GRADIENT
TRENDS
Risk Science & Application

Spring 2018
Issue 72

From Global Heat Balance to Balance Sheets

By Nicole L. Briggs, Ph.D. and Kate M. Munson, M.S., E.I.T.

Publicly traded companies are facing shareholder pressure to assess a wide range of climate change risks and potential impacts to the bottom line.

There is increasing pressure on publicly traded companies to disclose climate change risks to shareholders. For example, F. William McNabb, the chairman and chief executive officer of the Vanguard investment company, advised public company directors that, "Our evolving position on climate risk… is based on the economic bottom line for Vanguard investors" and "it is incumbent on all market participants… to embrace the disclosure of sustainability risks that bear on a company's long-term value creation prospects." (McNabb, 2017). Often, shareholders rely on Securities and Exchange Commission (SEC) disclosures to provide transparency concerning management of climate change risks. The majority of climate change financial disclosures in the last four years have focused on greenhouse gas emissions, compliance reporting, and other regulatory or legally mandated activities (EDGAR Database, 2018). However, ASTM International guidelines present a broader array of topics, "including but not limited to real or expected risks of physical damage to facilities, regulatory costs and incentives, and shifts in the market for products and services." (ASTM, 2016).

...potential financial impacts associated with climate change risks can be evaluated with existing data and liability estimation techniques...

In this article, we use a hypothetical example to illustrate quantitative techniques for evaluating a subset of these potential impacts, focusing

continued on pg. 2

I N S I D E

Letter from the Editors

May 2018

Dear Colleague,

In this issue of *Trends*, we discuss the evaluation of potential climate change impacts, including risks and vulnerabilities associated with shifting weather patterns and extreme weather events.

The first *Trends* article examines the issue of climate change financial disclosures, demonstrating quantitative approaches that can be used to develop more robust disclosures of the potential financial risks of climate change. The second article discusses the evolving legal implications and complexities of assessing coastal vulnerabilities, such as erosion, increased storm frequency and flooding, damage to coastal infrastructure, and impacts to stormwater and wastewater treatment systems. The third article discusses extreme weather events and the stress they can cause to the environment, human health, and infrastructure.

Gradient contributors to this issue include Dr. Nicole Briggs, Kate Munson, M.S., E.I.T., Matt Mayo, M.S., GISP, CPG, P.G., Dr. Jeff Rominger, Dave Mayfield, M.S., DABT, BCES, and Ife Bamgbose, M.S. Joining us with a guest editorial is John Guttmann from the law firm of Beveridge & Diamond providing legal perspective on the topic of climate change.

We hope that this issue of *Trends* gives you insight into some of the current hot topics related to climate change impacts.

Yours truly,

Kurt Herman, M.Eng., P.G. and Chris Long, Sc.D., DABT
kherman@gradientcorp.com clong@gradientcorp.com

GRADIENT
Trends is a free publication of Gradient

From Global Heat Balance to Balance Sheets

continued from pg. 1

on physical climate change risks to supply chains and infrastructure. This hypothetical company has multiple facilities located throughout the U.S. and manufactures a product from raw materials supplied by national and international manufacturers. This company receives raw materials *via* ship and rail and stores the raw materials and by-products in on-site tanks at each facility. Trucks are used to distribute the company's product within each facility's region. The potential climate change impacts on the company's facilities and supply chain could include wildfires, flooding, power loss associated with major storms, and changes to resource availability. While the types and magnitudes of facility impacts may be site-specific, the consequences of these impacts may include:

- possible plant upset conditions stemming from power loss, such as degradation or loss of chemicals requiring temperature controls to maintain stability;
- potential environmental releases from tanks or pipelines under the influence of flooding, wildfires, or other weather events;
- changes in availability of raw materials, especially from regions most impacted by climate change; and
- delays and disruptions to shipping distribution routes from major storms and wildfires.

Once the risks are identified, quantifying the potential financial impacts depends on projections of how the site-specific climate might influence different facilities. There are multiple options for selecting which climate change projections to use. For example, there may be the possibility of relying on the most recent International Panel on Climate Change (IPCC) assessment report, state- or municipality-specific climate change assessment reports, or other relevant scientific studies. Once the source of climate change projections is selected, a company can then evaluate scenarios for potential impacts to facilities, supply chain, and product distribution. For example, for a facility located in a coastal municipality where sea level rise has been modeled for the next 50 years, a Geographic Information System (GIS) can be used to evaluate the projected sea level rise impacts on facility flooding over time. In areas where region-specific climate changes, such as wildfire projections, are not well defined, it may be possible to develop modeling projections and compile existing data (*e.g.*, projections for the entire western U.S.) to evaluate the potential for major wildfires to shut down highways and impact regional product distribution.

Inherent in all these calculations is a degree of uncertainty; however, there are techniques for dealing with such complexity. For example, stochastic methods that have been applied in other contexts, *e.g.*, at legacy contamination sites, are well suited for valuing contingent environmental liabilities, such as costs of climate-related risks. This type of method can include decision trees that outline potential climate change risks to each facility and the supply chain; the associated probability of these risks occurring over time; and the predicted financial impact of the climate change risks. Monte Carlo modeling techniques can be used to develop an aggregate, probabilistic cost distribution (*i.e.*, range of costs and associated occurrence probabilities) for the entire company's operations, based on the information documented in the decision trees.

As this case study demonstrates, potential financial impacts associated with climate change risks can be evaluated with existing data and liability estimation techniques to provide shareholders with more robust disclosures of the potential financial risks of climate change to a company.

The authors can be reached at nbriggs@gradientcorp.com and kmunson@gradientcorp.com.

continued on pg. 5

Example Climate Change Vulnerability Assessment Tools and Resources

Identification of Climate Change Impacts	Evaluation of Facility and Climate Change Impacts	Quantification of Financial Impacts
• IPCC assessment reports • U.S. National Climate Assessment • U.S. state- or municipality-specific climate change assessments • Other governmental reports and data sources (*e.g.*, National Interagency Coordination Center wildfire projections)	• Site-specific modeling assessments • GIS for integrating multiple climate change data layers • Task Force on Climate-related Financial Disclosures (2016)	• Decision trees • Monte Carlo analysis

Evaluating Coastal Vulnerabilities in a Changing Climate

By Matthew J. Mayo, M.S., GISP, CPG, P.G. and
Jeffrey T. Rominger, Ph.D.

Local coastal water levels are affected by multiple complex issues, but scientists have many available techniques for evaluating the incremental effects of climate change.

Coastal facilities and municipal infrastructure are the focus of several recent climate change lawsuits. In some cases, municipalities have brought public nuisance claims against energy companies, alleging impacts related to greenhouse gas emissions. These lawsuits contend that the alleged effects of climate change (sea level rise and increased frequency and intensity of extreme weather) constitute a "nuisance." Another lawsuit has challenged the basis of stormwater management permits under the Clean Water Act for a coastal facility, alleging that climate-related impacts had not been adequately considered during the permitting process. While these cases are distinct, the scientific claims in both of them relate to coastal processes that may be evaluated with existing scientific techniques.

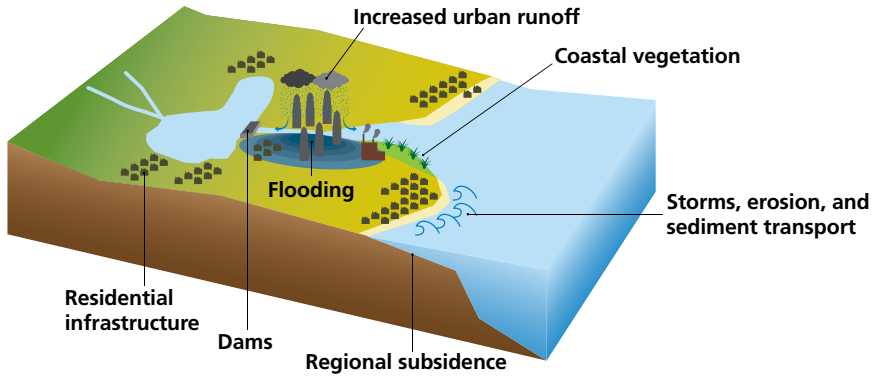
Coastal facilities and municipalities have always faced a special set of vulnerabilities that are associated with their location at the interface of land and sea.

Common to these types of lawsuits is the alleged role that increasing coastal water levels have on coastal facilities and municipal infrastructure. With higher water levels, lands adjacent to the coastline can be inundated more frequently during high tides and storm events, potentially affecting urban runoff and flow control structures (*e.g.*, dams). Changing water levels can also alter coastal waves and currents, thus affecting sediment transport (*e.g.*, processes of erosion or accretion). In addition, coastal vegetation, which protects sediments from erosion, may not be able to adapt to a new range of water levels (see figure).

While climate change has caused a net rise in global sea levels, local coastal water levels are affected by a complex set of factors, including natural factors, such as routine and "extreme" weather events, and multiple factors associated with human development. Other natural factors that can affect water levels include regional subsidence and net erosion, which can both cause higher water levels by lowering the level of the land relative to the sea. Climate change can potentially affect net coastal erosion, but it is not necessarily the sole cause – certain coastal areas are in a state of constant change, with sediment being locally eroded and deposited down-current. Human development, including jetties, seawalls, artificial beaches, harbors, and discharges, can alter currents and waves, affecting the local likelihood of flooding as well as erosion. The increase in impervious surfaces (*e.g.*, pavement, buildings, and sidewalks) in nearshore developments also prevents rainfall from slowly percolating into the soil, instead rapidly forcing it into sewer systems and drainage networks and increasing the likelihood of coastal flooding during storms.

continued on pg. 6

Coastal Land Cover, Infrastructure, and Processes that Influence the Effects of Sea Level Change



Fire & Rain

By Ifeoluwa A. Bamgbose, M.S. and David B. Mayfield, M.S., DABT, BCES

Stakeholders are proactively planning for the competing effects of increased population growth and extreme weather events.

Online and on television, the world witnesses images of swollen rivers, forests ablaze, and wind-blown news correspondents braving hurricanes. As the breadth and intensity of heavy rainfalls and wildfires have increased in some areas over the past decades (EPA, 2017), there is a critical need for planning to address the potential impacts of these extreme weather events.

While highly variable, floods and droughts can have extensive effects on public health, infrastructure, and the environment.

While highly variable, floods and droughts can have extensive effects on public health, infrastructure, and the environment. Direct impacts may include interferences with key transportation routes, energy transmission, and facility operations (see related article). For example, Hurricane Harvey left 336,000 people without power, damaged 203,000 homes and 75 schools, ruined one million vehicles, and flooded 800 wastewater treatment facilities and 13 Superfund sites (Amadeo, 2018). Public health consequences secondary to extreme weather events include the spread of infectious diseases, respiratory illnesses, and social disruption (EPA, 2017). For instance, particulate matter emissions (*i.e.*, $PM_{2.5}$, a contributor to respiratory illness) during the recent wildfires in Northern California were estimated at 10,000 tons of $PM_{2.5}$, equivalent to all annual automobile emissions in the state (Santiago and Scutti, 2017).

There is an often-overlooked distinction between weather events (*e.g.*, individual storms) and climate (*e.g.*, average temperature, types and frequencies of storms in an area). The root cause of changing tendencies in weather events is changes to the energy budget, which is an accounting of inputs and outputs of heat. The energy budget relates to both the water balance and conditions that influence some natural events, such as wildfires. For example, the amount of water evaporated (from open water or *via* leaves on plants) from an area depends on the amount of energy absorbed by surfaces, the temperature of the air, as well as other factors. The water that is not evaporated can move over (or under) the ground surface and contribute to flow in streams and rivers. When energy budgets change, characteristics of the climate (*e.g.*, frequencies of floods, droughts, and associated impacts) can potentially change as well.

A further complication in evaluating impacts from weather events is that increased population growth has led to increased human occupation of higher-risk areas. For example, recent research by the Nature Conservancy, the U.S. EPA and the UK University of Bristol (Living on Earth, 2018) projects a significant increase (*e.g.*, a 50% increase within the U.S. by 2050) in human occupation of high-risk flood areas – notwithstanding any potential impact from climate change. Currently, in developed low-lying areas, evaluating where flooding may occur is more complex than looking at simple flood maps, since the engineered environment interacts with natural factors (see related article).

To mitigate the impacts of these events, some stakeholders are developing resiliency plans to respond to climate projections. For example, the Urban Land Institute (2014) has developed a series of strategies for preparing communities at risk. These recommendations can aid stakeholders with developing resources pertaining to public safety and the environment. For example, one strategy is the formation of a resilience assessment team with the purpose of identifying environmental issues associated with certain weather events and tools or processes to aid recovery efforts. Additionally, for areas with potential sources of chemical releases (*e.g.*, manufacturing or storage facilities), environmental response plans can be developed to identify the likely chemicals present, monitor exposure routes (air, water, soil) and collect environmental samples to follow release pathways. Depending on the circumstances, robust sampling plans can provide the opportunity to supply defensible data to assess and communicate potential risks.

The authors can be reached at ibamgbose@gradientcorp.com and dmayfield@gradientcorp.com.

References:

Amadeo, K. 2018. Hurricane Harvey Facts, Damage and Costs: What Made Harvey So Devastating. *The Balance*. March 1.

Living on Earth. 2018. FEMA Flood Maps Miss the Mark. *PRI's Environmental News Magazine*. March 23.

Santiago, C., S. Scutti. 2017. Week of wildfires polluting air as much as year of cars. *CNN*. October 13.

Urban Land Institute. 2014. Resilience Strategies for Communities at Risk. Urban Resilience Program White Paper Series. Washington, D.C.

U.S. EPA. 2017. Climate Change Impacts.

What's New at Gradient

Awards and Announcements

Teresa Bowers has been appointed as a Trustee of the Geological Society of America Foundation for the 2018 to 2022 term.

Joel Cohen has been reappointed as a Visiting Scientist in the Molecular and Integrative Physiological Sciences Program at the Harvard T.H. Chan School of Public Health.

Tom Lewandowski has been appointed Secretary-Treasurer of the Dermal Toxicology Specialty Section of the Society of Toxicology for 2018.

Ari Lewis was elected to the Board of the Society of Chemical Hazard Communication for the 2018 to 2020 term.

David Mayfield was awarded the certification of Board Certified Environmental Scientist with a specialty in Environmental Toxicology by the American Academy of Environmental Engineers and Scientists (AAEES).

Michael Peterson has been appointed Vice President-elect of the Occupational and Public Health Specialty Section of the Society of Toxicology for 2018.

Publications

Borrelli, R., **A.P. Tcaciuc,** I. Verginelli, R. Baciocchi, L. Guzzella, P. Cesti, L. Zaninetta, P.M. Gschwend. 2018. Performance of passive sampling with low-density polyethylene membranes for the estimation of freely dissolved DDx concentrations in lake environments. *Chemosphere*. DOI:10.1016/j.chemosphere.2018.02.077.

Cohen, J.M., J. Beltran-Huarac, G. Pyrgiotakis, P. Demokritou. 2018. Effective delivery of sonication energy to fast settling and agglomerating nanomaterial suspensions for cellular studies: Implications for stability, particle kinetics, dosimetry and toxicity. *NanoImpact*. 10:81-86. DOI:10.1016/j.impact.2017.12.002.

Cohen, J.M., J.W. Rice, T.A. Lewandowski. 2017. Expanding the toolbox: Hazard-screening methods and tools for identifying safer chemicals in green product design. *ACS Sustain. Chem. Eng.* DOI:10.1021/acssuschemeng.7b03368.

Mayfield, D.B., D.G. Skall. 2018. Benchmark dose analysis framework for developing wildlife toxicity reference values. *Environ. Toxicol. Chem.* DOI:10.1002/etc.4082.

Munson, K.M., R.M. Vogel, J.L. Durant. 2018. Climate Sensitivity of Phosphorus Loadings to an Urban Stream. *JAWRA*. DOI:10.1111/1752-1688.12621.

Rhomberg, L.R., T.A. Lewandowski, D.M. Pizzurro, J.E. Goodman. 2018. Risk assessment. In *Comprehensive Toxicology (Third Edition). Volume 1: General Principles*. (Ed.: McQueen, CA), Elsevier Ltd., United Kingdom. p473-488.

Tcaciuc, A.P., R. Borrelli, L.M. Zaninetta, P.M. Gschwend. 2018. Passive sampling of DDT, DDE and DDD in sediments: Accounting for degradation processes with reaction-diffusion modeling. *Environ. Sci. Process. Impacts.* DOI:10.1039/C7EM00501F.

continued on pg. 7

From Global Heat Balance to Balance Sheets

continued from pg. 2

References:

American Society for Testing and Materials (ASTM). 2016. Standard Guide for Financial Disclosures Attributed to Climate Change. ASTM E2718 - 16. 4p.

McNabb, F.W. III. [Vanguard]. 2017. An open letter to directors of public companies worldwide. 3p.

Task Force on Climate-related Financial Disclosures (TCFD). 2016. Recommendations of the Task Force on Climate-related Financial Disclosures. 74p.

U.S. Securities and Exchange Commission. 2018. Electronic Data Gathering, Analysis, and Retrieval System (EDGAR).

By The Way...

Natural land shifts along the U.S. East Coast are causing the Mid-Atlantic Seaboard to sink, compounding the effects of climate change to that region.

Source: https://www.scientificamerican.com/article/sinking-atlantic-coastline-meets-rapidly-rising-seas/.

Guest Editorial: Legal Issues Rise With Climate Change

By John S. Guttmann

Sound science must drive the legal response to climate change, and will determine how these complex and critical issues play out.

Climate change is one of the most important, and yet most controversial, topics of our time. To state the obvious, it is also extremely complex. Climate change presents important scientific, legal, economic, public policy, and political questions for society.

…cases decided on bad science will serve as bad precedents for future cases.

From a lawyer's perspective, the list of ways in which climate change arises as an issue is already long. As is often the case, it reflects many of the larger scientific, economic, and public policy questions surrounding the topic. We have seen litigation related to the alleged causes and alleged effects of climate change. In those cases, judges must weigh the admissibility of evidence related to climate change under applicable evidentiary rules. Public companies must consider climate change issues in their SEC filings. Because investors and lenders consider the issue important, questions arise about disclosures in other contexts as well. Insurance issues can and will arise. Lawyers who represent architects and engineers are focusing on the impacts on their clients in those industries.

A good benchmark is the number of conferences and publications for lawyers related to all of the above subjects and more. At least weekly, lawyers who practice in the area find marketing materials related to climate change in their inboxes.

Courts, juries, and legislatures will address the myriad issues that arise in the legal context. Businesses and investors evaluate risks to their financial investments. Insurers are doing the same and will continue to do so. Public officials and policy makers, and ultimately the public as a whole, will make judgments about broader societal implications of climate change.

One thing should underlie all of the choices being made by these diverse decision makers – science. The best judgments require thoughtful and sound science in a variety of disciplines. That is true in law, economics, and public policy. If decisions are not based on sound science, they will in all likelihood be flawed and unintended consequences will follow, many of them negative. In the legal realm, cases decided on bad science will serve as bad precedents for future cases. Investors and insurers who rely on bad science will make erroneous assessments of risk. Public policy decision makers who act on bad science may make decisions that have unanticipated adverse effects on communities.

John S. Guttmann is a shareholder in Beveridge & Diamond, P.C.'s Washington, D.C. office. He is currently chair of DRI's Toxic Tort & Environmental Law Committee and vice chair of DRI's Climate Change Task Force. He can be reached at jguttmann@bdlaw.com.

Evaluating Coastal Vulnerabilities in a Changing Climate

continued from pg. 3

Although the claims involving climate change are new, the tools for understanding these types of issues and for disentangling competing environmental factors at both regional and local scales are well-established. Changes in coastal land shape and elevation can be measured using historical imagery, satellite data, engineering surveys, and other remote sensing data. Hydrodynamic models can be used to measure the impacts on flooding and coastal erosion of the host of competing effects that include routine storm events, extreme weather, direct runoff from developed areas, the presence or construction of coastal structures, and net sea level rise.

Coastal facilities and municipalities have always faced a special set of vulnerabilities that are associated with their location at the interface of land and sea. Climate change is now an additional variable in the equation that is driving a new wave of litigation. Fortunately, tools and strategies already exist for incorporating the climate change variable into well-understood scientific frameworks.

The authors can be reached at mmayo@gradientcorp.com and jrominger@gradientcorp.com.

What's New at Gradient

continued from pg. 5

Publications (continued)

Thomas, D.G., J.N. Smith, B.D. Thrall, D.R. Baer, H. Jolley, P. Munusamy, V. Kodali, P. Demokritou, **J.M. Cohen,** J.G. Teeguarden. 2018. ISD3: a particokinetic model for predicting the combined effects of particle sedimentation, diffusion and dissolution on cellular dosimetry for *in vitro* systems. *Part. and Fibre Toxicol.* DOI:10.1186/s12989-018-0243-7.

Upcoming Presentations

Philadelphia, PA. May 20-23, 2018. American Industrial Hygiene Conference & Expo.

- **"PDC 505: Introduction to Toxicology for the IH Professional."** J. Ovesen, L. Beyer.
- **"PDC 605: Toxicology of Particulate Matter."** D. Dodge.

Washington, D.C. May 22-23, 2018. Utility Solid Waste Activities Group CCR Workshop.

- **"Using Background Concentrations in the Absence of MCLs for Appendix IV Constituents: Challenges and Opportunities."** A. Lewis.

Portland, OR. June 18-20, 2018. American Chemical Society 22nd Annual Green Chemistry & Engineering Conference 2018.

- **"Challenges and Drivers Relating to Chemical Hazards in Consumer Product Design: Some Case Studies."** K. Reid.
- **"Predictive Toxicology Tools for Green Drug Development."** J. Cohen.

Chicago, IL. July 15-18, 2018. Institute of Food Technologists Expo 2018.

- **"Challenges in Evaluating Exposure to Lead in Food Products under CA Prop 65."** R. Mattuck.
- **"Coffee and Cancer: What Is the Epidemiology Evidence?"** K. Zu.
- **"Just How Dangerous Is the Food We Eat? Understanding Findings from Nutritional Epidemiology."** K. Zu.

Washington, D.C. September 24-26, 2018. International Occupational Hygiene Association Conference.

- **"Assessment of Volatile Organic Compounds in Indoor Air."** E. Light, P. Haas, L. Beyer.

Join Gradient's *Trends* authors for a live webinar for further discussion on this Climate Change Impacts issue.

Please click here for information about this event.

Gradient
Cambridge, MA
Seattle, WA
Charlottesville, VA
trends@gradientcorp.com
www.gradientcorp.com

The next issue will focus on:
Citizen Science

Do you have a scientific topic that you would like Gradient to write about in Trends? Send us your ideas for future Trends topics: trends@gradientcorp.com.

Trends is a free publication of Gradient. If you would like to be added to the distribution list, email trends@gradientcorp.com.