THE WEST VALLEY CITIZEN TASK FORCE

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Honorable Joseph M. Giglio, NYS Assembly
Honorable David DiPietro, NYS Assembly

FROM: West Valley Citizen Task Force

DATE: July 27, 2015

RE: **Actions Needed Related to Potential Change Impacts**

The Citizen Task Force believes the West Valley nuclear waste site, if not cleaned up, poses a significant hazard to downstream communities, Cattaraugus Creek, Lake Erie, and the drinking water for over a million people. Downstream communities include Gowanda, the Seneca Nation's Cattaraugus Territory, and much of Erie County including Buffalo.[1] We have known for some time that the West Valley site is highly vulnerable to erosion and that

[1] There is good evidence that radioactive contamination released from the West Valley site will continue past Buffalo into the Niagara River and Lake Ontario. See especially two articles by S.R. Joshi, "West-Valley-Derived Radionuclides in the Niagara River Area of Lake Ontario," *Water, Air, and Soil Pollution* **37**, 111-120 (1988), and "West Valley Plutonium and Americium-241 in Lake Ontario Sediments Off the Mouth of Niagara River," *Water, Air, and Soil Pollution* **42**, 159-168 (1988), and also NWS Buffalo information on the August 2009 storm that affected southern Erie, northern Chautauqua, and northern Cattaraugus Counties (http://www.erh.noaa.gov/buf/svrwx/web_080809_Derecho/indexderecho_1.html; http://www.erh.noaa.gov/buf/svrwx/web_090810_Flashflood/indexflood.html), where the sediment plume from Cattaraugus Creek can be considered a reasonable surrogate for dissolved and suspended radioactive contamination. Note, however, that mixing in the Niagara River, and mixing and deposition in Lake Ontario, would substantially dilute such contamination relative to the contaminant concentrations affecting the nearer downstream communities such as Gowanda, the Seneca Nation's Cattaraugus Territory, and much of Erie County including Buffalo.

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the dangerous radioactive waste cannot be contained over the long term due to erosion. These problems have been analyzed by a review team assembled by NYSERDA and presented as a dissent by NYSERDA in the Foreword to the 2010 Environmental Impact Statement (EIS) as well as an independent report, *The Real Costs of Cleaning Up Nuclear Waste: A Full Cost Accounting of Cleanup Options for the West Valley Nuclear Waste Site*, by Synapse Energy Economics, Inc., Nov. 2008. Both analyses express concern about the ability of the site to contain radioactive waste placed there because of the geology of the site. While erosion continues to be evaluated in the Phase 1 Studies process, the exacerbation of erosion processes due to climate change and severe weather events has not been adequately assessed.

Increased frequency and/or severity of extreme weather events is known to be related to climate change. This will compound the existing climate "baseline" in which the Northeast is already experiencing extremely heavy rainfall events which can saturate soils, erode and transport large quantities of soil and underlying till to nearby creeks and rivers. Heavy rainfall can even result in downslope movement of blocks of soil and till (slumps and landslides), as the West Valley site experienced in August 2009 when a 5-inch rainfall[2] led to an enormous landslide into Buttermilk Creek and other onsite effects. By comparison, parts of Long Island received 13 inches of rain in August 2014, with 11 inches falling within 3 hours.[3] Even if the government is willing to spend millions of dollars on engineered barriers at the West Valley site, such barriers are temporary short-term remedies, likely to fail in the face of extreme weather events. As we have seen, the federal government has difficulty finding the money necessary for nuclear waste cleanups, and budget cuts impair our ability to complete even planned tasks. Since current cleanup plans will stretch over decades, it is essential to recognize these risks and to provide adequate funding to maintain, contain, and remove long-lived and dangerous radioactive waste so that public health will not be harmed and the environment irreversibly contaminated.

Climate Adaptation, Preparedness, and Community Resilience Planning[4]

At the national and state levels, governments are calling for deliberative planning around preparation for climate change in local communities. The President in August of 2014 issued an Executive Order calling for concerted attention to climate preparedness at the local level with all federal agencies playing a collaborative role. The DOE plays a leading role as a federal agency in these efforts. At the state level DEC and NYSERDA are playing key roles in climate preparedness or community resilience planning with local communities around the state. The state is now implementing the "Community Risk and Resiliency Act" passed in 2014 and developing regulations.

Multiple Presidential Executive Orders on Climate Change have been issued since 2010 and multiple reports provide details of specific needed actions on climate. Federal agencies are supposed to identify vulnerabilities associated with federally owned or managed facilities, like the West Valley Nuclear Waste Site. At the state level DEC and NYSERDA have been involved in extensive climate action planning, including preparedness. In January 2014 NYSERDA issued a Draft Energy Plan which gave the cost of Hurricane Sandy to the state as $32 Billion, and also

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[2] The onsite rain gauge was inoperative during the storm. For rainfall amount, see R.C. Vaughan, *Comments on 2008 Draft EIS* (2009), esp. comments 204-215, as reproduced (but without the supporting figure and table) in DOE & NYSERDA, Final EIS (DOE/EIS-0226, January 2010), Vol. 3. Compare C.O. Szabo, W.F. Coon, and T.A. Niziol, *Flash Floods of August 10, 2009, in the Villages of Gowanda and Silver Creek, New York*, USGS Scientific Investigations Report 2010–5259, p. 3, which suggests that "On the basis of the weather observer's 'ground-truth' report, the radar-derived precipitation likely underestimated the actual precipitation quantities" – but note that this "weather observer's 'ground-truth' report" is from a location (Perrysburg) that the radar-derived estimates show as having received higher rainfall than the Cattaraugus Creek basin average. See Szabo et al., Fig. 2, and Vaughan, op. cit., Fig. 5. Thus, the best available estimate of rainfall received by the West Valley site during the August 2009 storm is approximately 5 inches.

[3] See http://www.weather.gov/okx/HistoricFlooding_081314 and NWS Hydrometeorological Design Studies Center, *Exceedance Probability Analysis for the Islip, NY Rainfall Event, 13 August 2014*, updated 22 August 2014. Other examples of heavy rainfall are provided below in the Appendix of this memo and by Vaughan, op. cit., comment 215.

[4] Climate Change Adaptation is now typically referred to as climate preparedness or climate resiliency, or as community resilience to climate change.

said future climate damage costs will amount to $10 Billion annually by mid-century.[5] DEC maintains extensive climate resources on its website including resources related to climate resilience or climate preparedness. These extensive resources can be accessed at the DEC Office of Climate Change. See http://www.dec.ny.gov/about/43166.html

Climate Preparedness or Community Resilience Planning relative to the West Valley Site

Unfortunately all this climate activity appears completely disconnected from the decommissioning of the West Valley nuclear waste facility with agencies considering leaving radioactive waste in place as a viable option. Failing to integrate climate change impacts into cleanup plans will skew agency assessments of the risk of leaving radioactive waste in place. In fact, there can be no successful containment of radionuclides over thousands of years in degrading containers in unlined dumps, nor in corroding tanks on an erosion-prone plateau. As we stated in our 1998 Final Report:

> *The CTF does not believe (based on currently available information) the Site is suitable for the long term, permanent storage or disposal of long-lived radionuclides (such as carbon-14 with a half life of 5,730 years, uranium-238 with a half life of more than 4 billion years, plutonium-239 with a half life of 24,100 years, and Technetium-99 with a half life of 217,000 years).*
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> *The site is in an area that:*
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> - *has an average rainfall of 40 inches,*
> - *has a relatively high and mobile water table which is hydrologically connected to the surface and perhaps in the future to subsurface aquifers,*
> - *has sand lenses that are irregularly distributed through the clay on which the site sits,*
> - *is on or near active earthquake faults, and*
> - *is located on a tributary of Lake Erie….*[6]

We have seen little evidence that climate impacts are being appropriately incorporated into the agencies' evaluations of site integrity over the next 1,000 or 10,000 years. Recently we have been told that climate change impacts will be considered in a 2019 Supplemental EIS. However, we need a more deliberative, open, and timely planning process for climate preparedness and community resilience, particularly a process that involves local government officials and other parties as is strongly recommended by federal and state governments. The preparation of a draft EIS occurs in the offices of an agency or contractor and does not see the light of day until it is released briefly for public comment. Analyses that are missing or incomplete will only be subject to public comment with no guarantee that additional analysis will be done.

The necessary analyses should generate 1) a reliable estimate of the baseline rainfall intensity-frequency relationship for the West Valley site and upstream watersheds, reflecting current climate or recent climate conditions of the past few decades and 2) robust predictions of how the rainfall intensity-frequency relationship will change over the next 1,000 or 10,000 years as a result of climate change. Both tasks are complicated by limited data and by the sporadic (temporally and spatially variable) distribution of historic and future rainfall. The end result, in any case, should be a vulnerability assessment that evaluates the potential health and environmental damage associated with severe weather events, flooding and loss of radioactive materials from the site. The habitability of the watershed for people and wildlife as well as the potential economic impacts should be included.

The August 2009 rainfall and flooding provide a useful example. This event resulted in the total loss of a local hospital in Gowanda, due to extensive damage beyond repair, in addition to other widespread damage in the village

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[5] NYSERDA Draft NYS Energy Plan, Vol. 2, p. 25, referencing Climaid report, *Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation.* http://www.nyserda.ny.gov/climaid

[6] West Valley Citizen Task Force, Final Report to NYSERDA and DOE, July 29, 1998, § III.3.

and surrounding area. Federal funds provided to three counties totaled $45 million. Total damage was $90 million, including impacts to water system infrastructure.[7] Much of the damage was from tributary streams rather than Cattaraugus Creek itself, but the analyses that we find necessary will need to look at impacts from more extreme rainfall and flooding than occurred in 2009.[8] With regard to impacts, it should be obvious that the damage experienced in 2009 would have been worse – and much more difficult to remedy – if the floodwaters and associated silt had carried radioactive contamination from the West Valley site. Such contamination would pose significant problems to the Seneca Nation, Village of Gowanda, Buffalo and lakeshore waterfronts, and public drinking water supplies. These are some of the impacts that need to be quantified in the analyses that we find necessary.

Developing a Reliable Estimate of the Baseline Rainfall Intensity-Frequency Relationship

A reliable estimate of the *current* baseline rainfall intensity-frequency relationship is needed for the West Valley site. This task is complicated by limited data, including the short time period during which official records have been kept, and by the sporadic (temporally and spatially variable) distribution of past and present rainfall.

An important distinction can be made between widespread rainfall events (such as those associated with hurricanes and tropical storms) and more localized storms that "are representative of thunderstorm phenomena, with intense rainfall over relatively small areas."[9] Extreme rainfall events are often associated with storms of the latter type, yet these storms tend to be poorly documented:

> It turns out that the most extreme point rainfalls of record are almost entirely from unofficial sources. This should be expected since there is practically no chance that the most extreme rainfall of a storm would occur over a preselected gage site.[10]

Despite the importance of localized extreme storms, some authors and some studies may refuse to recognize them! For example, Cornell climate scientist DeGaetano excluded such storms from one study that he conducted. This may be justified for the purpose of that particular study, but his discussion of the exclusionary procedure is worth noting:

> …the most extreme values were further screened for spatial consistency. Daily rainfall amounts in excess of 12.7 cm required a second precipitation total of at least 7.6 cm to be observed at a station located within 300 km of the first to be considered. In a similar way, for rainfall amounts in excess of 25.4 cm to be considered, a second total of 12.7 cm or greater was required to occur within 300 km of the first. This procedure was used by Wilks and Cember (1993) in developing an atlas of extreme-rainfall amounts for the northeastern United States. It can be argued that this relatively simple procedure may have excluded valid precipitation extremes—in particular, in data-sparse regions. This potential omission is problematic in applications in which the value of the extreme is of greatest importance, but in the current application, which looks at the temporal change in the extreme values, the omission is of somewhat less concern….[11]

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[7] See USGS report by Szabo et al., op. cit.

[8] The rainfall and flooding experienced in August 2009 can be assigned certain return intervals. These intervals will gradually become shorter due to climate change, as discussed in more detail in the text of this memo. Once the return interval Δt is established for a given level of rainfall or flooding, one can easily estimate how many times such rainfall or flooding will occur during 1,000 or 10,000 years, and one can also infer that *more extreme* rainfall or flooding events will occur during 1,000 or 10,000 years at a return interval that is longer than Δt..

[9] J. Harrison, "PMPs Never Happen – or Do They?", 23rd Annual Meeting and Conference Proceedings, United States Society on Dams, Charleston, SC, April 14-18, 2003 (http://www.schnabel-eng.com/portals/0/docs/floods/PMPs%20Never%20HappenFinal.pdf), at 7.

[10] F.P. Ho and J.T. Riedel, "Seasonal Variation of 10-Square-Mile Probable Maximum Precipitation Estimates, United States East of the 105th Meridian," NOAA/NRC Hydrometeorological Report No. 53 ("HMR No. 53"), April 1980, at 3.

[11] A.T. DeGaetano, "Time-Dependent Changes in Extreme-Precipitation Return-Period Amounts in the Continental United States," *Journal of Applied Meteorology and Climatology* **48**, 2086-99 (October 2009), at 2087.

This type of data exclusion would produce an erroneous estimate of the intensity-frequency relationship for rainfall at the West Valley site or any other nearby site. For example, such a procedure could effectively suppress or censor the localized storm that delivered more than 30 inches of rain in about 4.5 hours to Smethport, PA, on July 17-18, 1942. This extreme storm event is crucially important to climate science and dam safety in the northeastern United States,[12] and the proximity of Smethport to West Valley makes the 1942 Smethport storm an important benchmark for the intensity-frequency relationship for rainfall at the West Valley site.[13]

In our Appendix we list a variety of rainfall events, most being localized storms rather than widespread events, that have occurred near the West Valley site and in the surrounding region. The list provides examples; it is not a complete or comprehensive list. It illustrates both the complexity and the importance of drawing on regional data to develop a reliable intensity-frequency relationship for rainfall at the West Valley site. Data from a single site such as the NWS Buffalo weather station is simply too sparse, given the short period of record (~150 years) and the need to generate a reliable baseline intensity-frequency relationship that can support 1,000-year or 10,000-year projections of West Valley rainfall for purposes of assessing site integrity.[14]

The August 2009 storm which delivered roughly 5 inches of rain to the West Valley site has been considered a rainfall event with a return interval of approximately 100 years, as can be inferred from either the 2010 West Valley FEIS[15] or the 2012 *Climate Guidance for Phase 1 Studies*.[16] However, there is other evidence that suggests a shorter (more frequent) baseline return interval for a rainfall event comparable to the August 2009 storm:

> The peak flow in Cattaraugus Creek at Gowanda was computed, using the slope-area method, to be 33,200 cubic feet per second with an annual exceedance probability of 2.2 percent (recurrence interval of 45 years).[17]

Peak flow is obviously not the same measure as depth of rainfall, yet the two measures must be closely related, especially given the relatively uniform depth of rainfall over the Cattaraugus Creek watershed above Gowanda.[18] Thus, at the very least, we need better resolution of whether the August 2009 storm is an event with a return interval of 45 years or 100 years. This is a particularly obvious gap in the baseline rainfall intensity-frequency relationship for the West Valley site.

<u>How the Rainfall Intensity-Frequency Relationship Will Change Due to Climate Change</u>

Robust predictions are needed for *how the rainfall intensity-frequency relationship will change* over the next 1,000 or 10,000 years as a result of climate change. This task is complicated by limited data and by the sporadic (temporally and spatially variable) distribution of past, present, and future rainfall. The necessary climate-change analyses

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[12] For example, see J. Harrison, "Extreme Events: Graphs, Photos, Videos," in Dam Safety 2006: Proceedings of the 2006 Annual Conference of the Association of State Dam Safety Officials, Lexington, KY, September 10-14, 2006 (http://www.schnabel-eng.com/wp-content/uploads/2013/12/Extreme-Events.pdf), and E. Tomlinson, B. Kappel, and D.D. Hoare, "Evaluation of the Rainfall Reports and Storm Analysis of the Smethport, Pennsylvania Storm July 17-18, 1942," Northeast ASDSO Conference, State College, PA, June 14-16, 2009 (http://www.appliedweatherassociates.com/uploads/1/3/8/1/13810758/ne-region-asdso-smethport-reanalysis.pdf).

[13] Smethport, PA, is only a few miles further from the West Valley site than the NWS Buffalo weather station is, and the West Valley site's topography is intermediate between the flat terrain of the NWS Buffalo site and the dissected Allegheny Plateau terrain of the Smethport area.

[14] Methods using temporal-spatial tradeoffs may be capable of generating a reliable baseline intensity-frequency relationship and should be evaluated for this purpose. See, for example, J.R.M. Hosking and J.R. Wallis, *Regional frequency analysis: an approach based on L-moments* (Cambridge University Press,1997).

[15] Final EIS (2010), at F-83, showing a 100-year return period for a 24-hour rainfall of 5.2 inches, based on 1986 USDA maps. The relationship of these USDA-based return periods listed in the FEIS to the return periods produced by the stochastic rainfall generator used in the FEIS erosion model (CHILD) is unclear. See generally *Climate Guidance for Phase 1 Studies*, West Valley Demonstration Project, (November 2012), Appendix C, and Vaughan, op. cit., comment 172.

[16] *Climate Guidance for Phase 1 Studies*, op. cit., at 9, showing a 100-year return period for a 24-hour rainfall of 5.35 inches.

[17] Szabo et al., op. cit, at 1.

[18] This is discussed by Vaughan, op. cit., comments 210-215.

should assess whether temporal-spatial tradeoffs can simplify the task, particularly for rare events, over the long time periods needed to predict site integrity for the West Valley site.

DeGaetano, for example, notes that "Heavy-rainfall events have become more frequent since the middle of the last century…",[19] and this trend is now generally accepted in climate science. For the West Valley site, he and others have suggested that

> As a first order approximation, design storm precipitation totals…may increase by approximately 25 percent by 2100.[20]

This implies that a storm with the return frequency (return interval) of the August 2009 storm will deliver roughly 6.5 inches of rain by the year 2100. But would the return interval of such a storm be 45 years or 100 years? Better quantification is needed for both the current baseline and the effects of climate change.

Another important future uncertainty for the site involves *lake-effect rain*. Lake-effect rain, while less publicized than lake-effect snow, is a closely related phenomenon that has been recognized since the 1990s.[21] Either type of lake-effect precipitation involves narrow bands of moisture-laden clouds that deliver high rates of rain- or snowfall to areas downwind of the Great Lakes and other bodies of water. Areas downwind of Lake Erie frequently receive this type of precipitation during the fall. As an example of heavy lake-effect rain, the Buffalo suburb of Tonawanda, NY, received about 6 inches of rain on September 14-15, 1996.[22] High rates of lake-effect rain- or snowfall can sometimes be further intensified when moisture from Lake Erie is augmented by moisture from one of the upwind Great Lakes, typically Lake Huron or Georgian Bay.

Lake-effect snow can produce heavy runoff and associated erosion if and when a warm spell causes rapid melting, but lake-effect rain has no such delay; its runoff is more immediate. Climate change will likely cause areas downwind of Lake Erie to receive more lake-effect precipitation (as moisture availability increases due to warmer lake water and less ice cover), and will also cause those areas to receive a lesser proportion of lake-effect snow and a greater proportion of lake-effect rain (as ambient air temperatures below freezing become less frequent).[23] In combination, these two trends can be expected to bring a poorly constrained and highly variable amount of additional rain to the West Valley site. Here again, better quantification is needed for assessing long-term erosion and site-integrity impacts.

Erosion and site integrity depend not only on precipitation and runoff, but also on soil stability through such processes as slumping, freeze-thaw cycles, and groundwater "piping" through small subsurface channels. Each of these has negative effects on soil stability that may be aggravated by climate change. For example, climate change may increase the frequency and/or intensity of freeze-thaw cycles, which in turn may impact soil stability, not unlike the impact of winter conditions on asphalt roadways.

Conclusions and Recommendations

A vulnerability assessment and a climate preparedness plan or community resiliency plan should be prepared. These efforts should attempt to reduce some of the uncertainties reviewed above but must also focus on the removal of wastes from the West Valley site. In our understanding of the evidence thus far, there is no realistic possibility that long term, permanent storage or disposal at the West Valley site can safely contain long-lived radionuclides and prevent them from being washed downstream. Community resilience planning should be oriented toward waste removal.

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[19] DeGaetano, op. cit., at 2086-87.

[20] *Climate Guidance for Phase 1 Studies*, op. cit., at 10.

[21] T.J. Miner and J.M. Fritsch, "Lake-Effect Rain Events," *Monthly Weather Review* **125**, 3231-48 (1997).

[22] Ibid., footnote 7.

[23] NYSERDA, *Climate Change in New York State, Updating the 2011 ClimAID Climate Risk Information*, Supplement to NYSERDA Report 11-18, Final Report 14-26 (September 2014), at 15; J. Zremski, "Winter weather weirdness may be just beginning," *Buffalo News*, November 22, 2014.

Recommendations:

- We recommend that a climate vulnerability assessment and climate resiliency plan, directed toward waste removal, be prepared by DOE and NYSERDA for the West Valley nuclear waste site. Agencies must do what is necessary to protect public health and the environment, including addressing climate change. Impacts considered in the assessment and climate resiliency plan should include not only potential health and environmental damage associated with severe weather events, flooding and loss of radioactive materials from the site, but also the habitability of the watershed for people and wildlife as well as associated economic impacts.
- We recommend an early start in 2016 to facilitate an iterative Phase I study process that includes substantial participation and feedback from CTF and others. In addition, the climate vulnerability assessment and resiliency plan will eventually need to be integrated with the "performance assessment" currently planned as part of the Supplemental EIS.
- We recommend that all assessments that are prepared, including but not limited to exposure and health, erosion, climate vulnerability and performance, be completely transparent, with all factors, assumptions and steps detailed and explained for the public in advance of the draft Supplemental EIS.
- Some local government entities may decide to work individually or in collaboration with other government entities to assess the vulnerability of the nuclear wastes at West Valley to severe weather events associated with climate change, by seeking available grants in order to provide an independent review.

APPENDIX: Various extreme weather events that may be relevant to the current baseline intensity-frequency relationship for the West Valley site

This list is illustrative, not complete or comprehensive. Sources are listed only for events for which information may not be readily available.

August 16-17, 1864: Rushford, Allegany County, NY: Torrential rain and flooding sufficient to carry houses.[24]

July 26, 1874: Allegheny City [Pittsburgh], PA: Torrential rain and flooding; >100 deaths.[25]

May 30-June 2, 1889: Wellsboro, PA: Reportedly 7.45 inches rain in 24 hr; 9.80 inches in 72 hr.[26]

July 17-18, 1942: Smethport, PA: Reportedly >30 inches rain in about 4.5 hours, as discussed above in text of this memo.

July 1947: Erie, PA: Reportedly 20 inches rain in 24 hr.[27]

June 20-22, 1972: Bolivar, Allegany County, NY, during tropical storm Agnes: 14.3 inches rain in 24 hr; 18.5 inches in 72 hr.[28]

July 15, 2004: Peterborough, Ontario: Reportedly about 8 inches rain.

July 27-28, 2006: Lake, Geauga, and Ashtabula Counties, Ohio: Reportedly up to 10 inches rain in 24 hr.

April 15-16, 2007: NY and NJ: Reportedly 6 to 9 inches rain in several hours in Bergen, Hudson, and Union Counties, NJ, and in Central Park in NYC and at La Guardia Airport.

August 8, 2007: NYC: Reportedly about 3 inches rain in 1 hour.

August 22, 2007: Northwestern Ohio: Reportedly about 9 inches rain in 24 hr.

August 9-10, 2009: Cattaraugus Creek basin, including West Valley site: About 5 inches rain basinwide, as discussed above in text of this memo, and about 7 inches in Perrysburg, NY, with the localized distribution and approximate magnitude of this storm event being clearly evident on Buffalo NEXRAD weather radar.

May 19, 2011: Little Valley, Cattaraugus County, NY: Reportedly about 3 inches rain in less than 3 hours, with the distribution and approximate magnitude of this highly localized storm event being clearly evident on Buffalo NEXRAD weather radar.

May 26-27, 2011: Vermont: Reportedly >5 inches rain in Montpelier, VT.

August 30, 2011: Eastern NYS, during tropical storm Irene: Reportedly 12 inches rain in Greene County, NY.

July 8, 2013: Toronto, Ontario area: Reportedly about 4 inches rain in 2 hours, with the localized distribution and approximate magnitude of this storm event being clearly evident on Buffalo NEXRAD weather radar.

May 21, 2014: Chautauqua County, NY: Reportedly about 4 inches rain in 24 hours, with the localized distribution and approximate magnitude of this storm event being clearly evident on Buffalo NEXRAD weather radar.

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[24] H.J.W. Gilbert, *Rushford and Rushford People* (1910), at 514-16.
[25] B. Gelber, *The Pennsylvania Weather Book* (Rutgers University Press, 2002), at 181.
[26] Ibid., at 187.
[27] Pennsylvania State Climatologist, as cited by Vaughan, op. cit., comment 173.
[28] Ho and Riedel, HMR No. 53, op. cit., Table 2.

July 27, 2014: Southern Ontario, several locations: Reportedly about 4.5 inches rain in 24 hours at Burford, Ontario, with the localized distribution and approximate magnitude of this storm event being clearly evident on Buffalo NEXRAD weather radar.

July 13-14, 2015: Chautauqua, Cattaraugus, and Allegany Counties, NY: Reportedly more than 5 inches of rain in a 2-hour period in northern Chautauqua County, causing severe flooding in the villages of Brocton, Westfield, and Silver Creek, as well as the towns of Portland and Westfield; also heavy rain in northern Cattaraugus County which was measured as 3.90" rainfall at NYSERDA's SDA meteorological station at the West Valley site; also heavy rain and flooding in parts of Allegany County; with the localized distribution and approximate magnitude of this storm event being clearly evident on Buffalo NEXRAD weather radar.