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Risk and Vulnerability Assessment: A Case Study of Pakistan

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ABSTRACT

Climate change has put the planet earth on high risk due to flash, riverine flooding and droughts. Unprecedented frequent flooding, hurricanes, droughts and heavy snowfalls can be witnessed in the past few decades. Now no country can declare itself safe from the negative impacts of changing climate. To reduce the risk of potential damages, vulnerability and risk assessment can give a clear picture of a particular region regarding a specific hazard. It will help the administration to address those areas which are highly at risk due to a certain hazard so as to minimize collateral damages in future.

In Khyber Pukhtoonkhwa, Nowshera was one of the most affected districts. It has destroyed building stock, livestock and crops in most parts of the district. To minimize these losses in future, this research has been carried out to assess the current condition of building stock in Nowshera Cantt and Nowshera City area. This research explores in detail the building stock vulnerability and associated risk. This research has found that the flood reoccurrence time period is 7 years for zone 1and 7. While other zones 2, 3,4,5,6,8 and 9 have 81 years of reoccurrence time period. Based on the physical vulnerability, this research found that there are five types of buildings in the study area. Vulnerability of Type 1 to 5 are varying from strong to weak according to its structures having RCC roof, strong walls, plain concrete / tiles floor. Flood risk map has been produced on the basis of flood frequency and typology of high frequency structures in that particular area. The research explicitly shows different areas in risk map according to the level of risk i.e. from low to high risk zones. This research has found that binding material is the major factor in structural damages in the study area.

Keywords: Vulnerability, risk, building stock, concrete, cement, mud

Introduction

Riverine as well as flash flooding is a major problem for the whole world. From literature it is evident that the frequency of metrological disasters is increasing (Ramos et al 2002; Krausmann and Mushtaq 2008). A number of countries suffered from severe floods (2001-10) e.g Yangtze in China, Elbe in Germany, Brahmaputra in Bangladesh, Indus in Pakistan and Oder and the Vistula in Poland (Chowdhery, 2003; Gupta and Shah 2008; Khan et al, 2009). Like other South Asian countries, Pakistan is no exception to recurrent floods. There is a long history of disastrous floods in Pakistan. Nevertheless, the devastating 2010-flood is registered as the century's worst flood. During the past couple of years, the human encroachments onto the rivers and climate change have been considered as the major factors in increasing the flood risk (Gaurav et al, 2011; Shifeng et al, 2011). As a result of climate change, the magnitude and frequency of floods occurrence have been increased in the past 30 years (Shifeng et al. 2011). Due to climate change, high discharge will occur in future, which can lead to frequent river floods, unless adequate measures are taken to mitigate.

Floods are frequently devastating most parts of Pakistan. The share of each hazard in Pakistan 30 years history is shown in figure 3.

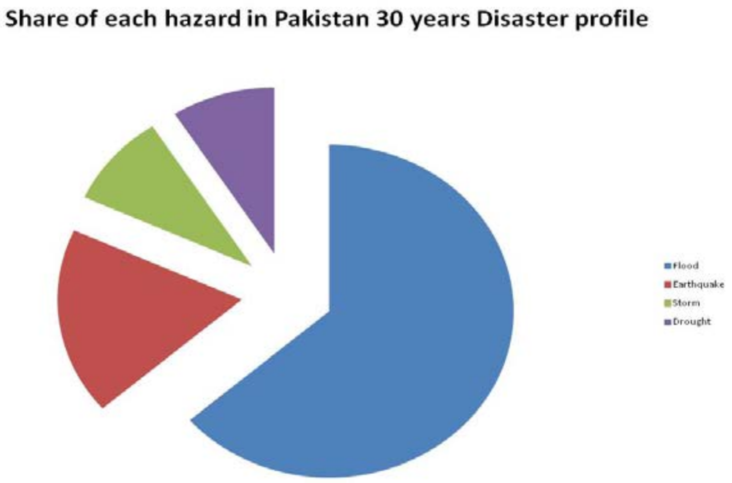

Figure 1. Pakistan 30 years disaster profile

In 2010 floods, most parts of Pakistan had effected severely. One of the most effected regions in Pakistan was the Province of Khyber Pakhtunkhwa. Out of 24 districts of KPK ten districts are more severely. The most affected districts were Peshawar, Nowshera, Charsada, Kohistan Dera Ismail Khan, Tank, Swat, Shangla, Upper Dir, and Lower Dir. The population affected by the floods including casualties and destruction during the 2010 floods are as follows:

Table 1. Destruction during 2010 floods (PDMA)

Affected Persons	3.8 million
Number of Deaths	1,070
Total Injured	1,056
Damaged Houses	295,684
Destroyed houses	119,000

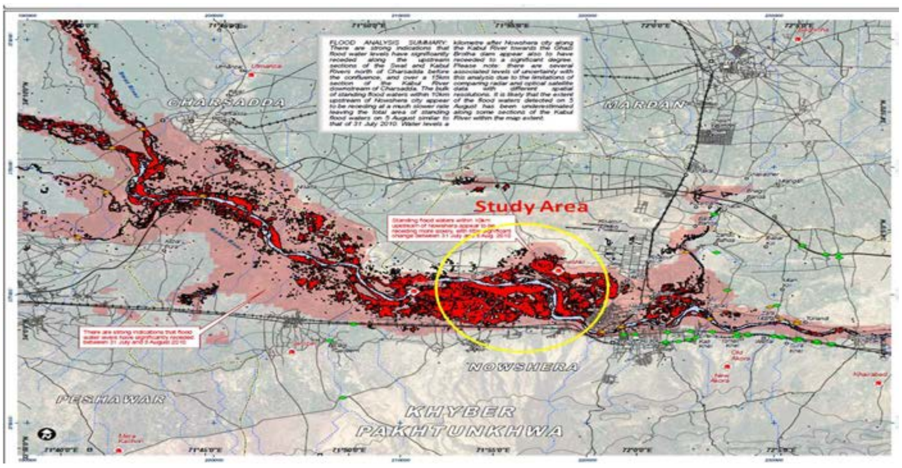

Figure 2. Flood extent in study area during 2010 floods

Flood extent in the districts of Charsadda and Nowshera (Study Area) has been shown in Figure-1.

District Nowshera in Khyber Pukhtunkhwa, is one of the most effected districts in Pakistan 2010 floods. River Kabul is the main source of riverine flooding in Nowshera as it passes through it. The aim of this research is to find the physical vulnerability of existing building stock and find the risk associated with any flood in future.

Methodology

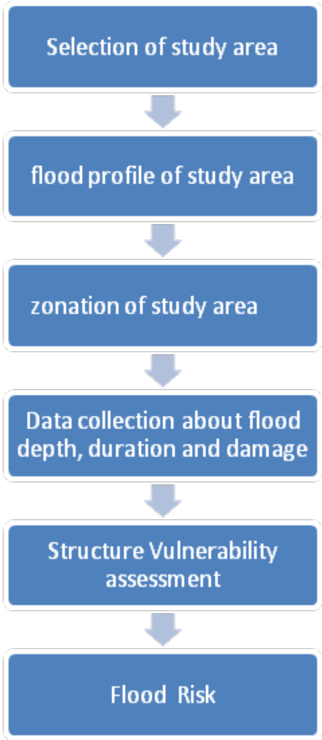

Chart 1. Methodology of this research is visualized in the following flowchart

Nowshera (34.0153° N, 71.9747° E) is one of the most strategically located districts of Khyber Pukhtunkhwa. Nowshera is surrounded to the west by Peshawar, to the northwest by Mardan and Charsadda, to the southeast by Attock and to the east by Swabi districts.

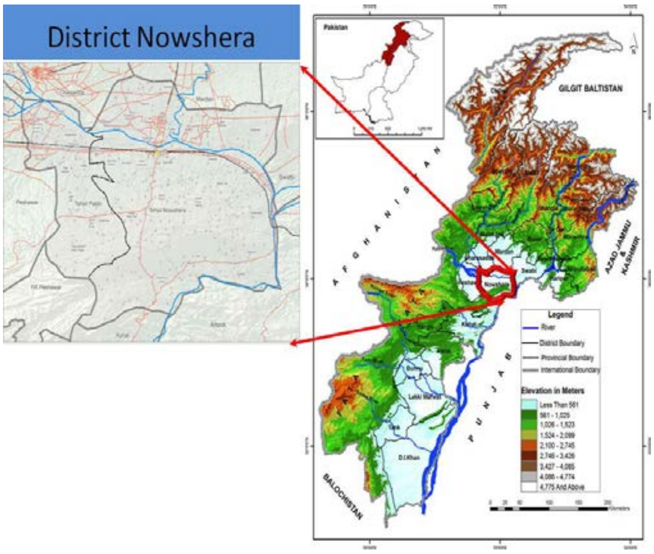

Figure 3: Map of District Nowshera

Two major rivers of KPK, Swat and Kabul are divided in Peshawar basin into tributaries, they are Khiali and Jindai , Naguman, Shah Alam and Sardaryab . All of these tributaries converge into main Kabul River within an area of 5 km^2 upstream. Therefore within a stretch of about 15 km between M1 Kabul River Bridge and Nowshera, Kabul River is mainly a confluence area for 7 river courses, which not only makes this region highly vulnerable to flood hazard but the main source of flooding in District Nowshera.

Zonation of the study area: - The whole area is divided into 9 zones according to frequency of floods and elevation from Mean Sea Level (MSL) as shown in the

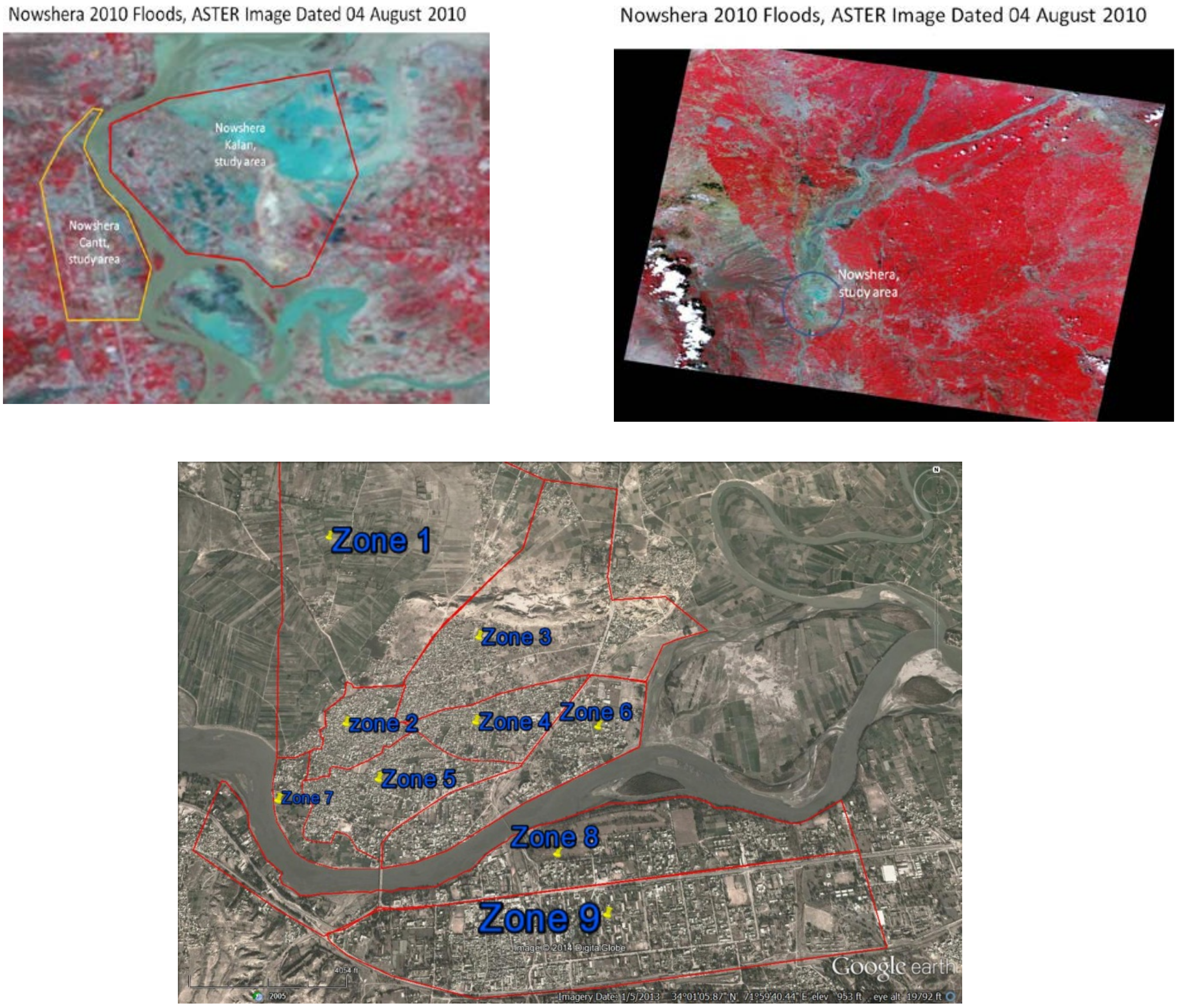

Figure 4. Zoning of the study area.

ASTER false colour image dated 04 August 2010 and LandSat, Aster image (04-08-2010) has been geo referenced on LandSat, NOAA image dated 1.5.2013 in same Projection Type (UTM, zone 45, spheroid and datum WGS 84) for demarcation of zones according to the severity of flood. It is clear from these images that that flood water has been receded after 4th August onwards but some areas were found where flood water was still stagnant that means flood water could not be receded those places from 27 July 2010 till 4th August. Therefore, those common areas are long duration inundated areas.

Study Area inundation profile

The study area elevation for MSL, depth and duration of flood water in 2010 is portrayed in the following figure;

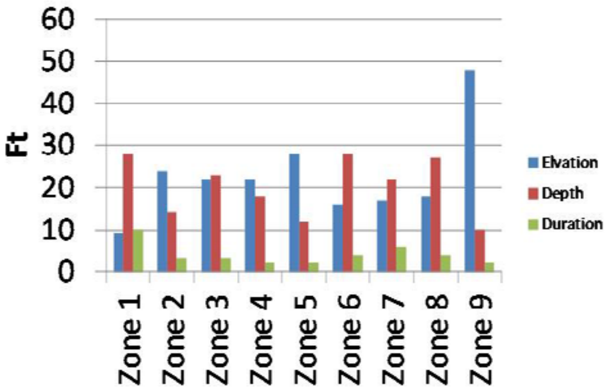

Figure 5. Elevation, Flood depth and duration of the study area

Sampling

The whole study area has been divided into 9 zones according to the flood frequency. Different samples have been taken from different zones. The sampling method which is used in this research is called non-proportional stratified random sampling. The number of samples from each zone has been shown in the following table:-

Table 2. Sampling proportion in the study area

Zone ID	Probable number of buildings	No. of samples
1	3000	60
2	7000	80
3	7000	80
4	6000	80
5	7000	80
6	2000	30
7	3200	40
8	3000	40
9	5000	60

Flood Frequency and Return Period

Method of Plotting Position has been used in this research to calculate flood frequency. The annual peak discharge data (Table 3) of the River Kabul (2001- 2013) (N=13 years) for zone 1 and 7 while N=80 years for zone 2,3,4,5,6,8,9 (Figure 4) after respondents response about the flood occurrence in their respective zones

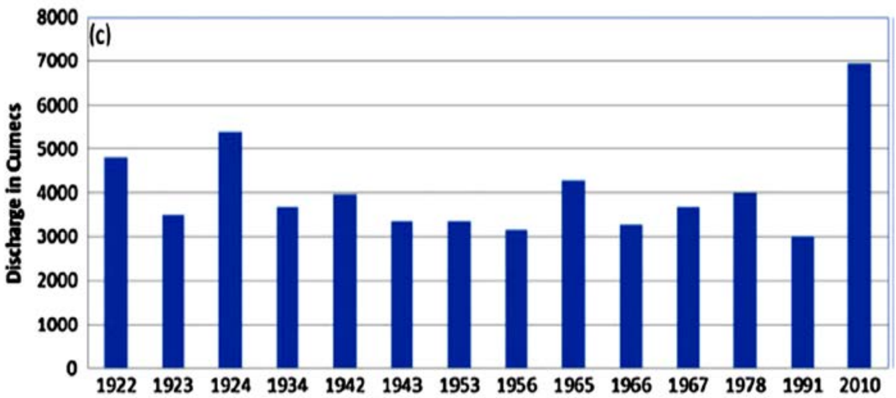

Figure 6: 80 years, annual discharge data of river Kabul at Nowshera.

Source: (Atta, Khan:2013)

Table 3: Annual discharge of river Kabul at Nowshera

S.No	year	Average annual discharge (m^3/s)	Sorting (high to how)	Rank "m"	Probability, "P"	Return Period "T"
1	2001	2628.25	10743.08	1	0.01	81.0
2	2002	2267.61	5752.48	2	0.14	7.0
3	2003	2468.65	4934.48	3	0.21	4.7
4	2004	3425.94	3815.06	4	0.29	3.5
5	2005	2193.17	3673.23	5	0.36	2.8
6	2006	5752.48	3565.24	6	0.29	3.5
7	2007	3565.24	3425.94	7	0.50	2.0
8	2008	3673.23	3383.65	8	0.57	1.8
9	2009	4934.48	2628.25	9	0.64	1.6
10	2010	10743.08	2468.65	10	0.71	1.4
11	2011	1438.05	2267.61	11	0.79	1.3
12	2012	3383.65	2193.17	12	0.86	1.2
13	2013	3815.06	1443.97	13	0.93	1.1

Flood frequency analysis was carried out. Return period as well as probability of occurrence for flood of River Kabul has been calculated using above formula. Return period for zone 1 and zone 7 is 7 years (probability of occurrence = 0.14) . At zone 2,3,4,5,6,8 and 9 the return period is 81 years. (probability of occurrence = 0.01) (Table 4). The following table shows zone wise probability and return period for every zone in Table 4:-

Table 4. Zones along with probability and return period

Zone	Probability	Return Period
Zone-1	0.14	7.0
Zone-2	0.01	81.0
Zone-3	0.01	81.0
Zone-4	0.01	81.0
Zone-5	0.01	81.0
Zone-6	0.01	81.0
Zone-7	0.14	7.0
Zone-8	0.01	81.0
Zone-9	0.01	81.0

Types of structures:

In the study area, this research has found five most frequent buildings structures on the basis of cross tabulation. Table 5 gives the details:-

Table 5. Types of buildings/structures in the study area.

Type 1	PCC-Bricks-RCC- Cement
Type 2	PCC-Bricks-RCC- Clay
Type 3	PCC-Bricks-Wood-Cement
Type 4	PCC-Bricks-Wood-Clay
Type 5	Soil-Stone-Wood- other

Vulnerability of structures
Structure Type 1 (PCC-Bricks-RCC-Cement)

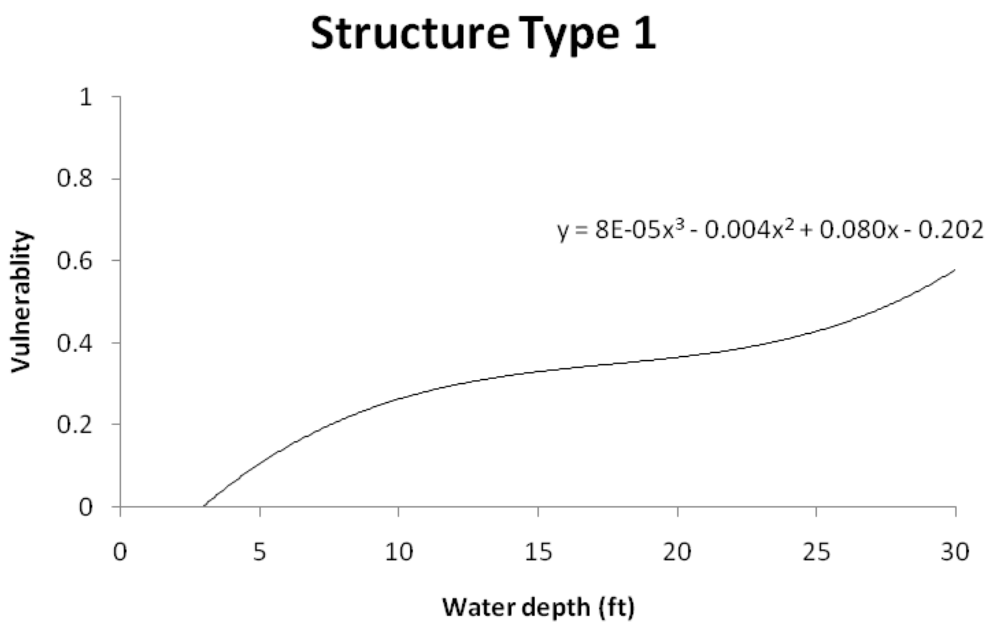

Figure 12. Vulnerability Function of Structure Type 1 with depth.

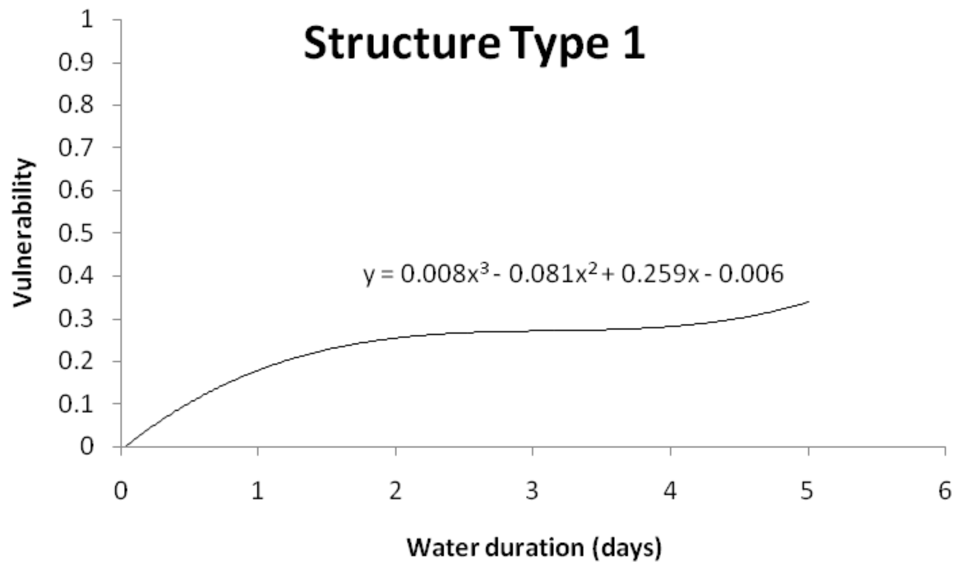

Figure 13. Vulnerability Function of Structure Type 1 with duration.

Structure Type 2 (PCC-Bricks-RCC-Clay)

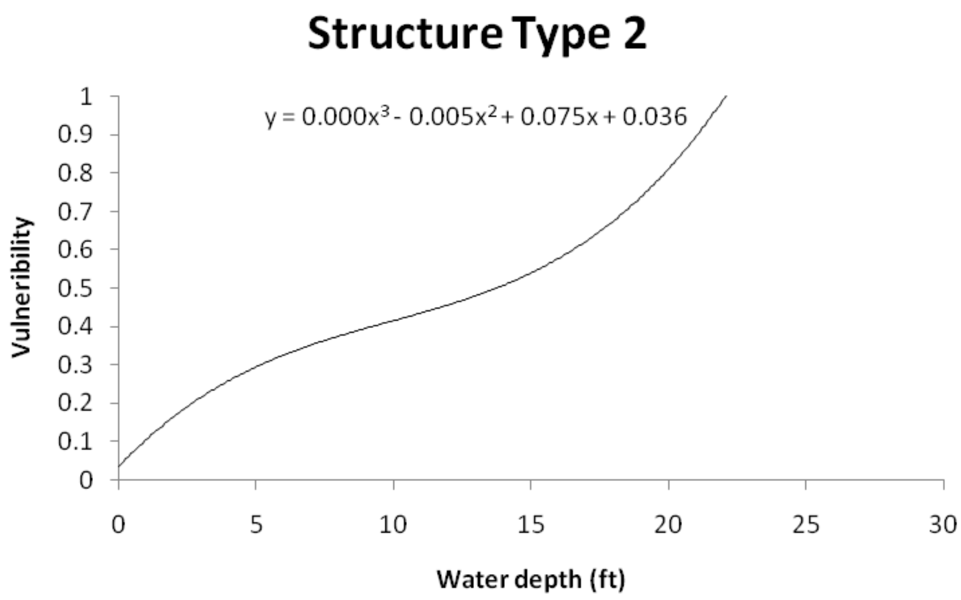

Figure 14. Vulnerability Function of Structure Type 2 with depth.

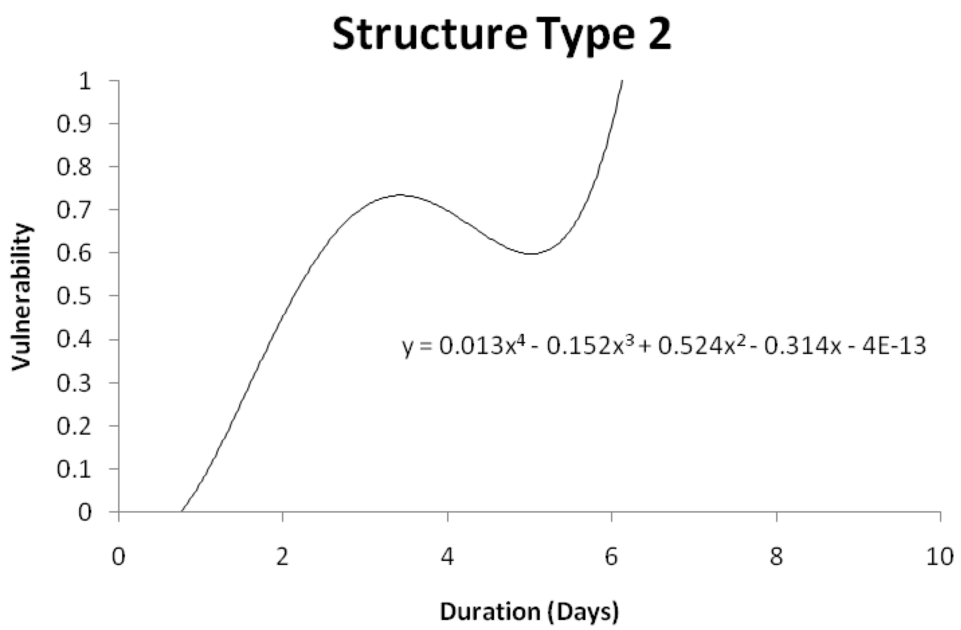

Figure 15. Vulnerability Function of Structure Type 2 with duration

Structure Type 3 (PCC-Bricks-Wood-Cement)

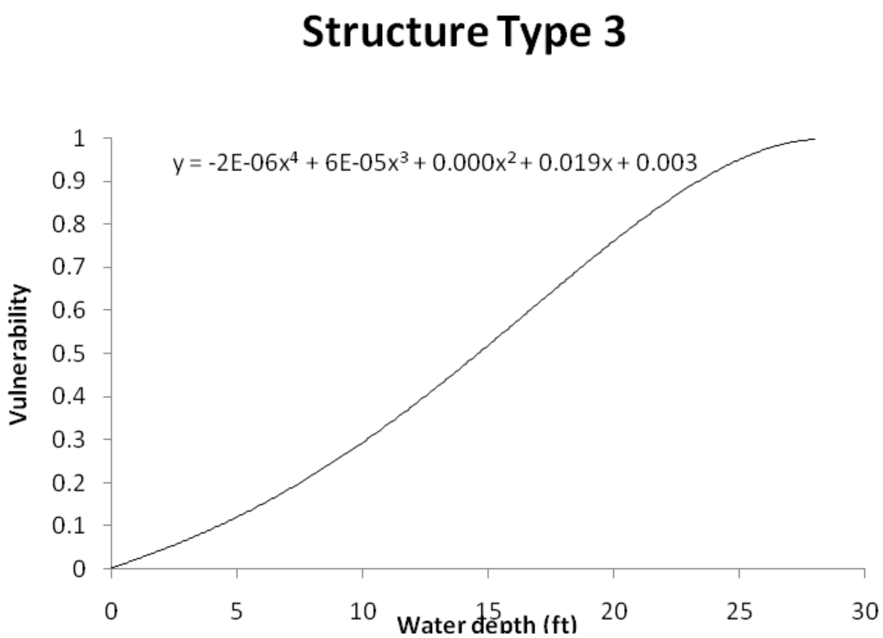

Figure 16. Vulnerability Function of Structure Type 3 with depth.

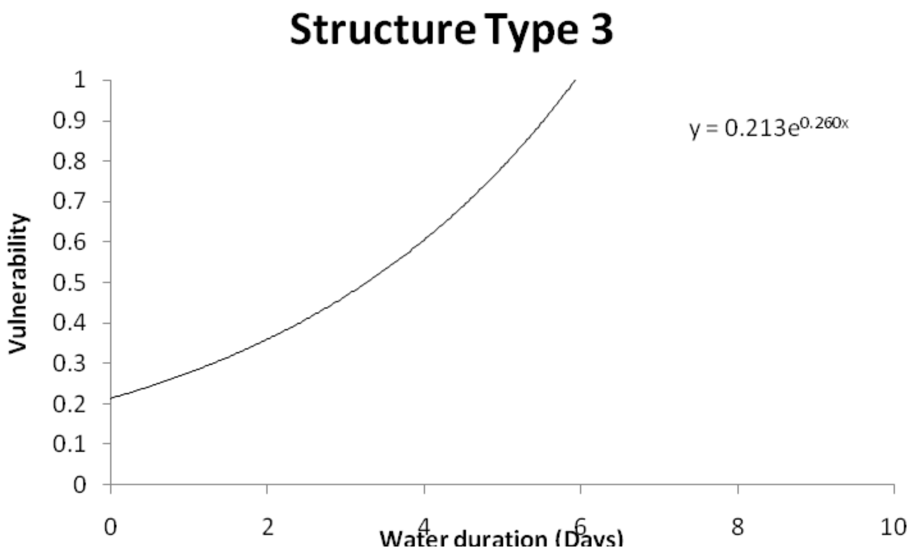

Figure 17. Vulnerability Function of Structure Type 3 with duration

Structure Type 4 (PCC-Bricks-Wood-Clay)

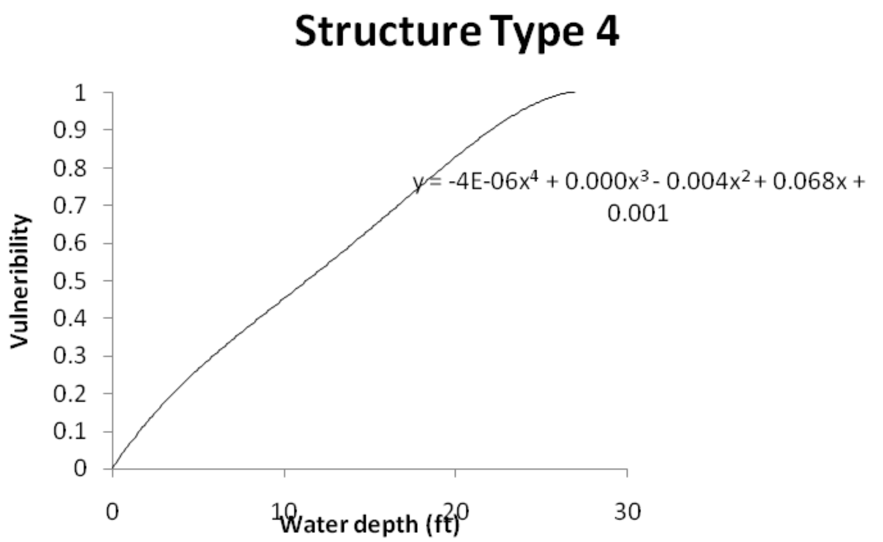

Figure 18. Vulnerability Function of Structure Type 4 with depth.

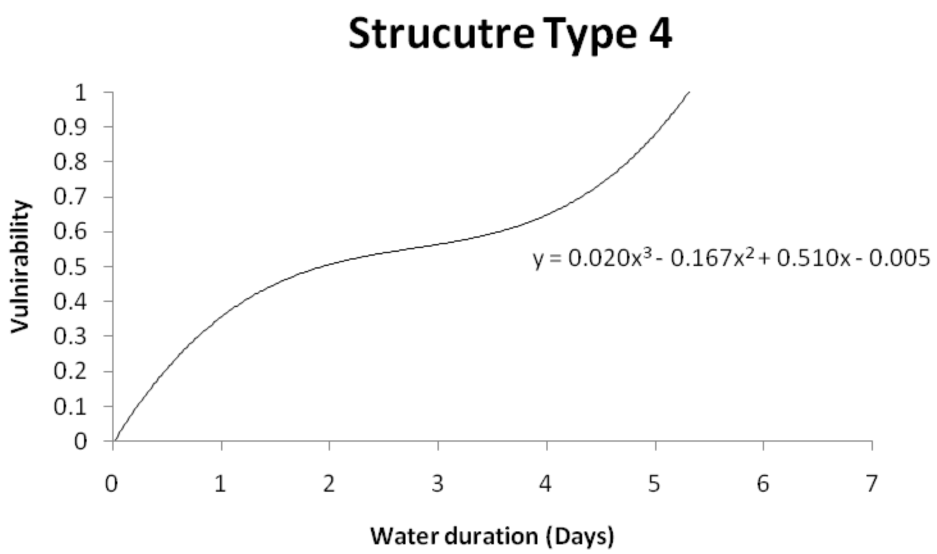

Figure 19. Vulnerability Function of Structure Type 4 with duration.

Risk Calculation

It was found that, if flood would occur once in 81 years as in zone 2,3,4,5,6,8,9 as the same magnitude of 2010 then risk would be varied between 3600 to 7200 Rupees for structural Type 1. If it happens in 7 years as in case of zone 1 and 7, it will be between 3600 to 85200 for structure Type 1.

In case of structure Type 2, risk varies between 113600 to 22730 Rupees if it occurs in 81 years. If it happens in 7 years as in case of zone 1 and 7, it will be between 1920 to 9600 for structure Type 2.

For structure Type 3, risk varies from 34080 to 45440 for 7 years return period. For 81 years return period, risk lies between 960 to 4800.

In case of structure Type 4, risk varies between 11360 to 56800 Rupees if it occurs in 81 years. If it happens in 7 years as in case of zone 1 and 7, it will be between 1920 to 9600 Rupees for structure Type 4.

If it happens in 81 years, risk varies from 10650 to 540 for Type 5 structures. The highest risk values (with respect to highest vulnerability for each element) were categorized into four classes such as:

>50000	High
20001-50000	Medium
1000 – 20000	Low
0	No Risk

Conclusion

In the study area, most of the structures which are constructed with clay mortar have been damaged the most. Whenever, the risk and vulnerability assessment is carried in a particular area, particular attention should be given to it.

Plinth material is another factor for the vulnerability of structures in flood risk areas. In most of the cases, in which Type 1 buildings were collapsed due to the use of rock stone in foundation to the plinth level of the structure. In a total of 4 feet depth, Type 1 buildings collapsed in zone 5 due to the swelling of soil and ultimate shattering of foundation.

Zone 1 & 7 are the high risk areas due to a short return period and high probability of floods. Zones 1, 7 has 7 years return period and zones 2, 3, 4,5,8 and 9 have 81 years return period.

Percentage of structures in Type 1, 2,3,4,5 are 36.84, 18.05, 19.55 13.53 and 3.01 respectively in the study area.

Vulnerability index has been defined as low, medium and high having percentages between 0-30, 31-60, 60- 100 respectively for all zones.

Vulnerability index of zone 1,2,3,4,5,6,7,8,9 are 0- 0.5, 02-0.8, 0-1,0-1,0-1 respectively.

Typology of structures in the Study Area

According to the interview with community's people and observation in the study area, it came up that after getting total damage of their houses people have constructed their new house at the same place by rising its plinth height and with almost new material e.g. by replacing stone wall and mud wall with bricks and concrete blocks along with cement mortar.

The reason is that people recognized that by rising plinth to certain level and changing wall material can save them from flood water damages in future. When flood occurred in 2010, the authority provided relief in terms of money, food, cloths etc, but the authority did not adopt any codes for each building.

The vulnerability functions of structural types of building clearly indicate that, the structure Type1 having a strong concrete wall, floor and roof material, this structural type is not so vulnerable to flood water. The structural Type 2 is prone to flood water and it gets half damage (0.5) in range 12 -15 ft water depth. The wall, floor and roof materials for this structural house entirely collapsed (1) when flood water reached 25 ft height or higher than that (Figure 4.6). As with the depth, structure Type 3 collapses when water depth reaches in the range of 20 -25 ft. Structure Type 4 is more vulnerable due to its binding material and as the depth increase, its vulnerability proportionally increase until its collapse. Structure Type 5 is vulnerable due to its wall material and weak binding material. It also collapses as the water depth increases.

Structure Type 1

Structure Type 1 is made from the combination of Brick wall, PCC floor and RCC roof along with cement mortar. Having a wall, floor and roof material, this structural type is not so vulnerable to flood water. Although this structural type is strong against floodwater, some people also spent some money to repair the minor damage. For instance, they repaired the cracks, some broken portion of house after floods by painting the wall or re-enforcing some holes that took place because of flood water remaining inside the house.

Structure Type 2

Buildings with structural Type 2 are made from the combination of Brick wall- PCC floor and RCC roof along with clay mortar. Having a strong wall, floor and roof material but weak binding material, this structural type is highly vulnerable to flood water. Due to its weak binding material, which liquidates with water, make this type of structure more vulnerable to floodwater.

Structure Type 3

Houses with structural Type 3 are made from the combination of Brick wall- PCC floor and wood roof along with cement mortar. Having a strong wall, floor material but weak roof material, this structural type is highly vulnerable to flood water. Although this structural type is strong against floodwater due to its binding material but it weak and light roof material make it vulnerable to the flood water.

Structure Type 4

Houses with structural Type 4 are made from the combination of Brick wall- PCC floor and wood roof along with clay mortar. Having a strong wall, floor material but weak roof material and binding material, this structural type is very highly vulnerable to flood water. This structural type is very weak against floodwater due to its binding material and weak roof make it vulnerable to the flood water.

Houses with structural Type 5 are made from the combination of Stone wall- Mud floor and wood roof along with brick powder plus lime mortar. Having a weak wall, floor material, roof material and relatively good binding material, this structural type is vulnerable to flood water due to non bonding of wall material because of stones. This structural type is weak against floodwater due to its wall material and weak roof make it vulnerable to the flood water.

Comparison of Structures

It is clear from the comparison of vulnerability curves that the most convenient structures in the study are Type 1 and the least suitable structures are Type 2, 4 and 5 as they are the most damaged structures in the area. So the local government should take care that in the study area, no resident should use clay as binding material so as to reduce the flood risk in future.

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