method for object-based diagnostic evaluation (MODE)\(^17\),\(^18\), which incorporates the time dimension (MODE time-domain or short MTD\(^19\)). This method is based on a four-step approach to identify MCSs. Gridded, hourly accumulated precipitation is smoothed with a square moving window having a side length of eight grid cells. The smoothed field is masked by applying a precipitation threshold of 5 mm h\(^{-1}\), which results in the exclusion of most of the stratiform rain areas and helps focus only on the regions of high rain rate. The masked field is applied to the original hourly precipitation field to obtain precipitation objects. An object is defined as a spatial and temporal contiguous precipitation region with a minimum size of 2,000 grid cells, which results in the detection of mature- to large-scale MCSs. MTD is able to incorporate merging or splitting of precipitation regions. As output, MTD provides MCS characteristics, such as MCS size, intensity, track, speed and total precipitation.

Statistical analysis. We divided our model domain into seven climate subregions: Mexico, the US Southwest, Southeast, Midwest, Mid-Atlantic and Northeast, and Canada (Supplementary Fig. 2). The regions were selected to account for coherent structures in convective system climate change signals and were also used for the evaluation of the convective systems in the current climate simulations.\(^20\)\(^21\). MCSs are assigned to a subregion according to their centre of hourly precipitation and therefore can be in multiple regions during their lifetime. The track-density differences shown in Supplementary Fig. 2 correspond to the numbers of MCSs that transect 100 × 100 km grid boxes in the current and future climate during the 13 investigated summer seasons. The binning of MCSs was equally spaced from 40 and 90 °N, with 10 °N increments chosen based on the density function of \(P_{\text{max}}\) (ref. 7) and allows us to differentiate frequency changes in weak to extreme \(P_{\text{max}}\) MCSs.

For the assessment of statistical significance, block bootstrapping was applied.\(^20\)\(^21\)\(^22\) MCSs are pooled randomly with replacement from the original sample of MCSs until the same number of MCSs as in the original sample is reached. This is repeated 100 times for the current and future climate period, which enables the assessment of statistical significance. Statistical significance is tested with the non-parametric Mann–Whitney U test using a confidence level of 99% (ref. 45).

The conditional distributions of MCS speed, size and \(P_{\text{max}}\) given a particular MCS hourly total precipitation (\(P_{\text{total}}\)) shown in Fig. 2a–c were calculated as follows. First, the MCSs are binned according to their \(P_{\text{total}}\) values in 1,200 m\(^3\) s\(^{-1}\) bins sizes with a 12,000 m\(^2\) window centred on the actual bin value. MCSs in each bin are classified further according to their motion speed in 2 × 10 km\(^{-1}\) bins, their size in 2,500 ± 12,500 km\(^2\) bins and their \(P_{\text{max}}\) in ≤2 ± 10 mm h\(^{-1}\). For example, the number of MCSs with 24,000 ± 6,000 m\(^3\) s\(^{-1}\) that have a speed of 40 ± 10 km h\(^{-1}\) is calculated. The overlap multiple bins improves the signal-to-noise ratio in the conditional distributions. Then, the relative frequency changes of future and current climate change is calculated for parts of the distribution that had at least five MCSs in both distributions. Block bootstrapping was used to estimate if the two distributions have statistically significant differences.

For the climate change analysis of the 40 MCSs with highest \(P_{\text{max}}\) in Fig. 3, we calculated the distance of the MCS centres on the location of \(P_{\text{max}}\) at the time of \(P_{\text{max}}\) and calculated the distance over the hourly precipitation at each grid cell. The average rainfall dependent on the distance to \(P_{\text{max}}\) was calculated by averaging over precipitation in radial bands of 4 km width. The intensity–area curves were calculated by accumulating the area that is covered by precipitation from highest to lowest precipitation rates for each of the 40 MCSs in the current and future periods. Then, the median of the covered area was calculated for all intensities. The MCS precipitation fields have not been rotated to account for the different orientation of MCSs to avoid interpolation errors, especially the smoothing of precipitation maxima. Rotating the MCSs according to their inflow direction leads to similar results.

Owing to data storage constraints, the 3D model output was saved only every 3 h. Only MCSs that lasted longer than 3 h were included to sample mature systems. The vertical cross-sections of MCSs shown in Fig. 4 were derived by selecting a square box of length 121 grid cells centred around the MCS centre (centre of precipitation of MTD). Thereafter, the data were remapped to a common vertical grid of constant height above ground levels using bilinear interpolation. The lowest level is at z = 20 m (the lowest model level) and the vertical grid spacing (Δz) is 100 m from z = 200 to 3,000 m. Between 3,000 m and 6,800 m, Δz = 200 m, and between 6,800 m to the highest model level at 26,800 m, Δz = 400 m. The MCS is horizontally rotated such that the MCS inflow/outflow is approximately parallel to the x axis. This is done by calculating the direction of the strongest horizontal equivalent potential temperature gradient in the average lowest three vertical levels. This approach is adopted from studies of a rotated \(\Delta z\) of et al.\(^23\). Angles of field MTD is shown in Supplementary Fig. 1. After the rotation, all the variables are averaged perpendicular to the inflow direction (along the y axis) of the rotated MCS. This approach allows us to sample a large number of MCSs in a systematic way to construct an average convective–system environment for current and future MCSs.

The speed and direction in hodographs are horizontal averages at each vertical level. The updraft/downdraft size in MCSs are determined by the area in which vertical wind speeds are larger/smaller than ±3.5 m s\(^{-1}\). Clouds are defined as grid cells in which the total mixing ratio of hydrometers is larger or equal to 0.01 g kg\(^{-1}\), which is used in the calculation of cloud top heights. Convective potential available energy and CIN calculated as the difference between cloud top heights in the lowest 100 hPa above the surface. They were calculated for every second grid cell in the inflow environment (80 km to 240 km upstream of the MCS centre) in the rotated coordinate system and averaged afterward.

Code availability. The source code of MTD is part of the Developmental Testbed Center’s (DTC) Model Evaluation Tools (MET) software and freely available online at http://www.dtcenter.org/met/users/downloads/.\(^24\) The code for the statistical analysis is available from the corresponding author on request.

Data availability. The datasets generated and analysed during the current study are available from NCAR’s Research Data Archive\(^25\).

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48. High Resolution WRF Simulations of the Current and Future Climate of North America (NCAR, accessed 5 August 2017); https://rda.ucar.edu/datasets/ds612.0/
Attachment 7

that the rate of change, 27% over 50 years, is much larger suggested by previous studies6.

Clearly, the Sea of Japan is not a perfect analog for the global ocean. It is only a single basin with a single deep-water formation region. The global ocean has at least an order of magnitude longer residence time and more complex deep-ocean mixing from multiple sources. The Sea of Japan may also represent an extreme case since a significant reduction of deep-water formation and commensurate cessation of excess carbon dioxide accumulation below 400 m has been observed since at least 1999 (ref. 8). A complete stop in the global overturning circulation is not expected in the foreseeable future. However, this study does point out the importance of understanding all sources of acidification beyond just absorption of atmospheric carbon dioxide.

The IPCC defines ocean acidification as “a reduction in the pH of the ocean over an extended period, typically decades or longer, which is caused primarily by uptake of carbon dioxide from the atmosphere, but can also be caused by other chemical additions or subtractions from the ocean”, and anthropogenic ocean acidification as “the component of pH reduction that is caused by human activity”. A change in pH because of ocean warming and stabilization of the water column would not be considered ocean acidification under this definition, but the work of Chen et al. suggests that a significant anthropogenic effect on deep-ocean acidity could be in store for the future and should be considered as part of the suite of anthropogenic impacts on the ocean.

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HYDROLOGY

Near doubling of storm rainfall

Large, intense thunderstorms frequently cause flooding and fatalities. Now, research finds that these storms may see a threefold increase in frequency and produce significantly heavier downpours in the future, far exceeding previous estimates.

Zhe Feng

Mesoscale convective systems (MCSs) are the largest type of intense thunderstorms on Earth, ranging in size from one hundred to several hundred kilometres. These storms produce well over half of the spring and summer rainfall in the central United States, and comprise the majority of extreme rainfall events with a 100-year return period. Global climate models generally fail to simulate MCSs, undermining our ability to predict changes in flood-producing storms in the future. Writing in Nature Climate Change, Andreas Prein and co-authors use high-resolution regional climate simulations to illustrate that MCSs will produce up to 80% more heavy rainfall volume than they do currently.

Except for heat waves, flash floods from intense thunderstorms cause more fatalities than any other weather hazard in the United States. A recent study noted that MCSs have become more common and more intense during spring in the central United States over the past 35 years. Globally, extreme rainfall from thunderstorms is expected to further increase by about 7% per degree of warming in the future. However, until now, it was unknown how regional MCSs and their rainfall may respond to a warming climate.

Prein et al. used a regional climate model with a grid spacing of 4 km. At this resolution — which is similar to current weather prediction models — they were able to realistically simulate large, intense thunderstorms such as MCSs, to project changes in summertime MCSs near the end of the twenty-first century. By perturbing the large-scale boundary conditions with changes in temperature, humidity and ocean surface temperature projected by global climate models, they found a threefold increase in the occurrence of the most intense summertime MCSs in North America, and identified some future storms that are almost unprecedented in the current climate.

MCS rainfall totals were found to increase between 40% and 80% in parts of the southern United States, and between 20% and 40% in the central and northeast United States. The authors attribute this increasing precipitation to the presence of warmer air, which has a greater moisture-holding capacity, within a few kilometres of the Earth’s surface. This condition allows more unstable energy to build up in the atmosphere and support more intense storms. Contrasting the most extreme rain-producing MCSs between the current and future climate produces an increase of up to 80% in rainfall volume. Prein et al. found that the most dramatic change causing this increase is in the heaviest-raining part of the storm, within a 10–30 km radius (the scale of major cities) of the storm centre. The amount of rainfall increase, as noted by the authors, is “equivalent to adding six times the Hudson River discharge to an extreme MCS” over the area of New York City.

As most current climate change assessments use models that do not Yet represent MCSs, they do not account for increasing storm intensity and size such as those reported by Prein et al. The results of Prein et al.10, along with other high-resolution modelling studies11, suggest that the future impact of floods may exceed current expectations. Planning for flood protection and water-management infrastructure should start taking into account the changes...
Prein et al. provide the first attempt to examine potential changes in MCSs and their heavy rainfall in a future warming climate. They report a significant increase in the occurrence and intensity of potential flood-inducing storms that are found across most regions east of the Rocky Mountains in North America. Government agencies responsible for planning water and other engineering infrastructure need to consider findings from studies using high-resolution models capable of simulating MCSs, and their attendant severe weather phenomena, to increase the resilience and adaptive capacity of society to weather future storms.

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