

Mitigating flood exposure

Reducing disaster risk and trauma signature

James M Shultz,^{1,*} Andrew McLean,² Holly B Herberman Mash,³ Alexa Rosen,¹ Fiona Kelly,⁴ Helena M Solo-Gabriele,⁵ Georgia A Youngs Jr,⁶ Jessica Jensen,⁶ Oscar Bernal⁷ and Yuval Neria⁸

¹Center for Disaster & Extreme Event Preparedness (DEEP Center); University of Miami Miller School of Medicine; Miami, FL USA; ²School of Medicine and Health Sciences; University of North Dakota; Fargo, ND USA; ³Department of Psychiatry; Center for the Study of Traumatic Stress; Uniformed Services University of the Health Sciences; Bethesda, MD USA; ⁴Clinical & Health Psychology; University of Edinburgh; Scotland, UK; ⁵Department of Civil, Architectural, and Environmental Engineering; College of Engineering; University of Miami; Miami, FL USA; ⁶Department of Emergency Management; North Dakota State University; Fargo, ND USA; ⁷School of Medicine; Universidad de Los Andes; Bogota, Colombia; ⁸Trauma and PTSD Program; Department of Psychiatry & The New York State Psychiatric Institute; Columbia University; New York, NY USA

Keywords: flood, disaster, resilience, community resilience, mitigation, mental health, trauma, trauma signature analysis, psychological, psychosocial

Introduction. In 2011, following heavy winter snowfall, two cities bordering two rivers in North Dakota, USA faced major flood threats. Flooding was foreseeable and predictable although the extent of risk was uncertain. One community, Fargo, situated in a shallow river basin, successfully mitigated and prevented flooding. For the other community, Minot, located in a deep river valley, prevention was not possible and downtown businesses and one-quarter of the homes were inundated, in the city's worst flood on record. We aimed at contrasting the respective hazards, vulnerabilities, stressors, psychological risk factors, psychosocial consequences, and disaster risk reduction strategies under conditions where flood prevention was, and was not, possible.

Methods. We applied the "trauma signature analysis" (TSIG) approach to compare the hazard profiles, identify salient disaster stressors, document the key components of disaster risk reduction response, and examine indicators of community resilience.

Results. Two demographically-comparable communities, Fargo and Minot, faced challenging river flood threats and exhibited effective coordination across community sectors. We examined the implementation of disaster risk reduction strategies in situations where coordinated citizen action was able to prevent disaster impact (hazard avoidance) compared with the more common scenario when unpreventable disaster strikes, causing destruction, harm, and distress. Across a range of indicators, it is clear that successful mitigation diminishes both physical and psychological impact, thereby reducing the trauma signature of the event.

Conclusion. In contrast to the experience of historic flooding in Minot, the city of Fargo succeeded in reducing the trauma signature by way of reducing risk through mitigation.

Introduction

Hazard avoidance, achieved through a combination of prevention and mitigation, has been advocated as a prudent and cost-effective approach to disaster risk reduction, particularly when compared with preparedness, response, and recovery from disaster impacts.¹ We illustrate this principle with a comparison of the flood experiences of two communities.

During Spring 2011, flooding was widespread throughout the United States Northern Plains. We selected two demographically-comparable North Dakota cities, Fargo and Minot, that were both threatened by flooding in order to compare the hazard profiles, the salient psychological stressors, community response actions, and the "trauma signature,"²⁻⁸ under conditions of successful flood mitigation vs. historic flooding (Figs. 1 and 2).

Fargo is not invulnerable to flooding, having experienced significant inundation in "The Great Flood of 1997." However, thereafter, Fargo has mounted 14 consecutive, successful "flood fights." Once again, in Spring 2011, Fargo constructed an elaborate network of flood fortifications and maintained surveillance throughout flood stage. Although the Red River of the North rose to near-record heights, Fargo sustained negligible flood damage. Dikes and levees were erected with sufficient durability to contain the rising waters, thanks to respected leadership guiding the vigorous, coordinated efforts of thousands of Fargo citizens.

In contrast, during June 2011, Minot experienced inundation that surpassed the previous record "Flood of 1881." The Souris River carves deeply through, and transects, the city center of Minot. There was no practical way to effectively mitigate flooding in downtown Minot. The extensive system of

*Correspondence to: James M Shultz; Email: jamesmichaelshultz@gmail.com
Submitted: 08/04/12; Revised: 11/26/12; Accepted: 11/30/12
<http://dx.doi.org/10.4161/dh.23076>



Figure 1. Minot, ND, July 6, 2011. Aerial view of flooding in Minot, ND. Photo by: David Valdez/FEMA.

dams and reservoirs upstream from Minot required engineers from two nations to make flood control decisions over a period of weeks. The timing and quantity of water releases directly affected the water flow rates and river heights through Minot. Minot engaged in pre-impact citizen preparedness and evacuation, and following major flooding, the focus shifted to recovery and reconstruction.

The public health and psychosocial impact of flood disasters.

Public health impact. Globally, among types of natural disasters, floods are the most common, affect the most people, and produce the most deaths.^{1,9-11} Floods include both “fluvial” events, characterized by the overflowing of rivers and streams resulting from precipitation and snowmelt, and “coastal” flood events associated with hurricane storm surge or seismically-generated tsunamis.^{1,11} Human factors interplay with natural phenomena to exacerbate flood risks: examples include human settlement in flood-prone areas, dam failures, levee breaches, water runoff from agricultural drainage systems, deforestation¹¹ and climate change with increased precipitation.¹ Public health consequences of floods include damage to homes leading to population displacement, damage to community infrastructure, cross-contamination of water and sewage systems, infectious disease threats, physical injury and disruption of access to primary and specialty health-care services.^{1,9-14} Death may occur from drowning in submerged structures or vehicles driven on flooded roadways, entrapment in rising floodwaters or trauma from floating debris or flood-collapsed structures.^{1,10,15,16}

Psychosocial impact. Qualitative studies have demonstrated that psychological consequences are almost universally experienced by flood survivors,¹⁷ relate to the degree of community vulnerability to flooding,¹⁸ and are closely associated with the personal perceptions of “place” and home that may be fundamentally altered in the aftermath of severe flooding.¹⁹

Posttraumatic stress disorder (PTSD) has been diagnosed in adult survivors of major floods,²⁰⁻²² child survivors,²³ disaster responders²⁴ and community leaders.²⁵ Additional psychological outcomes include emotional distress;²⁶ anxiety, disrupted sleep, flashbacks and lack of motivation;^{27,28} major depressive disorder

(MDD);^{20,29} and difficulties in intimate relationships.²² Survivors of the 1997 floods in North Dakota experienced shock and disbelief, uncertainty, grief and loss, and emotional exhaustion.³⁰

Among flood survivors, women are significantly more likely than men to experience PTSD, MDD, and anxiety symptoms.³¹ Diagnosis of flood-associated PTSD in female survivors was found to predict poor relationship adjustment and increased relationship aggression and violence.^{32,33} Flood-affected citizens may also experience impaired physical and social functioning and diminished health-related quality of life.³⁴ Youth who reported high levels of stress during the flooding associated with Hurricane Katrina also experienced long-term “serious emotional disorder: SED.”³⁵

An important mediator in assessing the psychological impact of flooding is the degree and severity of flood exposure. Norris³⁶⁻³⁸ differentiated disasters into low, moderate, and high impact events and showed convincingly that intensity of disaster exposure predicts the degree of psychological impairment and psychopathology. The Norris team reaffirmed this finding in a detailed analysis of flood disasters.²⁰ Moreover, floods occurring in highly-resourced, “developed” nations are less likely to produce widespread PTSD and other severe psychiatric sequelae compared with floods of comparable severity in developing nations.²⁰

Flood-associated PTSD can be predicted based on the type and severity of the flood event, survivors’ flood experience, and pre-flood mental status.³⁹ Verger and colleagues⁴⁰ devised quantitative “cumulative exposure indicators” (CEIs) for survivors of floods that included physical presence during flooding (with or without shelter), property damage, endangerment and displacement. CEIs were in close agreement with objective geographic measures of flooding severity and significantly predicted PTSD. Psychological consequences vary in accordance with indicators of flood severity including numbers of casualties and deaths, economic losses, presence of epidemic diseases and rises in chronic disease prevalence.⁴¹

The intensity of flood exposures such as water in the home, financial losses and disruption of essential services predicted a range of psychological outcomes: psychological distress, anxiety, and probable depression and PTSD.⁴² “Depth of flooding,” when used as a quantitative indicator of exposure, predicted both psychological distress and concomitant physical complaints.⁴³ Tracy, Norris and Galea⁴⁴ found that PTSD was directly related to hurricane/coastal flood exposure among Galveston survivors of Hurricane Ike in 2008, but that depression was associated with exposure to both acute hurricane impact and chronic post-impact life stressors.

Emphasizing the need for careful quantification of disaster-specific exposures, Xiong and colleagues⁴⁵ found that pregnant women with severe exposure to Hurricane Katrina flood waters were more likely to experience depression, PTSD, pre-term deliveries and low birthweight babies. These findings were echoed in a study of women who were pregnant during the catastrophic flooding of the Red River of the North in 1997; a longitudinal study found higher rates of medical complications, pre-term deliveries and low birth weight infants.⁴⁶

Table 1. Community characteristics of Fargo, ND and Minot, ND

Community characteristics		FARGO, ND	MINOT, ND
River community		The Red River of the North creates the eastern boundary of Fargo, ND	The Souris River runs directly through the center of Minot, ND
Population	Population (2010 est.)	105,549	40,888
	Population density (persons/sq. mile)	2,388	2,513
Demographics	Female (%)	50.0%	51.8%
	White (%)	94.2%	93.2%
	Foreign-born (%)	4.0%	2.1%
	Language other than English (%)	6.3%	4.6%
	Top 6 ancestry groups (%)	German (43%), Norwegian (36%), Irish (9%), Swedish (7%), English (5%), French (5%)	German (41%), Norwegian (32%), Irish (9%), English (5%), Swedish (4%), French (3%)
Educational Attainment	High school grad	91.0%	86.3%
	Bachelor's degree	34.4%	24.1%
Housing	Households	39,268	15,520
	Housing units	41,200	16,475
	Home ownership	47.1%	62.4%
Employment	Median household income: 2009 inflation-adjusted	\$39,921	\$43,853
	Top 5 employers	Sanford Healthcare North Dakota State University Blue Cross/Blue Shield Fargo Public Schools Essentia Healthcare	Minot Air Force Base Trinity Health Minot Public Schools ING Minot Service Center Minot State University

Psychosocial impact of the 2011 North Dakota floods. In response to the 2011 statewide flooding, the State of North Dakota activated Project Renew, a mental health outreach and emotional support program, funded by the Federal Emergency Management Agency (FEMA) Crisis Counseling Program. Project Renew's outreach workers, based in flood-affected counties, provided free, confidential psychosocial support and referrals as necessary to local resources and agencies. Project Renew staff conducted door-to-door outreach and participated in community events to help flood survivors improve their coping strategies and build resilience.

In 2011 Project Renew provided in-person brief educational or supportive contact, community networking, coalition building, and materials distribution for 60,030 North Dakotans (9% of the state population). An additional 2,561 North Dakota citizens received individual crisis counseling and 2,897 received group crisis counseling. Among recipients of Project Renew services, 24% had sustained flood damage to their homes, 17% had been displaced for at least one week and 15% had received direct rescue or recovery assistance.



Figure 2. Minot, ND, July 3, 2011. Flood damage in Minot, ND. FEMA is supporting the emergency management team in providing disaster assistance to those affected by the flooding. Photo by: David Valdez/FEMA.

Table 2. Hazard profile of 2011 flood events in Fargo, ND and Minot, ND

Hazard description and indicators		FARGO ND	MINOT ND
Disaster type		Natural disaster: Hydrological/River Flooding	Natural disaster: Hydrological/River Flooding
Geographic features		Red River Valley is the lakebed of prehistoric Glacial Lake Agassiz Flat terrain-flooding area is vast Floods: shallow and slow-moving	Souris River valley is deep and narrow, carved by catastrophic glacial meltwater drainage Waters are confined by the high valley walls Floods: deep and fast-moving
Contributory climatological events		Very wet Autumn 2010 Winter snowfall twice the climatological average Above normal snowpack Moderate to heavy rainfalls	Very wet Autumn 2010 Winter snowfall above climatological average Above normal snowpack upstream in Canada and North Dakota Above normal Spring 2011 rainfall in May/June
Upstream floodcontrol		Upstream drainage area of 5,400 km ² Upstream flood storage capacity of 206 billion m ³	Upstream drainage area of 8,370 km ² Upstream flood storage capacity of 860 billion m ³ Extensive upstream flood control (reservoirs/dams) in Canada and North Dakota Flood control directed by agencies from two nations Meltwater and precipitation overwhelmed storage capacity of upstream flood control structures. Flows overtopped flood protection structures in Minot
Scale/scope of flooding		Expansive overland flooding of rural farmlands around Fargo Minimal flooding in Fargo	Most destructive flooding on record 4,100 homes inundated
Magnitude of water flow	Peak flow rate	740 m ³ /s at crest on April 9, 2011 Average flow: 22 m ³ /s	730 m ³ /s at crest on June 26, 2011 Average flow: 4.3 m ³ /s
	River crest	April 9, 2011: 11.8 m (6.3 m above flood stage of 5.5 m)	June 25, 2011: 7.4 m (3.1 m above flood stage of 4.3 m)
	2011 Rank	4 th highest crest in recorded history (record crest: 2009)	Highest crest in recorded history (recording commenced in 1904)
Duration	Days at/above flood stage	144 d above 5.5 m during March 30-August 27, 2011 (except June 13–16, June 19–21) 26 d above 9.1 m (“major” flood stage) during April 6-May 1, 2011	113 d above 4.3 m during April 10-July 31, 2011
Frequency		Fargo is in a “wet cycle” Flood stage has been exceeded every year, 1993-2011 Flood stage exceeded 29 times between 1903 and 1992	Souris River floods periodically but not regularly The flood in 2011 was “historic” rather than usual and predicted
Predictability		Based on almost two decades of river rises exceeding flood stage, Fargo predicts and anticipates annual flood threats	Flooding is sporadic and much less predictable The very heavy snowfall and deep snowpack provided a warning of possible flooding.

Project Renew surveyed recipients of services regarding behavioral, emotional, physical, and cognitive stress symptoms. Regarding behavioral symptoms, hyper-vigilance was reported by 30% and “extreme change in activity level” was reported by 26%. In the realm of emotional stress signs, 25–28% reported each of the following: sadness, anxiety/fear symptoms and/or anger/irritability. Cognitive signs were prominent, with 43% experiencing impaired decision-making and 25% reporting distraction and lack of concentration. Finally, most (61%) described themselves as physically fatigued and exhausted. Ten percent experienced sleep problems and 9% reported deterioration of physical health.

The preceding review of the research literature on the psychosocial impacts of flood events appears to be corroborated by the survey data from Project Renew that is specific to the 2011 statewide flooding throughout North Dakota. Floods disasters disrupt the daily functioning of individuals, families, and communities regardless of whether flood survivors develop diagnosable psychological disorders. Data on disaster-related patterns of substance use and domestic violence were not readily available but may be incorporated in future flood events. North Dakota has low rates of illicit drug use and suicidal ideation (www.samhsa.gov/data/spotlight/Spotl098SuicideByState2012.pdf) but

Table 3A. Disaster stressors associated with the 2011 flood threats by disaster phase: Pre-impact phase

Pre-impact phase		
Forces of harm	Fargo, ND	Minot, ND
Hazard	<ul style="list-style-type: none"> High perceived threat of major flooding Heavy snowpack throughout watershed: Realistic expectation of flooding Rapidly rising river levels Overland flooding all around Fargo Media coverage of impending flood Official predictions a “major” flood stage (predicted: 12.3 m; flood stage: 5.5 m) Cumulative stress from annual threats every year since 1993 Stress from widespread inundation in 1997 Time-urgent sandbagging operations Time-urgent preparation/protection of personal property Winter storms during mitigation operations Potential for injury during mitigation activities 	<ul style="list-style-type: none"> High perceived risk of major flooding Heavy snowpack upstream in Canada and North Dakota: Realistic expectation of floods Rapidly rising river levels Overwhelm of upstream flood control structures Media coverage of impending flood Flooding predicted > 1 mo in advance Stress from impending unusual event—record flooding Predicted failure of floodgates and levees Compromise of upstream Lake Darling Dam and levees Emergency messages warning of flooding Evacuation orders Time-urgent preparation of dikes to maintain several major highways Reality that mitigation to protect homes in the steep valley along the river was not possible
Loss	<ul style="list-style-type: none"> Fears of city-wide losses if flood fight failed (breach of dikes, failure of levees) 	<ul style="list-style-type: none"> Expectation of major unpreventable losses Lack of flood insurance coverage
Change	<ul style="list-style-type: none"> Redirecting community focus and actions to engage in the annual “flood fight” Citizen involvement in sandbagging operations (filling sandbags at Sandbag Central, placement of sandbags, patrolling dikes and river banks) Stress inherent in community mobilization Disruption of usual routines Impact on school/work/productivity Area students deployed to assist “flood fight” Evacuation from high-threat homesites Pre-impact sheltering 	<ul style="list-style-type: none"> Protecting/evacuating valued possessions Activation of community shelters Evacuation to shelters Evacuation to homes of family/friends 48 h before high flows expected Sandbagging efforts Creation of earthen dikes Closing of schools, community centers and places of business Road closures Limited access to regional hospital

very high rates of binge drinking (www.samhsa.gov/data/2k12/NSDUH113/SR113StateSubUseDisorder2012.htm).

Methods

We conducted trauma signature analyses (TSIG)²⁻⁴ of the Fargo and Minot flood threats. Trauma signature (TSIG) analysis is an evidence-based method that examines the interrelationship between population exposure to a disaster, extreme event or complex emergency and the interrelated physical and psychological consequences for the purpose of providing timely, actionable guidance for effective mental health and psychosocial support (MHPSS)—or disaster behavioral health (DBH) support—that is organically tailored and targeted to the defining features of the event.²

For each TSIG analysis we perform, we classify the disaster and review the literature regarding the public health and psychosocial consequences specific to the type of event; in this case, flood disasters of mixed natural and human causality (presented



Figure 3. Fargo, ND, March 29, 2009. The Red River Valley Water Rescue team brings in a home owner who needed to be rescued from the rising waters of the Red River. Photo by Patsy Lynch/FEMA.

Table 3B. Disaster stressors associated with the 2011 flood threats by disaster phase: Impact phase

Impact phase		
Forces of harm	Fargo, ND	Minot, ND
Hazard	<ul style="list-style-type: none"> No major inundation in Fargo Rapid water rise to peak levels Constant threat from river at major flood stage for > 3 weeks Ongoing fears of dike or levee failure Stress for citizens with individually-sandbagged home sites, constant pumping/dike repair Physical fatigue Safety concerns Winter weather during impact phase 	<ul style="list-style-type: none"> Catastrophic, record flooding in Minot Rapid river rise during flood stage One-quarter of homes (4,100 housing units) submerged Reconstruction and re-stabilization of levees and flood gates during water rise City “cut in half” by the flood waters disrupting transportation and access to vital services
Loss	<ul style="list-style-type: none"> No loss of life or life-threatening injuries Flooding of some households Moderate basement flooding common with minimal property damage 	<ul style="list-style-type: none"> No loss of life or life-threatening injuries Loss of basic survival needs Loss or serious damage to 4,100 homes and many downtown businesses Loss of valued possessions Loss of access to neighborhoods Loss of essential services Major financial losses \$509 million estimated event cost Extensive damage to infrastructure
Change	<ul style="list-style-type: none"> No shelter residents Constant surveillance and repair of dikes, sandbag barriers Staffing pumps 24/7 to control water seepage School closures Worksite closures/decreased output Decreased commerce 	<ul style="list-style-type: none"> Federal disaster declaration 11,000 residents evacuated 4,100 homes uninhabitable Displacement to disaster shelters (shelter residents-less than 350) or alternative housing Flood waters bisected the city Extreme disruption of transportation Disruption of government, business, education, and medical services

in the Introduction). Beyond the review of the scientific literature, the TSIG analysis consisted of five steps. First, using census and civic data, we compared community characteristics for Fargo and Minot. Second, using government and local data sources and expert consultation, we created a detailed physical hazard profile of the flooding in the two communities. Third, relying on published reports and personal accounts (from co-authors A.M., G.Y., J.J.), we delineated the major disaster stressors by disaster phase experienced by residents of Fargo and Minot. Fourth, we enumerated the flood preparedness and response actions across “community sectors” based on the community resilience framework of Gurwitsch and colleagues.⁴⁷ Fifth, we summarized the “trauma signature,” contrasting the salient psychological risk factors for the flood events in Fargo and Minot.

Results

Community characteristics (Table 1). Fargo and Minot have relatively comparable, stable, and homogeneous populations. Fargo’s population is 2.5 times larger than the population of Minot but

with similar population densities. Both populations are about 50 percent female, predominantly composed of White, US-born, English-speaking citizens, with German, Scandinavian, and English/Irish ancestry. Families have resided in the area for multiple generations, own their homes, know their neighbors, have connections to the surrounding rural farming communities, and come together to help each other in times of need. The communities have similar income levels. Fargo has slightly higher high school and college graduation rates and Minot has a higher rate of home ownership. For both cities, primary employers are health-care, insurance, and schools/universities. Minot is also home to an Air Force base. No strangers to challenging climatic conditions, both communities experience exceptionally broad annual temperature extremes and endure very cold winters, frequently with heavy snowfalls and periodic blizzards.

Hazard profile (Table 2). Fargo and Minot are both situated along rivers that pose flood threats associated with upstream snowmelt and precipitation.

Red River of the North at Fargo. This north-flowing river originates in southern North Dakota, passing the cities of Fargo and

Table 3C. Disaster stressors associated with the 2011 flood threats by disaster phase: Post-impact phase

Post- impact phase		
Forces of harm	Fargo, ND	Minot, ND
Hazard	<ul style="list-style-type: none"> Major flood stage lasted until May 1 River over flood stage until late August Impassable roads - difficulty commuting Hazards hidden in standing water Driving hazards on flooded roads 	<ul style="list-style-type: none"> Protracted flooding Infectious disease risk from contamination Impassable roads Boil water orders issued Mold risks Risks for collapse in flood-damaged structures Driving hazards on flooded roads Damage to roadways Hidden hazards in standing water
Loss	Loss of limited number of residences and structures	<ul style="list-style-type: none"> Loss of worksites/employment Permanent loss of homes Long-term lack of access to damaged homes that can be repaired Unsustainable financial losses for families especially those without flood insurance Major financial losses for area businesses Loss of several schools
Change	<ul style="list-style-type: none"> Re-mapping of evacuation zones Fine tuning of flood preparation strategies Ongoing discussion of long-term solutions including proposed flood diversion project 	<ul style="list-style-type: none"> Relocation of students for Fall 2011 classes Temporary residence in community shelters Medium-term sheltering in FEMA trailers (need to retrofit trailers for harsh ND climate) Long-term displacement for thousands Living doubled up with friends/family Domestic instability and reports of domestic violence Reports of substance abuse problems

Grand Forks as it forms the boundary between North Dakota and Minnesota before entering southern Manitoba, Canada, skirting around Winnipeg (by means of the Red River Floodway diversion), emptying into Lake Winnipeg and eventually, Hudson Bay. The Red River of the North at Fargo has a drainage area of 5,400km², with upstream flood storage capacity of 206 billion cubic meters.⁴⁸ Average river flow rate during its 108 y period of record is 22 m³ per second (m³/s).⁴⁹

Souris (Mouse) River at Minot. The Souris (Mouse) River originates in Saskatchewan, Canada, dips south into North Dakota, passes through Minot, and swings back north into Manitoba, where it empties into the Assiniboine River, which flows into the Red River of the North. The Souris River at Minot has a drainage area of 8,370 km², with a flood stage storage capacity of 860 billion cubic meters.⁵⁰ Average river flow rate during its 106 y period of record is 4.3 m³/s.⁵¹

2011 Flooding. Winter 2010/2011 brought heavy snowfalls to the northern United States and neighboring provinces of Canada, setting the stage for river rises and record flooding as the snows melted. The Red River at Fargo rose above the 5.5 m flood stage in late March, with a peak stage of 11.8 m (6 m above flood stage) and peak flow of 740 m³/s at river crest on April 9. The 2011 crest was the fourth highest in the history of recording, just one-half meter lower than the record crest

in 2009. The Red River remained above flood stage through August 27.

The Souris River at Minot rose above its 4.3 m flood stage on April 10, with a peak stage of 7.4 m and peak flow of 730 m³/s on June 25. The river remained above flood stage through July 31. The 2011 crest was the highest in history, surpassing the previous record crest, set in 1881, by 1.3 m.

Disaster stressors (Table 3). Disaster stressors are different in type, intensity, and timing under situations of successful mitigation (Fargo) vs. unpreventable flooding (Minot). In Minot, the major stressors were associated with the widespread inundation, stressors not shared by citizens of Fargo where floodwaters were retained and the flood hazard was avoided. In Fargo, stressors were most prominent during the pre-impact “flood fight” and during peak flood stage while actively monitoring the flood fortifications. Stressors rapidly dissipated as the river subsided. In Minot, stress levels persisted throughout the pre-impact warning and evacuation phase, the impact phase flooding, and the prolonged post-impact phase (response, recovery and reconstruction).

Resilience indicators (Table 4). Based on the framework of Gurwitsch et al.,⁴⁷ Table 4 is organized according to the interconnecting “community sectors” that participate in disaster preparedness and response and collectively define resilient communities.

Table 4. Community resilience in the 2011 flood threats

Flood operations by community sector			
Community sectors	Disaster phase	Fargo, ND	Minot, ND
Overarching community identity		“Floodplain identity” Annual “flood fight” History of shared successes	Identity in process of change, as major oil boom takes place in region Last devastating flood was 1969.
Community leadership	Pre/Impact	Active, respected, flood-experienced leaders Dual theme: promote calm and urgent action Promote “hopeful realism” Daily televised “leadership table” Coordination with state and federal resources and leadership	Mayoral position only part-time Respected leadership Frequent leadership communication in traditional press-conference format Coordination with state and federal resources and leadership Including visit by Secretary of Homeland Security Frequent communication with Canadian officials
	Post-Impact	Increased community solidarity Coordination of resources	Continued advocacy for resources
Emergency management/first responders	Pre/Impact	EOC activation Active participation in flood fight High-level readiness to respond to levee breaches and other emergencies National Guard member days-12,429	EOC activation Active participation in flood fight High-level readiness to respond to levee breaches and other emergencies National Guard member days-28,158
	Post-Impact	Returned to normal operations	Disaster impact on first responders (one-third of staff personally impacted) Gradual reduction in EOC operations
Voluntary organizations	Pre/Impact	Promoting active citizen engagement Volunteer coordination hotline Preparations to open shelters with American Red Cross/VOAD participation Red River Resilience (RRR): education materials, expert research, promotion of citizen self-care	Promoting active citizen engagement Volunteer coordination hotline Sheltering operations activated American Red Cross/VOAD participation Limited volunteer housing available (due to lodging of Bakken Shield oil workers)
	Post-Impact	Monitoring needs of individuals and households Limited case management and limited volunteer activities in Fargo due to lack of need Volunteers undertook projects outside of the Fargo area	Ongoing volunteering Reliance on local volunteers due to limited housing 3,135 volunteers, 212,000 volunteer hours, 215,000 meals served, 16,000 shelter nights provided
Cultural/faith-based organizations	Pre/Impact	Active participation through VOAD, RRR, mental health providers	VOAD with assistance from RRR
	Post-Impact	Active monitoring of the recovery situation through participation with VOAD agencies Limited volunteer activities due to lack of need Undertook projects outside of the Fargo area	Active monitoring of the recovery situation Participation by VOAD agencies Faith-based assistance in recovery and clean-up

RRR, Red River Resilience; VOAD, voluntary organizations active in disasters.

In Fargo, based on two decades of mounting annual flood fights, the process of developing, augmenting and connecting these sectors has become increasingly refined and routinized. Comparative examples of actions performed in Fargo and Minot are presented for each community sector.

Trauma signature (Table 5). In relation to exposure to hazards, neither Fargo nor Minot experienced flood-related deaths or serious impact phase injuries. These river floods were predicted in

advance, providing a warning period that facilitated community activation and citizen protection. Regarding loss, very few homes were affected in Fargo, while in contrast, one-quarter of the homes in Minot were flooded. Few structures were swept away; most flooded homes remained in place but partially submerged for days and uninhabitable for months. Almost 20 percent of homes were damaged beyond repair. In terms of exposure to change, peak population displacement was estimated at 11,000

Table 4. Community resilience in the 2011 flood threats (continued)

Flood Operations by Community Sector			
Community Sectors	Disaster phase	Fargo, ND	Minot, ND
Media/communications	Pre/Impact	Leadership-guided communications Liberal use of Midwest humor Daily briefings, media interviews, simple messages 2-1-1 information hotline Internet resources and websites RRR and mental health communications Motivation to remain goal-oriented Support to remain confident and hopeful	Leadership-guided communications with use of sign-language Media interviews, including mental health experts 2-1-1 information hotline Internet resources and websites Continual stream of local media coverage
	Post-Impact	Media interest quickly dissipated	Concert/fund-raiser by renowned rock band Telethon fund-raiser Television series on flood impact
Health care	Pre/Impact	Evacuation as needed of vulnerable patients Readiness to respond to mass casualties	230 nursing home residents evacuated Readiness to respond to mass casualties Temporary closure of inpatient psychiatric and addiction facility
	Post-Impact	Monitoring of recovery situation through VOAD	Original behavioral health facility closed Temporary facilities utilized elsewhere
Public health	Pre/Impact	Active monitoring of health status Maintenance of community health programs	Active monitoring of health status Maintenance of community health programs Increase in vaccinations (Td/Tdap, etc.)
	Post-Impact	Monitoring of recovery situation through the VOAD and City/County government agency meetings on both sides of the river	Ongoing monitoring via local and state health departments Reports of slight increase in substance use, domestic violence and home accidents
Mental health	Pre/Impact	Coordination with RRR Provision of mental health messaging, videos Participation on flood hotline Neighbors helping neighbors	Public, private and VOAD messaging Mental health messaging via interviews, PSAs Neighbors helping neighbors
	Post-Impact	Monitoring of recovery situation through VOAD and City/County government agency meetings on both sides of the river	Project Renew-crisis counseling grant, assisting thousands Over 1/3 of providers personally impacted
Schools/universities	Pre/Impact	Involvement of youth in sandbagging and mitigation activities "Flood fight" as "civics lesson" Ongoing community resilience research Scientific publication with collaboration from local and national resilience experts	Minot State Auditorium used as shelter
	Post-Impact	Returned to normal operations	Multiple school buildings unable to be reopened in Fall 2011
Businesses	Pre/Impact	Business closures to decrease traffic Active engagement in flood fight	
	Post-Impact	Rapidly resumed normal operations	Major business impact from direct damage, lack of access, or loss of employees

RRR, Red River Resilience; VOAD, voluntary organizations active in disasters.

Table 5. Trauma signature summary for the 2011 flood threats

Forces of harm	Psychological risk factors	Fargo, ND	Minot, ND
Hazard	Threat of exposure to flood waters	Potential damaging flood threat to entire Fargo population of 105,000 Three weeks at high flood stage	Potential catastrophic flood threat for 10–15,000 of the 41,000 Minot citizens living directly in the Souris River Valley
	Direct exposure to flood waters	None	4,100 housing units submerged 11,000 citizens displaced Severe impact for entire city population
	Fear of life-threat	Life threat: Minimal	Life threat: Minimal
	Fear of property damage	Fear of threat to property: Moderate but widespread	Fear of threat to property: Extreme and widespread
	Physical injuries	No major injuries	No life-threatening injuries
Loss	Deaths due to flooding	No flood deaths	No flood deaths
	Loss of primary dwelling	No primary dwellings lost	4,100 homes damaged, Up to 20% beyond repair
	Loss of business	No businesses lost	Extensive loss/damage to downtown businesses
	Economic losses	\$ millions for “flood fight” Future flood protection in vulnerable areas: \$160 million Proposed river diversion cost: \$1.7 billion	Exceeding \$2 billion (taxpayer cost to Minot-\$500 million)
Change	Relocation/Displacement	No individuals or households relocated or displaced	11,000 evacuated
	Dependence on public shelter	No public shelters opened	16,000 shelter nights of stay provided (up to 350 sheltered citizens per night) Low percentage use of shelters
	Sheltering with family, friends	Two households	8,000–9,000 initially homeless Most stayed with other families
	Lack of access to basic needs	No lack of access to basic needs as a result of the flood event Some road and interstate detours	City was divided into north and south North end lacked grocery stores and health care until satellite clinics were opened Boil water order in effect for weeks
	Lack of power, essential services	No lack of power or essential services as a result of the flood event	Power outages widespread Loss of access to medical care, essential services due to city “cut in half” by flood waters

persons (about 4,000 families), representing more than one-quarter of the Minot city population.

Discussion

Disaster risk reduction. Fargo’s successful mitigation efforts reduced disaster risk, prevented disaster impact, and diminished the trauma signature. The degree of reduction in disaster risk achieved by Fargo, relative to Minot was largely determined by the plausibility of enacting structural mitigation. The Fargo experience is a testament to the effectiveness of disaster risk reduction involving concerted citizen action focused on reducing hazard exposure.

The comparison of the Fargo and Minot flood experiences illustrates that hazard avoidance is the most prudent, cost-effective, and humane approach to disaster risk—when it can be accomplished.¹ The ability to foresee, predict, mitigate and

successfully prevent a major disaster is an atypical event. Yet, in relation to river flooding, the city of Fargo has succeeded in accomplishing this feat for 14 consecutive years. This rare phenomenon has galvanized the attention of researchers specializing in disaster risk reduction and community resilience.

Synopsis of flood events. The hazard profiles for the Fargo and Minot flood events presented several important similarities. Both riverside communities experienced Spring 2011 river rises that exceeded the flood stage threshold. Both flood events were preceded by a similar sequence of contributory climatologic conditions: a multi-year “wet cycle” and three consecutive seasons of above-average precipitation, including markedly heavy snowfall during Winter 2011. Peak river flows were almost identical (730 to 740 m³/s) and flood stage persisted for months. Despite these documented similarities for two flood threats in two cities in the same state during the same season, the outcomes were starkly

different; Fargo successfully mitigated the flood threat and prevented major damage but Minot sustained severe inundation. These divergent outcomes relate to geography, flood control, and recent flooding history.

Geography. While the Red River of the North flows along the eastern border of Fargo in a broad, shallow river basin, the Souris River flows through a steeply-sloping river valley in the heart of Minot. Significant sandbagging mitigation is possible for the Red River at Fargo but not for the Souris River at Minot. Geologist Dr. Donald Schwert provides this comparison of the flood potentials:

“Geographically, the 2011 flooding at Minot presents strong contrasts to the flooding at Fargo. Fargo lies at the center of the Red River Valley, which is the lakebed of ancient Glacial Lake

Agassiz and one of the flattest land surfaces on Earth. When the Red River of the North floods, waters spill out of its shallow floodplain onto the old lake plain, creating areally vast floods that are slow-flowing and shallow. But spring flooding is predictable, based on the depth of the developing snowpack over the winter; hence, major flooding can be predicted weeks in advance of the actual event.

In contrast, much of Minot lies in a deep, narrow valley that had been carved by catastrophic glacial meltwater drainage. Waters are confined by the high valley walls, leading to deep, comparatively fast-moving floods.”

Flood control. Fargo is located a short distance from the origin of the Red River of the North. Upstream from Fargo (that is, south of Fargo, because this river flows north) there are several large reservoirs used for mitigation. The Souris River flows through Saskatchewan and into North Dakota. The buffering capacity for major flood events involves the human operation of a complex network of dams and reservoirs; upstream flood control decisions determine the timing and level of the flow reaching Minot.

Recent flooding history. Immediately preceding the 2011 flood threat, Fargo citizens experienced 18 consecutive annual river floods from 1993 through 2010, while flooding is a more sporadic occurrence in Minot.

Trauma signature analysis. Trauma signature (TSIG) analysis is under development by an international team of investigators with expertise in disaster behavioral health and public health.² We are in the process of calibrating and refining the six components that comprise the TSIG analysis process: 1) initial pre/post-impact trauma signature (TSIG) analysis, 2) TSIG-targeted deployment of disaster mental health assets, 3) evidence-based early intervention with evaluation, 4) on-scene validated mental health assessment, 5) identification and intervention for high-risk individuals and 6) monitoring and evaluation throughout recovery. This paper presents only the



Figure 4. Fargo, ND, March 29, 2009. Volunteers from the Red River Valley and beyond work to fill sandbags in the Fargodome in preparation of upcoming storm. Over 300,000 sandbags were stockpiled on this day. Andrea Booher/FEMA.

first component, the initial TSIG analysis, consisting of population description, hazard profile, stressor matrix, community resilience indicators and TSIG summary. This manuscript is one in a series of papers that apply the initial TSIG analysis to a range of natural and human-generated disasters and complex emergencies.³⁻⁸ A description of TSIG methodology has been published elsewhere with open access to the templates used in TSIG case studies.² We recently published the following brief description of TSIG:⁶

“TSIG provides a much-needed tool to expedite the provision of evidence-based, actionable guidance for a coordinated disaster health response. This process integrates disaster public health and disaster mental health. It is premised on the notion that each disaster leaves an imprint on the affected population. Understanding this distinctive “signature” can help prepare and protect responders and better serve survivors by tailoring response to the disaster’s defining features.

TSIG is epidemiological, examining the person, place, and time dimensions of exposure to natural and human-generated hazards during the impact phase of disaster, and to a variety of losses and changes in the aftermath.

The initial step of TSIG involves constructing a hazard profile of the disaster to delineate the types, magnitude, intensity, scope, and scale of exposures. This information can be rapidly gleaned from disaster situation reports released in real time as the event is unfolding, and from disaster monitoring and research centers.

The next step of TSIG involves assessing the potential psychological effects of the physical forces of harm characterized in the hazard profile. A stressor matrix is created, presenting the salient risk factors for psychological consequences within each of the disaster phases and this is cross-referenced with a review of the evidence-based literature. Finally, TSIG juxtaposes hazard, vulnerability, and resilience factors and provides a synopsis of findings in a TSIG summary.”



Figure 5. Fargo, ND, March 23, 2009. Thousands of student and community members work together with the National Guard at the Fargo Dome making sand bags on a 24 hour operation. Photo: Michael Reiger/FEMA.

Once the psychological risk factor database for a wide spectrum of disasters is completed and algorithms for translating the initial analysis into actionable guidance are refined, TSIG will be ready to fulfill its promise for informing disaster behavioral health response to disasters in a manner that is evidence-based and tailored to the event-specific exposures and experiences of citizens in disaster-threatened communities.³⁻⁸ TSIG intends to offer emergency managers and mental health providers a scientific framework for identifying and rapidly determining the psychosocial resources that are likely to be required in a disaster and its aftermath. The TSIG framework focuses attention on the extent to which survivors are exposed to a constellation of disaster threats and hazards that have been documented to trigger stress, harm, loss, and change. In the current study, we have illustrated the success of Fargo in reducing trauma signature by way of diminishing risk by reducing exposure (mitigation).

TSIG findings. The TSIG analysis presented in Tables 1–5, clearly displays the contrasts in the hazard profiles; the timing and types of stressors experienced; the sets of prominent psychological risk factors that were operating; and the specific exposures of residents to hazards, loss, and change. In the case of Fargo, for all components of the TSIG analysis, the major focus was directed toward the pre-impact and impact phases because flood mitigation was possible. In the case of Minot, the major focus was directed toward the impact and post-impact phases because the city sustained the full brunt of unstoppable flooding. Moreover, upstream flood control decisions affected the timing, volume, and velocity of water released to flow through Minot. This “human-generated” component became a magnet for anger and blame in the aftermath.

In Fargo, event-related stressors were most evident when the flood fight was in full force; stressors dissipated rapidly as water

levels receded. However, in Minot, the anticipatory stress of the approaching flood was supplanted by the distress of observing the unrelenting and unstoppable inundation of the city, followed by the post-impact stressors of flood-forced displacement and irreplaceable loss (it was estimated that only 5% of affected home owners had flood insurance).

While both cities faced a realistic flood threat associated with rapid river rises from the snowmelt of massive snowpack accumulations, only Minot experienced direct exposure to flooding, loss, and change.

Community resilience. The widespread but foreseeable impact of river floods, prompting the urgent activation of multiple community sectors to respond to the flood threat, creates a natural laboratory for examining individual and community resilience throughout the phases of the disaster cycle. Individual resilience describes a process in which individuals who are exposed to a trauma “bounce back” and adapt, returning to their prior levels of functioning, wellness, and quality of life.⁵²⁻⁵⁵ While it is typical for individuals to experience initial distress post-impact, only a minority of disaster-exposed individuals progress to psychiatric diagnosis.^{36,37,56} The extent to which social resources are available to provide support and a sense of connectedness is critical to influencing an individual’s resilience.⁵⁴

Community resilience is determined by the extent to which community-level disaster resources are available to provide community members the ability to adapt positively to risk.^{54,58-60} TSIG incorporates the definition of resilience crafted by Norris and colleagues: “A process linking a set of networked adaptive capacities to a positive trajectory of functioning and adaptation in constituent populations after a disturbance.”⁵⁴

Pfefferbaum and colleagues^{54,61-63} indicated that community resilience following disaster is characterized by connectedness and commitment; engaged participation; defined roles and responsibilities; resources; support and nurturance; skill building; communication; and disaster prevention, mitigation, preparedness and response capabilities. Resilience resources must be robust, redundant and rapidly delivered to meet time-urgent demands.⁵⁴

Particularly relevant to the Fargo and Minot flood studies, community resilience is now conceptualized by some researchers as both a pre-impact strategy, acting to prevent or mitigate negative consequences, as well as a post-impact approach.^{57,64} Resilient communities not only are able to collectively and effectively manage their disaster experience, they also act to replenish resources and prepare for future risks.⁵⁸ Recall that Fargo sustained severe flooding in 1997, a still-vivid memory that drives the annual citizen actions to mitigate and prevent recurrence of such a devastating event.

Application of resilience concepts, including elements of social capital, social support, and Midwest culture have been applied to studies of flood events.⁶⁵⁻⁷⁰

Fargo. Since The Great Flood of 1997, when the entire Red River Valley sustained record inundation, Fargo has successfully activated its citizens every March/April to engage in sandbagging and construction of dikes and levees to prevent flooding of

the city. Fargo faced its greatest challenge in 2009 when the Red River of the North reached its highest flood stage on record. Flood mitigation required the energized and coordinated efforts of 85,000 individuals who collectively filled 8.5 million sandbags in The Fargo Dome (dubbed “Sandbag Central”) and placed the sandbags along riverbanks and around individual structures, braving blizzard conditions, as the river rose precipitously (see Figs. 3–6).⁷¹⁻⁷³

Fargo’s demonstratively resilient behavior predated the popularity of the concept of community resilience. Recent research initiatives are seeking to create disaster resilient communities. Although appealing, this is not an easy feat. Major disasters are uncommon events in most localities, so prioritizing and maintaining momentum for community resilience is challenging. Fargo represents the exception; this community has an annual “date-certain” encounter with a major flood threat.

As best exemplified by the annual “flood fight,” pragmatic Fargo citizens and enlightened community leaders have been operating in disaster risk reduction mode for decades—but without putting “voice” to what they do as a matter of routine. Given the option each March and April to sandbag rather than experience inundation of homes in frigid Red River waters, the choice seems clear. “It’s just what we do,” intoned one perennial “flood fighter.” Now Fargo professionals and resilience researchers have come together and Fargo is likely to become a model for exploring community resilience.

Minot. Minot last experienced devastating flooding 43 y ago, in 1969. In 2011, the community responded heroically and effectively to evacuate citizens in a timely and life-saving manner, provide shelters, and maintain community security. No lives were lost and no major injuries were sustained. Particularly remarkable was the willingness of non-flooded citizens to welcome displaced neighbors into their homes; some households provided shelter for two or more families for weeks to months. First responders and health care professionals maintained their vital services despite estimates that 25–40 percent of these professionals were personally flood-affected. An August 2011 benefit concert, performed by an internationally-renowned band (with a personal connection to Minot) raised \$1 million dollars for the Minot Area Flood Recovery Fund and a telethon generated an additional \$2 million for the Fund. The Department of Human Services partnered with Lutheran Disaster Response to provide crisis counseling services as part of “Project Renew,” funded jointly by SAMHSA and FEMA. Minot benefitted from the robust and effective coordination of volunteer and agency actions through VOAD (Voluntary Organizations Active in Disasters).

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Figure 6. Fargo, ND, March 26, 2009. Volunteers help with sand bagging in Oak Grove neighborhood. Photo: Michael Rieger/FEMA.

Conclusions

TSIG analysis was performed for two comparable communities facing major flood threats in 2011. One community was able to mitigate and prevent the threat while the other community experienced its worst inundation in history. TSIG demonstrates that effective prevention and successful mitigation dramatically alters citizen exposure to the physical and psychological consequences of natural disaster. These findings suggest a desirable enhancement for disaster research: expanding the focus on risk reduction measures (prevention/mitigation/preparedness) in addition to the traditional emphasis on crisis-management measures (response and recovery).¹

Disclosure of Potential Conflicts of Interest

Please note that Barbara Lopez-Cardozo served as Monitoring Editor of this manuscript, and the authors have no potential conflicts of interest to disclose.

Acknowledgments

The authors wish to acknowledge the expert contributions from Dr. Donald Schwert, Professor of Geology, North Dakota State University, Fargo, ND; and Dr. Steven M. Robinson, Chief, Hydrologic Records and Information Section, North Dakota Water Science Center, US. Geological Survey, Bismarck, ND; regarding the nature and technical details of the 2011 flood events in Fargo and Minot, ND.

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