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Increasing Flooding Impact in Manitoba: Is the Environment is Changing?

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***Abstract*— Historically, flooding is a recurring phenomenon in the province of Manitoba, Canada. Homeowners and communities across Manitoba increasingly feel the financial impacts of these flooding events. This scenario pushes researchers around the province to develop a more comprehensive flood management approach, and for this, essential understanding is needed about the causes behind these changing flooding scenarios. Secondary sources of flooding history and their causes have been explored as part of this research work. The research found that both biophysical and human causes are responsible for increasing flooding scenarios in Manitoba. Although, the scientific explanations for bio-physical causes have been explored in several research as synthesized here and found that physiographical, geological and meteorological conditions are highly responsible for extreme flooding events. However, the research also explores that a remarkable decline of wetland (about 98% in the last 200 years), rapid urban growth, and deforestation of the coniferous forest create an environment where additional water intake of the province fails to cope.**

Keywords*— *Flood; Flood Management; Flooding Impact; Environmental Change; Manitoba.

I. INTRODUCTION

Flooding is one of the major natural hazards around the world. Although the flood loss and damage scenarios from few underdeveloped countries are well publicized in the existing hazard literature, developed countries like Canada also face worsened flooding scenarios since the beginning of population settlement in this part of the world. Manitoba, being one of the world's greatest prairie lands, faces tremendous flood scenarios over the years. Residents of Manitoba have been coping with the floods since the province was settled (Welsted et al., 1996). However, physiographically south-central Manitoba is highly vulnerable to Red River flooding (Renni, 1998). Originating at the confluence of the Bois de Sioux and Otter Tail rivers between the USA states of Minnesota and North Dakota, The Red River flows toward the North through the center of Manitoba. The river primarily empties into Lake Winnipeg, whose waters join the Nelson River and ultimately flows into the Hudson Bay (Klassen, 1975). The meandering Red River produces a vast flood plain with lots of opportunity and misery in the form of the most significant floods in the history of Manitoba (Halsey et al., 1997; Haque, 2000). Figure-1 represents the rivers and lakes in Manitoba province.

II. MATERIALS AND METHODS

The major source of information used in this research work has been collected from different secondary data sources. The floods data has been compiled from various historical records of different organizations like Royal Commission Report, Manitoba Water Stewardship, Government of Manitoba, Manitoba Infrastructure and Transportation, and published papers. For a geographical illustration of the study area to conceptualize the fundamental understanding of the flooding scenario of Manitoba, the physical setting of the province of Manitoba has been presented here. The lakes, rivers, and administrative boundaries were collected from the Esri source database. ArcMap software has been used for mapping the spatial organization and distribution of lakes and rivers in Manitoba provinces. These distributional patterns of lakes and rivers play a vital role in the flooding of Manitoba.

III. RESULT AND DISCUSSION

A. Flood vulnerability in Manitoba

The hazard of flooding is a severe threat to south-middle Manitoba. Major floods with substantial damages occurred along the Red and Assiniboine Rivers during the past couple of centuries. Devastating floods of 1826, 1852, 1861, 1950, 1979, 1997, 2009, and 2011 have reaffirmed this fact. Each year, flooding threatens the loss of life, property, communications, transportation, and public utilities of south-central Manitoba. Although regular inundation and normal floods are helpful for the floodplain ecology of Manitoba to support its wetland ecology and diverse biodiversity (Haque, 2000), the high flooding events cause a substantial adverse impact on life and livelihood system of the province (Rannie, 1998). The agro-based economy of the province is suffered much from this flooding. Because of the snow-covered Winter for about six months, the farmer has only one growing season in summer. Flooding in spring demolishes all the fortunes of the local farmers. Farmers in southern Manitoba cannot seed millions of acres of land because of the spring floods (Rashid et al., 2000). Figure 1 below represents a general structure of the physical setting of the province of Manitoba, which influences hazardous flooding scenarios in the study area. The presence of enormous water bodies in the form of great lakes like Lake Manitoba, Lake Winnipeg plays a vital role here. The Table-1 briefly describes the devastating flooding scenario in the recorded history of Manitoba.

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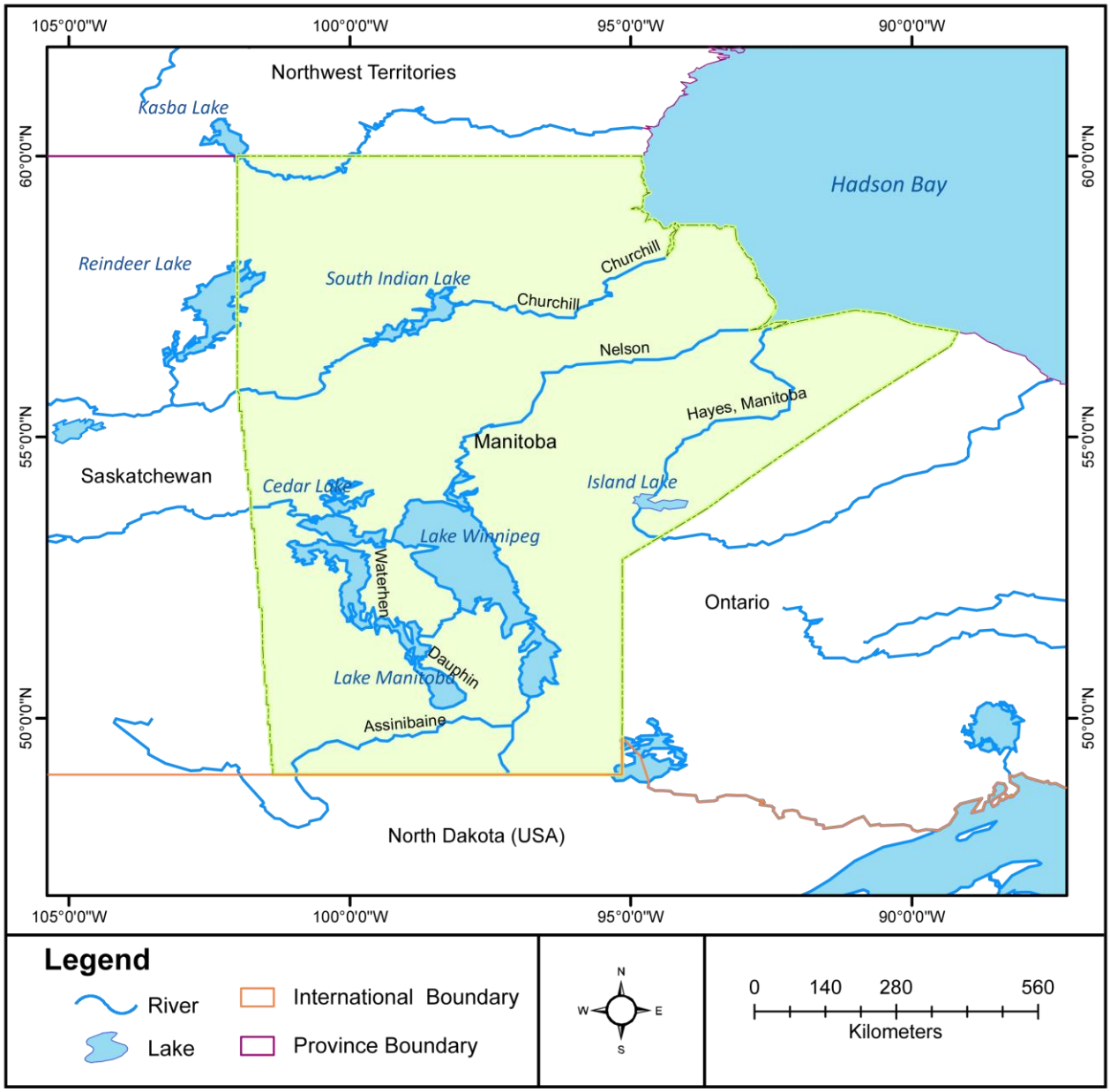

Figure 1: Rivers and Lakes in Manitoba. Compiled by Authors, 2021. Compiled by Authors, 2021.

Table-1: Statistics of top 8 floods in Manitoba (benchmark of 3000 m3/s peak flow rate)

Floods	Peak Flow Rate (m^3/s)	Area Inundated ($mile^2$)	Household Damaged	People Evacuated	Flood Cost (Estimated at 2014)	Return Period
1826	6400	900	-	3,500	5 billion	667
1852	4700	380	-	2,500	30 million	150
1861	3540	310	-	2,200	35 million	45
1950	3060	640	10,000	100,000	1.2 billion (125 million)	28
1979	3030	390	1,100	7,000	200 million (60 million)	27
1997	4615	710	1,000	28,000	750 million (500 million)	110
2009	3625	386	250	2,800	1.1 billion (1 billion)	33
2011	3300	140	3,500	7,100	1.3 billion (1.25 billion)	30

Source: Data compiled from Royal Commission Report, 1958; Welsted, 1996; Renni, 1998; 2002; Bumsted, 2000; Manitoba Water Stewardship, 2006; Government of Manitoba, 2004; Manitoba Infrastructure and Transportation, 2013 and Environment Canada 2013 in Mahmud, 2015.

B. Why these flooding in Manitoba?

From the above discussion, it is clear that flood is a severe concern in Manitoba regarding loss, damages, and human suffering. In response to the flooding, the Government of Manitoba implemented several large scales (such as Red River Floodway), medium-scale (such as Winnipeg's Dike System), and small scale (such as Ring Dikes) flood control interventions but yet to control the flood impacts at a large scale. A good number of research indicates the biophysical characteristics as the controlling factors for the devastating

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floods in Manitoba. The changing hydro-meteorological factors induced by climate change make the scenario much worse. However, significant numbers of research show that human development activities could essentially worsen the flooding scenario. The goal of this position paper is to investigate both of these ideas and conclude on the findings.

C. Biophysical dimensions of flooding in Manitoba

Manitoba is highly vulnerable to flooding due to its vulnerable geotectonic and geological settings (Bluemla, 1977). Along with the geologic setting, the meteorological factors play the most significant role in the flooding of Manitoba. The changing climatic scenario creates much more uncertainties and complexity to flooding.

C.1. Physiographic/Geologic conditions for flooding in Manitoba

The physiographic/geologic conditions that responsible for high flooding in Manitoba are:

- **Glacial Lake Plain:** Manitoba is one of the world's greatest sinuous and incised shallow valleys – the floor of Glacial Lake Agassiz (Kalssen, 1975; Bluemla, 1977). One of the significant factors contributing to the flooding of the Red River basin is this low-lying topography (Figure-2). The flatness of the region brings on prolonged drainage of the waters and limits the formation of sizeable natural water reservoirs. In this way, even if it is possible to build small dams, no large reservoirs can be constructed to retain the floodwaters. Moreover, nothing can hold back the Red River when the water level rises. The whole valley is a flood plain. The waters can stay there for days and even weeks before receding (Brooks, 2003; Brooks et al., 2005).

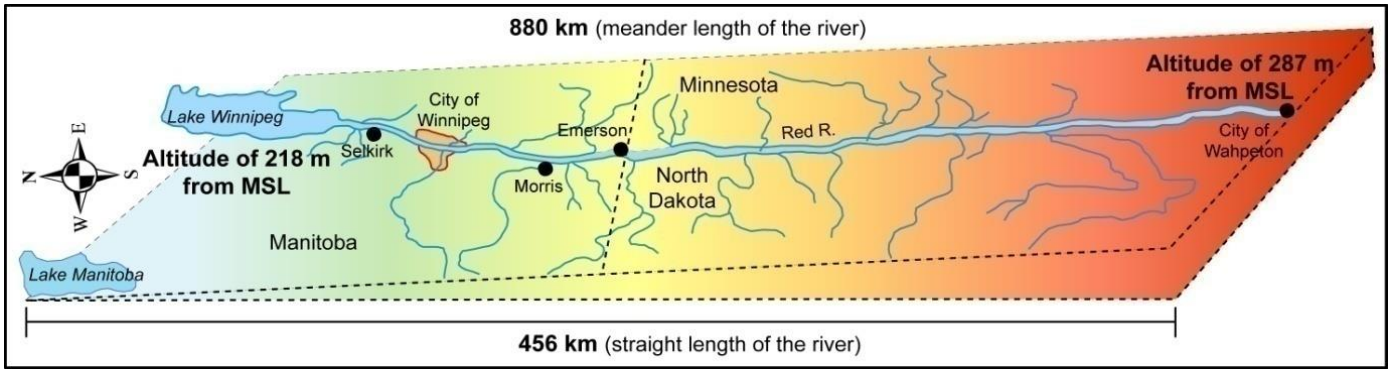

Figure 1.2: South-North unusual orientation of Red River with a glacial lake plain topography. Source: Compiled after Musée du Fjord, 2002.

- **Gradual gradients decrease towards downstream:** The unusual physiographic orientation of the Red River's flow from the South to the North with gradual gradient decline in the topography (Figure 1.2) contributes to the flooding in Manitoba at a large scale (Kalssen, 1975; Bluemla, 1977; Buckland and Rahman, 1999; Rannie, 2003). In effect, the upstream water is situated to the South thaws out before the downstream part of the river, located in Manitoba, thus creating ice jams, blocking the passage of the water, and increasing local flooding. When the slow rate of snow melting in Manitoba's part coincides with heavy spring rainfall and heavy snow thawing from North Dakota, the flooding scenario becomes further worsens (Brooks, 2003; Brooks, Thorleifsonl and Lewis, 2005).
- **Isostatic rebound:** The isostatic rebound process is responsible for rising landmasses to the North of Manitoba and tilting towards the South. This happens due to the depression of the massive weight of ice sheets during the last glacial period. The glacial Tyrell Sea has already been raised at a notable height to form the present-day Hudson Bay, and the process is continuing. The geologist has confirmed the increasing size at North along the Tyrell Sea, remarkable shoreline change, and lake Winnipeg and lake Manitoba (Matile et al., 1996; McNeely et al., 2000; Manitoba Hydro, 2000). The increasing height at the North of Manitoba, especially at Lake Winnipeg insecure Manitoba's flooding scenario, is much more in the long term. Suppose Lake Winnipeg gets enough elevation to flow its water towards the South. In that case, the unusual south-north orientation of the Red River flow will create a devastating flooding scenario for Manitoba in the future.

C.2. Meteorological conditions for flooding in Manitoba:

Periodically weather conditions exist, which promote widespread flooding through the Red River valley. The most troublesome ones (especially when most or all happen in the same year) are presented in Table 1.2, showing that the 1826, 1950, and 1997 flood has all favorable meteorological conditions for flooding. However, with a changing climatic scenario, it is hard to forecast, and the meteorological conditions of flooding are much more complex to understand these days (Francis and Hengeveld, 1998; White and Etkin, 1998; Simonovic and Li, 2004).

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Table-2: Meteorological conditions for the significant historical floods in Manitoba.

Meteorological conditions	Flooding Year							
	1826	*1852*	*1861*	*1950*	*1979*	*1997*	*2009*	*2011*
Heavy precipitation in the previous year	√	√	x	√	√	√	√	√
Very cold and long Winter	√	x	x	√	x	√	x	√
Substantial snowfall in Winter	√	√	√	√	√	√	x	x
Snowfall/blizzard in late Winter	√	√	√	√		√	x	x
Quick melting of ice upstream	√	x	√	√	x	√	x	x
Heavy early spring precipitation	√	√	x	√	√	√	√	√
Late and sudden thawing	√	x	x	√	√	√	√	√
Ice jam condition	√	x	√	√		√	√	√

Source: Data compiled from Royal Commission Report, 1958; Welsted, 1996; Renni, 1998; 2002; Bumsted, 2000; Manitoba Water Stewardship, 2006; Government of Manitoba, 2004; Manitoba Infrastructure and Transportation, 2013 and Environment Canada 2013 in Mahmud, 2015.

D. Human dimensions of flooding in Manitoba

On the other hand, many scholars believe that flooding is not solely responsible for physical landscape and hydro-meteorological parameters. Flooding is also impacted by the scale and magnitude of human development. In Canada's prairie provinces, huge wetland areas were converted to farmland, and by 1970 a total of 1.2 million hectares of wetland had been converted to cropland (Adams, 1988). The Red River basin itself loses 98% of the total wetlands since establishing the agricultural community in Manitoba (Sierra Club, 1998). Southern Manitoba loses about 100,000 hectares of wetland since 1950 (Ducks Unlimited Canada, 2011). Wetland loss increases flood damage in two ways (Ducks Unlimited Canada, 2008; 2011):

- First, with wetland loss, the surrounding watershed's ability to store water is also reduced. This is because wetlands hold and slowly release water, reducing and delaying peak water movement, which helps lessen the impacts of flooding. The water holding capacity of the wetland that southern Manitoba loses since 1950 is more than double the capacity of the man-made Shellmouth Reservoir on the Assiniboine River.
- Secondly, the ditches that are built to drain wetlands are responsible for draining surrounding wetlands. On average, for every acre of wetland drained, four additional acres of surrounding lands are also drained. As a result, water holding capacity is reducing significantly, and all impacted through overland flow, making flood damages much worse than expected.

The establishment and flourish of the Red River colony in the early 18th century were also responsible for the extensive removal of forest cover along with the Red and Assiniboine River and the area of present-day Birds Hill Provincial Park. Some of these forests cover converted to farmland, while the majority have been cut down for building materials and firewood. Another essential fact about tree cutting in Manitoba is that aspen has replaced white spruce because of aspen's fast growth rate and ability to regenerate from sprouts, making reforestation after harvesting much cheaper, since no planting or sowing is required (Manitoba Forestry Association Incorporated, 2011). White spruce is a coniferous tree with a much larger canopy, while aspen is a deciduous tree with a light canopy. This, as a result, reduces the interception capability of forest resources in Manitoba, which in turn added more water through surface flow during precipitation, thereby increasing flooding magnitude.

The population of Manitoba increased from 25,228 in 1871 to 1,208,268 in 2011 (StatCan, 2011), allowing a massive amount of construction work and conversion of open space to paved areas. In urban areas, the soil is replaced by impervious surfaces such as roads, roofs, parking lots, and sidewalks that store little water, reduce water infiltration into the ground, and accelerate runoff to ditches and streams. With less storage capacity for water in a built environment and more rapid runoff, urban streams may rise more quickly during flooding and could have higher peak discharge rates. Development activities along the river and floodplains can alter the capacity of the river to convey water and increase the height of the water surface corresponding to a given discharge (Konard, 2014).

IV. CONCLUSION

From the above discussion, it is clear that the leading cause of Red River flooding is excessive runoff following heavy rains. But it is hard to say what are the driving factors behind this high magnitude of runoff. The low-lying topography of the province largely affects the overall flooding scenario. There is no doubt that the favorable meteorological conditions also largely impact the province's flooding scenario. But it is also possible that the rate of runoff could be significantly increased by human development activities and urbanization (i.e., the conversion of open land to water-resistant surfaces such as roads and buildings) and by removal or change of vegetative cover (water runs off cropland faster than forested land).

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