

Lessons from Irene: Building resiliency as we rebuild

Sacha Pealer, January 4, 2012

Climate data show that Vermont is experiencing more extreme rain events, and that trend is predicted to continue.^{1, 2, 3} Likewise, Vermont's more significant floods may be occurring more frequently, and major flooding (as experienced in spring and summer 2011) is expected to pose a recurrent challenge to our communities. While flooding is a natural river process, it is uncertain how changes in flood frequency, intensity, and timing may affect river responses over time, especially when combined with the effects of both historic and modern land use.^{4, 5} Given these predictions and uncertainties, how can Vermonters best prepare?

From August 28-29, 2011, Tropical Storm Irene pummeled the slopes and valleys of Vermont with heavy rain and wind. Rainfall totals of 3-5" were recorded throughout the state, with many areas receiving more than 7", especially on higher, eastern slopes.⁶ As a result, major floodwaters and debris poured through our river ways and communities, from the Mad River valley south to the Deerfield River, affecting 225 municipalities. In many areas, flood levels rivaled or approached the historic flood of 1927, which for 83 years has been a benchmark of Vermont floods.⁶ Irene's devastation sent the state into disaster mode, and to date, the storm's effects are still being realized.

What follows is a brief look at the multi-sector impacts of Irene, as reported so far. Much of this information is subject to change and refinement, particularly as we begin to grasp the long-term consequences for Vermont's local communities, economy, and natural environment.

Irene Impacts So Far....

Transportation

- State highway system: >500 miles of road and ~200 bridges damaged; costs to rebuild: \$175 million- 250 million (lowered from initial estimates of \$620 million)^{7,8}
- Municipal Roads: Estimated >2000 road segments damaged, >280 bridges and ~960 culverts damaged^{9,10, 11}
- Railroad: >200 miles of rail and 6 bridges in the state-owned rail system damaged, costing the state an estimated \$21.5 million. New England Central Railroad also reported damage to private railways, with repairs required at 66 locations.¹²



Figure 1: VT Route 107 Source: VTRANS

- Bus: Green Mountain Transit Authority offices in Berlin sustained flood damages, including 13 vehicles.¹²

Emergency Response

- Main offices for both Vermont Emergency Management and Vermont Agency of Natural Resources were flooded in Waterbury; disaster response headquarters had to be relocated¹³
- Extensive road damage meant some areas were initially hard to access; 13 communities were without any passable roads leading in or out of town¹²



Figure 2: Rochester pedestrian foot bridge

Buildings and Infrastructure

- Power outages for ~73,000 customers, with 55% restored within 24 hours; restoration complete a week after Irene¹⁴
- 7,215 individuals and families registered for FEMA assistance (by 11/15/11); > \$45.9 million in grants and low interest loans for Vermont residents, businesses, and non-profit organizations have been approved by FEMA and the U.S. Small Business Administration;¹⁵ also, nearly \$ 15 million loaned to businesses and farms by Vermont Economic Development Authority¹¹
- FEMA completed over 4,954 property inspections to document damage¹⁵; ~1,500 residences had significant damage (433 of these residences were mobile homes) and at least 1405 households were temporarily or permanently displaced^{11, 12}
- Municipal infrastructure (including transportation) costs are projected to be >\$1 million for at least 12 of the 45 southern and central Vermont towns with severe impacts; an estimated \$140 million in FEMA reimbursements will likely be needed by Vermont towns⁹, with \$2 million in public assistance dollars obligated for Irene as of 12/6/11¹⁶
- Waterbury State Office Complex, R.A LaRosa Agriculture and Environmental Laboratory, and Vermont State Hospital severely damaged in flooding; ~1,500 employees displaced, and costs to rebuild/upgrade estimated at \$50 million to \$85.4 million^{7, 17}
- Significant damage to White River National fish hatchery in Bethel; ~10% of hatchery fish were killed, and thousands of other reared fish may be contaminated^{18,19}
- State Roxbury Fish Hatchery damages estimated at \$500,000²⁰



Figure 3: State Office Complex Flooding, Waterbury
Source: VT ANR

Public Health and Safety

- American Red Cross set up 13 emergency shelters and distributed ~16,000 meals, plus “thousands and thousands” of water bottles^{12,21}
- Food safety advisory for any food touched by floodwaters²²
- Increased allergen exposure from mold growth in flooded buildings and possessions²²

Water Supply

- Drinking water advisory issued for wells submerged by floodwaters—possibility of harmful chemicals or pathogens²²
- About 30 public water systems issued Boil Water Notices as a result of Irene; in many cases, broken pipes lowered a system’s water pressure, which increased the likelihood of harmful contaminants mixing with treated drinking water²³
- An estimated 16,590 people in Vermont were affected by Irene-related Boil Water Notices; 6,215 of these people use the large public water systems affected in Wilmington, Bethel, Woodstock, and Cavendish²³

Hazardous waste and fuel spills

- Potentially hazardous waste (such as household chemicals or spilled fuels) mobilized along rivers, contaminating floodwaters and sediment and soil deposits.²⁴
- In the first week after Irene, hazardous spills reported to state officials increased over routine levels by a factor of fourteen; many spills were related to home fuel tank connections breaking as floodwaters moved tanks.²⁵
- Both US EPA and Vermont Department of Environmental Conservation investigated and assessed hundreds of Irene-related spills; oil-water separators were used to process roughly 300,000 gallons of contaminated waters near the Waterbury state complex.²⁶
- An estimated \$1.75 million in total costs have been incurred to the state (and hopefully will be covered by FEMA) to clean up above ground storage tank oil spills²⁵



Figure 4: Kerosene oil release in a Waterbury mobile home park
Source: Vermont ANR Spill Team

Wastewater Treatment

- Seventeen municipal wastewater treatment facilities (WWTFs) reported compromised operations, with issues ranging from pump station overflows to incomplete processing of sewage (no structural damages, but damages relating to mechanical, electrical, and debris accumulation problems). Most problems were resolved within 24 hours and the vast majority within one week of Irene; estimated discharge of partially unprocessed or raw sewage is 10 million gallons during this period (all 91 WWTFs in Vermont successfully process roughly 44 million gallons of sewage each day on average). Several facilities implemented work-around solutions that prevented further sewage discharge.²⁷

- On-site septic systems around the state were also damaged by high groundwater levels and river or stream erosion. In the two months following Irene, state officials tallied 17 septic system failures due specifically to Irene. Additional systems may have failures attributable to Irene, but displaced homeowners may not yet have discovered failures because they have not been back to use them.²⁸

Solid Waste Disposal

- Vermont landfills received an estimated 32,000-42,000 tons of Irene-related waste during the month following Irene.²⁹
- Household Hazardous Waste collections around the state amassed an estimated 4,385 gallons and 8,464 units* of waste, with ~\$82,000 cost incurred (*units refer to disposed items and range from small bottles to five-gallon buckets of material).²⁹



Figure 5: Furniture and electronic waste piles removed from the flooded Waterbury State Complex
Source: VT ANR Solid Waste Section

Forests

- High flows and saturated ground conditions undermined tree roots, and floating debris injured tree stems. Brief duration of standing water at most locations prevented further near-term tree damage; however, great amounts of accumulated sediment and debris in some streamside forests or establishment of invasive plants may inhibit tree growth over time.^{30,31}
- Aerial surveys found 9,213 acres with trees exhibiting flood damage symptoms from both spring and Irene-related flooding.³⁰
- Green Mountain National Forest: Multiple trails, recreation sites and roads closed (as of 11/18/11, 20 trail closures, 5 recreation site closures, and 20 roads closed).³²
- State Forests and Parks suffered damage sufficient to close numerous roads, trails, and bridges (as of 11/7/11, infrastructure still affected included 33 roads, 14 trails, numerous bridges, 1 canoe access area).³⁰
- Damage to state forest roads delayed work on active state timber sales.³¹
- Green Mountain Club reported multiple trail closures and worked to clear downed trees from trails.³³
- Numerous Vermont Association of Snow Travelers (VAST) trails damaged on federal, state, and private lands; some trails will remain closed to snowmobiles this winter.³¹



Figure 6: Tree dam that formed during the flood
Source: VTRANS

Agriculture

- Farm fields and barns were washed out or covered with flood sediments and debris; more than 450 farms filed Farm Loss claims with USDA and roughly 20,000 acres of farmland were affected.^{11,34, 35}
- Food advisories forced farmers to throw away food crops that may have been contaminated by flood waters^{21,36,37}
- Estimated value of crop losses and crop land damage: >\$10 million dollars statewide^{12,34}
- Producers reported more than 1,000 acres of sugar bush damaged by winds³⁵
- Farm product deliveries were impeded by road closures³⁸
- Shortages in hay and forage this winter may continue to stress farms³⁹; the potential remains for further damage to silage from mold or poor fermentation¹²



Figure 7: Evening Song Farm greenhouse that was eventually washed away

Source: Evening Song Farm Facebook Page

Water Resources

- Intense flooding occurred in at least 10 of Vermont's 17 major river basins
- Major rivers in Vermont demonstrated record or near record flood crest levels^{6,40}:
 - Otter Creek gage in Center Rutland showed the highest flood crest since the gage began operating 83 years ago—9.21' above flood stage
 - Mad River gage in Moretown and White River gage in West Hartford both showed second highest flood crests on record (only 1927 was higher)—12.1' and 10.4' above flood stage, respectively
 - Nine stream gaging stations in Vermont recorded peak flows estimated to have a 1% or less chance of occurring or being exceeded in any given year⁴¹
- Some river locations appeared relatively unscathed, while others underwent catastrophic channel enlargement, deposition, and relocation; pre-Irene geomorphic studies of many Vermont rivers probably flagged some of these damaged areas as being susceptible to channel adjustment (further investigation of this question will be needed as mapping of Irene-damaged areas is completed)⁴
- In-stream channel work and gravel removal occurred in multiple locations during Irene recovery period (largely in the 2-3 months after the flood); in some cases, work occurred without official authorization⁴²

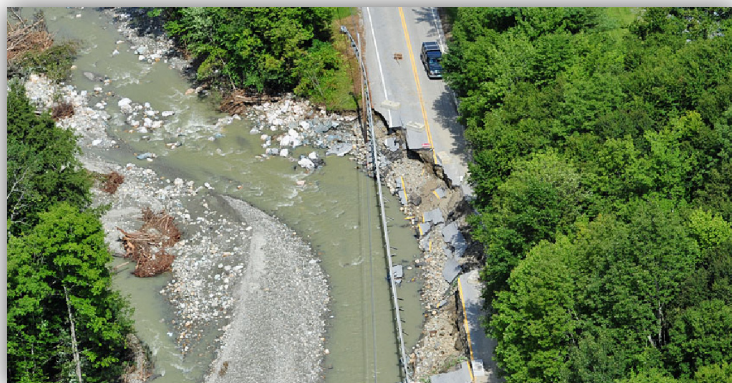


Figure 8: River claims a new channel through VT RT100.

Source: Mansfield HeliFlight

Aquatic Life and Habitat

- In many locations, daily turbidity of waters (related to in-stream work) and habitat disruption may stress fish and macroinvertebrates (insects, snails, mussels, crayfish, etc.); extreme scour from powerful floodwaters likely reduced total numbers of fish and macroinvertebrates in some rivers, and species composition of fish and macroinvertebrates may shift to species that more readily withstand these stresses⁴³
- For example, state fish biologists studied wild trout populations in the Mad and Dog River watersheds both before and after major Irene-related flooding. After the flood, wild trout populations in studied streams were reduced to 33-58% of pre-flood levels.⁴⁴
- Fish and macroinvertebrate populations have a long history of surviving floods when quality stream habitat is available, and reduced numbers are usually temporary, but an increase in flood return rate due to changing climate may have long term impacts.⁴³⁻
⁴⁵ In addition, where habitat is compromised (due to historic channelization practices, encroachment, or post-Irene channel remediation efforts such as streambed excavation and fallen tree removal), fish populations may be affected over a longer term, depending on how quickly natural stream processes can re-establish habitat features.^{4,44}
- Increased algae growth with ongoing influx of river silts (elevating available nutrient levels)⁴³
- Mussel populations (including some rare, threatened, or endangered species) likely harmed as sand and silt deposition and bank collapse buried and suffocated individuals⁴³
- Chemical contaminants distributed along river ways may enter food chains or otherwise harm sensitive plants and animals
- Japanese knotweed, an invasive plant that spreads by sprouting from broken plant rhizomes, has been spread with flood debris, threatening riparian forests, future bank stability, and agricultural fields^{31,46}



Figure 9: White River National Fish Hatchery
Source: US Fish and Wildlife Service

Bouncing Back...and Stepping Back

Undoubtedly, every day Vermonters are making great strides in putting our lives back in order after Irene. But what will we learn from Irene's impacts, knowing that severe flooding may continue to become more common? How can we rebuild intelligently, incorporating greater flood resiliency in our communities while protecting our natural environment? Certainly, the multi-faceted challenges posed by this storm will require careful review, so that we may renew and deepen our societal commitment to smart, collaborative planning and pursuit of the most sustainable solutions for the long term. We will need to ask ourselves hard questions, such as

- In what ways has our built environment imposed on rivers, possibly exacerbating flood damages, endangering our communities, and forcing us to use expensive and risky channel management activities?
- What parts of our livelihoods or parts of our societies are most vulnerable to disasters like Irene?
- What natural features on the landscape, such as stretches of river, lakes, wetlands, riparian forests, and floodplains play a key role in reducing flood impacts and preserving biodiversity? How do we ensure that these features are protected for the benefit of all?
- What do we still need to know about the hydrologic changes our streams may be experiencing as the climate changes, and how can we plan for uncertainty?

As other storms continue to come our way, we want to be ready, so we can allow the river systems to drain the land and sort the debris in the least damaging way...and whenever possible, so we can employ the low risk principle of avoidance. In other words, we'll recognize when it's time to step back and keep our investments out of harm's way.

References

1. Betts, Alan. June 2011. "Climate change in Vermont." <http://www.anr.state.vt.us/anr/climatechange/Pubs/VTCCAAdaptClimateChangeVTBetts.pdf>
2. Frumhoff, P.C., J.J. McCarthy, J.M. Melillo, S.C. Moser, and D.J. Wuebbles. 2007. *Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions*. Synthesis report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA: Union of Concerned Scientists (UCS).
3. Stager, J.C. and M. Thill. *Climate change in the Champlain Basin: What natural resource managers can expect and do*. The Nature Conservancy, May 2010.
4. Vermont River Management Program, Department of Environmental Conservation. <http://www.anr.state.vt.us/dec/waterq/rivers.htm>
5. Pealer, S. and G. Dunnington. 2011. "Climate change and Vermont's waters." Vermont Agency of Natural Resources, Climate Change Team. <http://www.anr.state.vt.us/anr/climatechange/>
6. National Weather Service, Burlington, VT. www.weather.gov/btv
7. Gram, Dave. Associated Press. "Vermont officials provide dramatically lower cost estimates for post-Irene road, bridge repairs." *The Republic*, Columbus, Indiana. 10/31/11.
8. Vermont Agency of Transportation presentation, "Tropical Storm Irene." <http://www.aot.state.vt.us/Irene/Irene.htm>
9. Galloway, Anne. "Shumlin asks towns for input on Irene recovery; a dozen communities borrow more than \$1M each to rebuild." *VT Digger.com*. 11/9/11.
10. Dillon, John. "Post-Irene, Towns Consider Larger Culverts." Vermont Public Radio News, 11/28/11, 7:34am.
11. Spaulding, J., N. Lunderville, S. Minter. 11/10/2011. Presentation, "Irene recovery legislative update: I am strong Vermont." http://www.leg.state.vt.us/ifo/reports/Legislative%20Briefings/2011_11_10_Lunderville_LegislativeUpdate.pdf
12. Lunderville, Neale. Irene Recovery Report, Draft. State of Vermont. 12/19/11.
13. Vermont Division of Emergency Management, <http://vem.vermont.gov>
14. Central Vermont Public Service. News release. "24 hours later: 39,700 of 72,300 restored." 8/29/11, <http://www.cvps.com/>
15. FEMA. News release. "More than 7,200 Vermonters registered for FEMA Irene aid." Release Number: 4022-066, 11/18/11. <http://www.fema.gov/>
16. FEMA. "Public assistance funding making a difference in Vermont." Release Number: 4022-068, 12/6/11. <http://www.fema.gov/>

17. Galloway, Ann. "State office complex could cost as much as \$85.4 million to replace; Shumlin administration urges lawmakers to expedite plans for state hospital." VTDigger.com. 12/13/11.
18. Ring, Wilson. Associated press. "Algae threat could force destruction of 450,000 fish." *The Portland Press Herald*, 11/10/11. <http://www.pressherald.com/>
19. US Fish and Wildlife Service, <http://www.fws.gov/whiterivernfh/irene.html>
20. Nemethy, Andrew. "Fish and Wildlife Department hit with \$1.7 million in Irene-related costs." VTDigger.com. 11/27/11.
21. Bishop, Doug. "Irene response transitions from sheltering to relief and recovery." American Red Cross press release, 9/6/11. <http://www.redcrossvtnhuv.org/>
22. Vermont Department of Health. www.healthvermont.gov
23. Kievit-Kylar, Doug. Personal communication, 12/7/11. Vermont Department of Environmental Conservation, Drinking Water and Groundwater Protection Division.
24. Vermont Agency of Natural Resources. "Tropical storm Irene flood sediment and soil clean-up information." 9/9/11. <http://www.anr.state.vt.us/dec/wastediv/solid/pubs/FloodDebrisMemo.pdf>
25. Geller, Alex. Personal communication, 11/1/11, 12/5/11. Vermont Agency of Natural Resources, Waste Management Division.
26. Moran, Matt. Personal communication, 12/6/11. Vermont Department of Environmental Conservation, Waste Management Division.
27. Fehrs, Jeff and Akielaszek, John. Personal communication, 11/28/11. Vermont Department of Environmental Conservation, Wastewater Management Division.
28. Christianson, Ernest. Personal communication, 12/8/11. Vermont Department of Environmental Conservation, Wastewater Management Division.
29. Surwilo, James. Personal communication, 11/28/11. Vermont Department of Environmental Conservation, Solid Waste Management Program.
30. Wilmot, Sandy. "2011 flooding summary for Forests, Parks, and Recreation." Vermont Department of Forest, Parks, and Recreation. 11/9/11.
31. Maciejowski, Jay. Personal communication, 11/29/11. Vermont Department of Forests, Parks, and Recreation, Forestry Division.
32. Green Mountain National Forest, News release, 9/16/11. http://www.fs.usda.gov/Internet/FSE_MEDIA/stelprdb5330581.pdf
33. Hardy, Dave. "Field Notes," *Green Mountain Club Long Trail News*, Winter 2011. http://www.greenmountainclub.org/images/file/LTN/gmc_ltn_w11_web.pdf
34. Vermont Agency of Agriculture. News release. "Vermont farm disaster relief fund grants over \$237K to farmers in second round." 10/17/11. <http://www.vermontagriculture.com/>
35. USDA Farm Service Agency, Tropical Storm Irene statistics reported by Vermont Association of Conservation Districts, <http://www.vacd.org>
36. US Food and Drug Administration. "Notice from the Food and Drug Administration to growers, food manufacturers, food warehouse managers, and transporters of food products about the safety of food affected by hurricanes, flooding, and power outages." <http://www.fda.gov/Food/FoodDefense/Emergencies/FloodsHurricanesPowerOutages/ucm112723.htm>
37. UVM extension. News release 9/2/11. "Many vegetable farms flooded but plenty of safe local produce available."
38. Bodette, Melody. "Dairy farmers trying to return to normal operation." Vermont Public Radio News, 9/19/11, 7:34am.
39. Vermont Agency of Agriculture. Hay and Forage Directory. <http://www.vermontagriculture.com/>
40. US Geological Survey. Stream real-time water data for Vermont. <http://waterdata.usgs.gov/vt/nwis/rt>
41. US Geological Survey. "High flows in New Hampshire and Vermont from Tropical Storm Irene estimated." September 2011. http://nh.water.usgs.gov/WhatsNew/Irene_aug2011.htm
42. Langlois, Krista. "Mining Vermont's rivers." *Valley News*, 11/20/11. <http://www.vnews.com/>
43. Fiske, Steve. Personal communication, 11/2/11. Vermont Department of Environmental Conservation, Watershed Management Division.
44. Kirn, Rich. "Flood impacts to wild trout populations in Vermont." Vermont Department of Fish and Wildlife. Fall 2011.
45. Meffe, Gary. "Irene and Streams," Vermont Center for Ecosystem Studies *Field Notes*, Fall 2011.
46. Bodette, Melody. "Flooding, clean-up efforts spread invasive plants." Vermont Public Radio News, 10/3/11, 7:34am.