AN INTEGRATED WEB BASED RIVER OBSERVATION GIS PLATFORM FOR FLOOD MANAGEMENT IN PAKISTAN

By

Anum Naqvi

(2010-NUST-SCEE-BE-GI-01)

Faisal Ismail

(2010-NUST-SCEE-BE-GI-19)

Hasan Javed

(2010-NUST-SCEE-BE-GI-20)

Muhammad Mateen Mahmood

(2010-NUST-SCEE-BE-GI-27)

Sana Zahid Shah

(2010-NUST-SCEE-BE-GI-08)

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Institute of Geographical Information Systems

School of Civil and Environmental Engineering

National University of Sciences & Technology

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CERTIFICATE

Certified that the contents and form of thesis entitled **"An Integrated Web Based River Observation GIS Platform for Flood Management in Pakistan"** submitted by Ms. Anum Naqvi, Mr. Faisal Ismail, Mr. Hasan Javed, Mr. Muhammad Mateen Mahmood and Ms. Sana Zahid Shah have been found satisfactory for the requirement of the degree.

Supervisor: ______________________

Assistant Professor (Dr. Salman Atif, IGIS)

Member: _______________________

Associate Dean (Engr. Dr. Ejaz Hussain, IGIS)

Member: _______________________

Assistant Professor (Dr. Ali Tahir, IGIS)

Member: _______________________

Lecturer (Mr. Ahsan Mahboob, IGIS)

External Examiner: Signature _________

Name______________________________

Designation_________________________

DEDICATION

Dedicated to All the Flood Victims of Pakistan.

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(By: Anum Naqvi, Faisal Ismail, Hasan Javed, Muhammad Mateen Mahmood, Sana Zahid Shah)

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
AJAX	**Asynchronous Java Script and KML**
AMP	**Annual Maximum Peak**
AMSR-E	**Advance Microwave Scanning Radiometer – Earth Observing System Sensor**
ANDES	**Asia Pacific Network for Disaster Mitigation using Earth Observation Satellite**
API	**Application Programming Interface**
CBDM	**Community Based Disaster Management**
CSV	**Comma Separated Value**
DEM	**Digital Elevation Model**
DFO	**Dartmouth Flood Observatory**
DMSP	**Defense Meteorological Satellite Program**
DRM	**Disaster Risk Management**
DRR	**Disaster Risk Reduction**
ENSO	**El Nino Southern Oscillations**
ENVI	**Environment for Visualizing Images**
EOS	**Earth Observation System**
EPSG	**European Petroleum Survey Group**
ERP	**Emergency Response Paradigm**
ESRI	**Environmental Systems Research Institute**
EURNASIA	**Europe and North Asia**
FAO UN	**Food and Agricultural Organization of the United Nations**
FATA	**Federally Administered Tribal Areas**
FEWS	**Flood Early Warning System**
FFC	**Federal Flood Commission**
FOSS	**Free and Open Source Development**

FTP	**File Transfer Protocol**
GIS	**Geographical Information Systems**
GML	**Geography Mark Up Language**
GPL	**General Public License**
GPS	**Global Positioning System**
GRASS	**Geographic Resources Analysis Support System**
GSM	**Global System for Mobile Communication**
GUI	**Graphical User Interface**
HDF	**Hierarchical Data Format**
HTML	**Hyper Text Mark Up Language**
HTTP	**Hyper Text Transfer Protocol**
ICT	**Information and Communication Technology**
ILWIS	**Integrated Land Water Information System**
IPCC	**Inter-Governmental Panel on Climate Change**
IT	**Information Technology**
KML	**Keyhole Markup Language**
KPK	**Khyber Pakhtunkhuwa**
LED	**Light Emitting Diode**
LP DAAC	**Land Processes Distributed Active Archive Center**
LSWI	**Land Surface Water Index**
MODIS	**Moderate Resolution Imaging Spectro-Radiometer**
MRT Web	**MODIS Reprojection Tool**
MST	**Mountain Standard Time**
NASA	**National Aeronautics and Space Administration**
NCMEC	**National Center for Missing and Exploited Children**
NDMA	**National Disaster Management Authorities**

NDSI	**Normalized Difference Snow Index**
NDVI	**Normalized Difference Vegetation Index**
NDWI	**Normalized Difference Water Index**
NGO	**Non-Government Organization**
NIR	**Near-Infrared**
NOAA	**National Oceanic and Atmospheric Administration**
NOAMER	**North America**
OGC	**Open Geospatial Consortium**
OGP	**Office of Global Programs**
OLS	**Operational Line Scan System**
ORNL	**Oak Ridge National Laboratory**
OSI	**Open Source Initiative**
PKR	**Pakistani Rupees**
PL	**Procedural Language**
QGIS	**Quantum GIS**
RS	**Remote Sensing**
SAGA	**System for Automated Geo-Scientific Analysis**
SDBMS	**Spatial Database Management System**
SLD	**Styled Layer Description**
SMS	**Short Messaging Service**
SOA	**Service Oriented Architecture**
SOAMAFR	**South America Africa and Antarctica**
SQL	**Structured Query Language**
SWIR	**Short Wave Infrared**
TCL	**Tool Command Language**
uDig	**User Friendly Desktop Internet GIS**
UNDP	**United Nations Development Program**
URL	**Universal Resource Locator**

VIR	**Visual Infrared**
VMAP	**Vector Smart Map**
VPF	**Vector Product Format**
WAPDA	**Water and Power Development Authority**
WCS	**Web Coverage Service**
WFS	**Web Feature Service**
WGS	**World Geodetic System**
WMS	**Web Mapping Service**

ABSTRACT

Study of natural hazards like floods, and their mitigation emanates from physical and human geography, and its management is efficient and proper with significant use of one of the outcomes of neo-geography i.e. Geographic Information Systems. Survey of literature on floods and natural hazards suggests the use of *WebGIS* and *Spatial Mash-Ups* as the most effective solution. This project aims at protyping the idea of a Web based Spatial Mash-Up for flood disaster mitigation integrating information from various sources and of different types that be Spatial as well as Non Spatial. The different components comprise of a Data Center to visualize Base Data information regarding floods, Real Time Ground Observations about flood related attribute for preparation as well as SMS based Distress Calls from victims to facilitate rescue and relief service providers, Near Real Time Web Based data, e.g. News and Discharge information from other web sources. Mashing Up all the information from various sources as a useful product for the analyst and the decision makers to help disaster management for better mitigation and policy making.

Chapter 1

INTRODUCTION

In the last decade alone Pakistan has come to face with a series of devastating natural hazards. These mainly were climate related such as floods, heat-waves and cyclones. Of these, floods being the more pertinent and damaging in all their respective aspects. The floods of 2003, 2005, 2010 and 2011 are few of the prominent examples, incurring massive damages to property and human lives. However, a comprehensive spatial representation of disaster risk and a decision support mechanism priority evacuation strategy is missing. This research aims to provide for that. A system that databases past floods and at the same time acts as a positive decision support system for disaster rescue and management.

History reveals that civilizations develop near river courses; reasons being availability of fertile land for agriculture, medium of transportation and continuous water supply. The river flows through the landscapes but when changes its nature, turns bitter in form of floods. Similar to this manner of civilization development, The Indus Civilization developed (2500 – 1900 B.C.) along Indus River whose foundations are deep in time, going back to consider transition from hunting and gathering to agriculture and pastoralism early in the Holocene. This food production and its high productivity played an important role in the growth of people of Indus Civilization which include mainly regions, now-a-days known as India and Pakistan.

A large concentration of Pakistan's population lives in the river Indus basin. The Indus basin is popularly known as cradle of civilization since prehistoric times, however modern irrigation was introduced by British in around 1850's by upgrading and extending the networks of canals and drains (Hasan, 2010). Since then there have been continuous changes in land use of Indus valley and adjacent areas along with recurrent floods.

The floods of 2010 are the most devastating disaster in the history of Pakistan. They were riverine in nature, originating from northern parts of the country due to collision of western and eastern weather systems, affecting 78 districts of Pakistan and affecting more than 20 million people. Floods of 2011 occurred only in southern part of Sindh and eastern part of Baluchistan owing to heavy monsoon rains, rendering up to 9 million people as victims of flooding. In 2012 flashfloods devastated the piedmonts of the Koh e Suleiman due to heavy rainfall.

The floods have been so severe that recovery from the damage is still underway. Being a highly attractive substrate for floods, efficient mitigation measures are important for reducing the anticipated loss. The mitigation measures taken in Pakistan are both structural and nonstructural. Key non-structural methods include flood forecasting and warning, permanent relocation of people, flood insurance and land-use regulations, flood plain mapping of some major river reaches (FFC, 2012). The flood hazard zonation and vulnerability mapping techniques have been used in Pakistan for efficient flood management, having identified the severity of flood hazard and vulnerability of certain areas. Khan (2013) suggests that proactive management of natural disasters needs an identification of the risks, the developmental strategies to reduce those risks, and the formulation of programs and structure to make those strategies work. The technique helps ensuring a balance between flood preparedness and methods adopted for reduction of flood hazard and vulnerability as well as in assessment of capacities available that may expedite flood risk management (NDMA-UNDP, 2010)

Effective and efficient management of a flood hazard has many constraints associated with it at every level. A little has been done in the past years to develop and maintain a sound knowledge repository and associated human and institutional set ups for management of massive and complex Indus basin. Much of the water infrastructure is in a poor repair state with no modern asset management plans. Inefficiencies, time and cost overruns and completion delays degrade the implementation of capital investment projects (Briscoe et al., 2008).

Apparently, Pakistan has regulations and policies for Disaster Risk Reduction (DRR), developed in a consultation process with UN organizations, international development agencies, civil society and other crucial stakeholders, incorporating international guidelines and standards on Disaster Risk Management (DRM). However, the incompetence of the DRM system in the country explains the incapacity or unwillingness, or a combination of both, of the state apparatus. National organizations responding to natural disasters have roles and responsibilities that mostly overlap, with coordination lack and no linkages between each other. This makes the government's disaster response policies to shift more towards 'Emergency Response Paradigm (ERP)'. Lack of comprehensive scheme development for pre and post disaster scenarios, irregular monitoring of flood works and the administrative and technical barriers regarding inefficient flood forecasting systems come up as big challenges to be faced. There exist constant requirements for intensive project planning and designing, building institutional capacity, system efficiency and no political interference in departments concerned with the DRM, requirements for reducing the rampant corruption and the criminal negligence among the network of disaster management institutions. It therefore, requires that the DRR in Pakistan be put on right policies at the right place with application of the solutions for DRR that are well known (Ahmed, 2013).

As an effort to contribute towards the solutions of the issues identified above, combining the knowledge of GIS with computer science and web technologies, the research is on developing a system capable of providing automated near real time visualization of a flood disaster, to prototype disaster management and rescue services and initiating flood surveillance, on an open platform for all decision makers and emergency planners.

1.1 BACKGROUND INFORMATION

Natural disasters are there since the start of mankind but have turned great in frequency with increasing human interventions to natural phenomenon. Natural disasters of any kind affect both, materials and human lives. This constant vulnerability to be exposed to a natural disaster is itself horrible but when combined with socio-economic vulnerability poses a great challenge for authorities and sufferers in every form imaginable (Ahmad, 2011). Disasters worsen when governments and authorities lack in emergency support and it gets complicated with breakdown of communication structure. 90% of Natural Disasters and 95% of disaster related deaths worldwide occur in developing countries (Mundial, 1995). It takes months if not years for people to rise again from such devastating impacts.

Among various unannounced natural disasters, floods are one of the most common hazards affecting infrastructure, materials and most importantly human lives and livelihoods. Each year flood kills 20,000 lives and around 75 million people are badly affected (Akhtar, 2011). The reason is the same, widespread distribution of civilizations around river basins from hilly terrains to low lying plains, typically observed in South Asia.

Asia is categorized as the world's most disaster prone region. According to statistics, 38% of the world's disasters in the period of 1975-2000 have occurred in Asia, with 57% of total causalities belonging to Asia in the past 25 years (ADRC Data Book, 2002). The region's climate is dominated by the South-West monsoon, with substantial spatial and temporal variations in rainfall and temperature throughout (Shrestha, 2008). Hydro-meteorological disasters including floods and cyclones are most evident in this region. The scenario is more acute during the monsoon, when cloudbursts, landslides, mass movements and flash floods are common in mountains (Dixit, 2006). With 3.2% of the world's terrestrial and 10% of Asia's terrestrial area, the region has major rivers namely Indus, Ganges, Brahamputra and the Meghna and their tributaries which brings one third of population of the world in a state of vulnerability. One such major river passes through the whole of Pakistan from Northern Areas to Arabian Sea.

Pakistan is one of the most natural disaster-prone countries around the globe which faces earthquake, landslides and floods periodically. Heavy rains in monsoon season are one of the major reasons for river rise and flooding in Pakistan. Another being glacial dam outburst which occurs when glacier crosses river and forms a lake.

Latest flooding (2003, 2005, 2010, and 2011) in Pakistan is the perfect example of how a flood of these magnitudes can put an entire country in state of anarchy and affects the very root of the system as it affected all the provinces of the country badly. The July-September 2010 floods are known as one of the worst natural disasters ever occurred in terms of number of people affected, 20.2 million out of which 1985 people were killed (Fleiss et al., 2011). Out of 143 districts, 67 districts of Pakistan were ruthlessly affected. In which 1 million houses were destroyed, 10 million people displaced and millions were affected with diseases and lack of basic requirements of life. About 130 million hectare of cropland was inundated (Akhtar, 2011). Pakistan 2010 floods were marked as one of the major disasters of 21st century due to the widespread area affected by it from Himalayan Plateau to Arabian Sea. Comparatively, a wider area and more people were affected than those affected combined in Indian Ocean Tsunami (which affected fourteen countries), Pakistan Earthquake 2005 and Haiti Earthquake 2010 (Polastro, Ricardo et al., 2011). In 2010 floods, the catchment area of River Indus was highly affected. The rainfall intensities recorded were Risalpur (415mm), Islamabad (394mm), Murree (373mm), Cherat (372mm) and Ghari Dopatta (346mm). About 500 tons of wheat was destroyed and other destructions were Cotton (3,000 km^2), Rice (800 km^2), Sugar cane (800 km^2) animal fodder (1,000 km^2). These floods cost an estimated 43 billion US dollars in losses (Ali, 2012).

Heavy rains in the upstream areas of the country cause floods in the downstream areas while irregular monsoon rains add to the problem. Oxley (2011) states that monsoon rains in the northern region of Pakistan may be the cause of floods in southern Pakistan. Apart from that the various land use changes and environmental degradation are also the causes of the increasing risk of floods. Ghafar and Javaid (2011) worked on impact of global warming on monsoon variability in Pakistan. Comparing the temperature and rainfall data of six different cities namely Islamabad, Muree, Kakul, Gilgit, Muzafarabad and Peshawar for the last 50 years, they concluded that as Pakistan lies in the corner most north of the subcontinent so the variability in the weather and rainfall is greater than any other place which causes abnormal weather patterns. Water flow in the rivers is highly dependent on rain fall and snowmelt on the icecaps. The heavy snowfall in winters and increasing temperature in summers can also be the cause of abnormality and can cause floods in the rivers. Overview of bioclimatic variables for different cities of Pakistan (1950-2000) is provided in Table 1.1. and Figure 1.1.

Floods, like all other types of disasters, have numerous direct and indirect impacts on the surroundings. Statistics indicate the extensive impacts on human well-being at global levels, triggered by floods. Direct consequences of floods include human loss, damage to infrastructure and equipment, vehicles, structures, inventories, leading to economic damage and damages to eco-systems and historical and cultural values (Jonkman, 2004) (Asgary et al., 2010). Indirect

TABLE 1.1. Overview of Bioclimatic Variables for Different Cities of Pakistan 1950-2000 (Data Source: World Climate Database)

Temperature (^{o}C) - Precipitation – (mm)	RAWALPINDI	KARACHI	GILGIT	SIBBI	QUETTA	AZAD KASHMIR
Bioclimatic Variable	**Value**	**Value**	**Value**	**Value**	**Value**	**Value**
Annual Mean Temperature.	22.5	26	-3.4	24.6	22.3	13.7
Mean Monthly Temperature Range.	14.2	11.4	9.8	15.3	17.9	11.8
Isothermality.	38	45.1	24.8	40	44.3	37.1
Temperature Seasonality.	798.7	473	1042.7	826.6	884.4	815.6
Max Temperature of Warmest Month.	40.6	35.7	16.4	42.5	42.4	30.2
Min Temperature of Coldest Month.	3.3	10.5	-23	4.3	2	-1.7
Temperature Annual Range.	37.3	25.2	39.4	38.2	40.4	31.9
Mean Temperature of Wettest Quarter.	29.9	29.4	-4.4	32.1	13.5	13.7
Mean Temperature of Driest Quarter.	17.7	23.6	-7.9	19.3	27.1	9.1
Mean Temperature of Warmest Quarter.	31.4	30.8	8.9	33.7	32.9	23.3
Mean Temperature of Coldest Quarter.	12	19.1	-16.8	13.6	11	3.3
Annual Precipitation.	574	207	98	205	85	719
Precipitation of Wettest Month.	150	84	17	43	20	117
Precipitation of Driest Month.	7	1	2	4	0	24
Precipitation Seasonality (CV).	90.2	150.7	55.5	67.6	101.2	48.2
Precipitation of Wettest Quarter.	326	160	43	95	54	304
Precipitation of Driest Quarter.	39	9	11	22	3	97
Precipitation of Warmest Quarter.	297	93	24	93	7	151
Precipitation of Coldest Quarter.	97	22	17	45	46	161

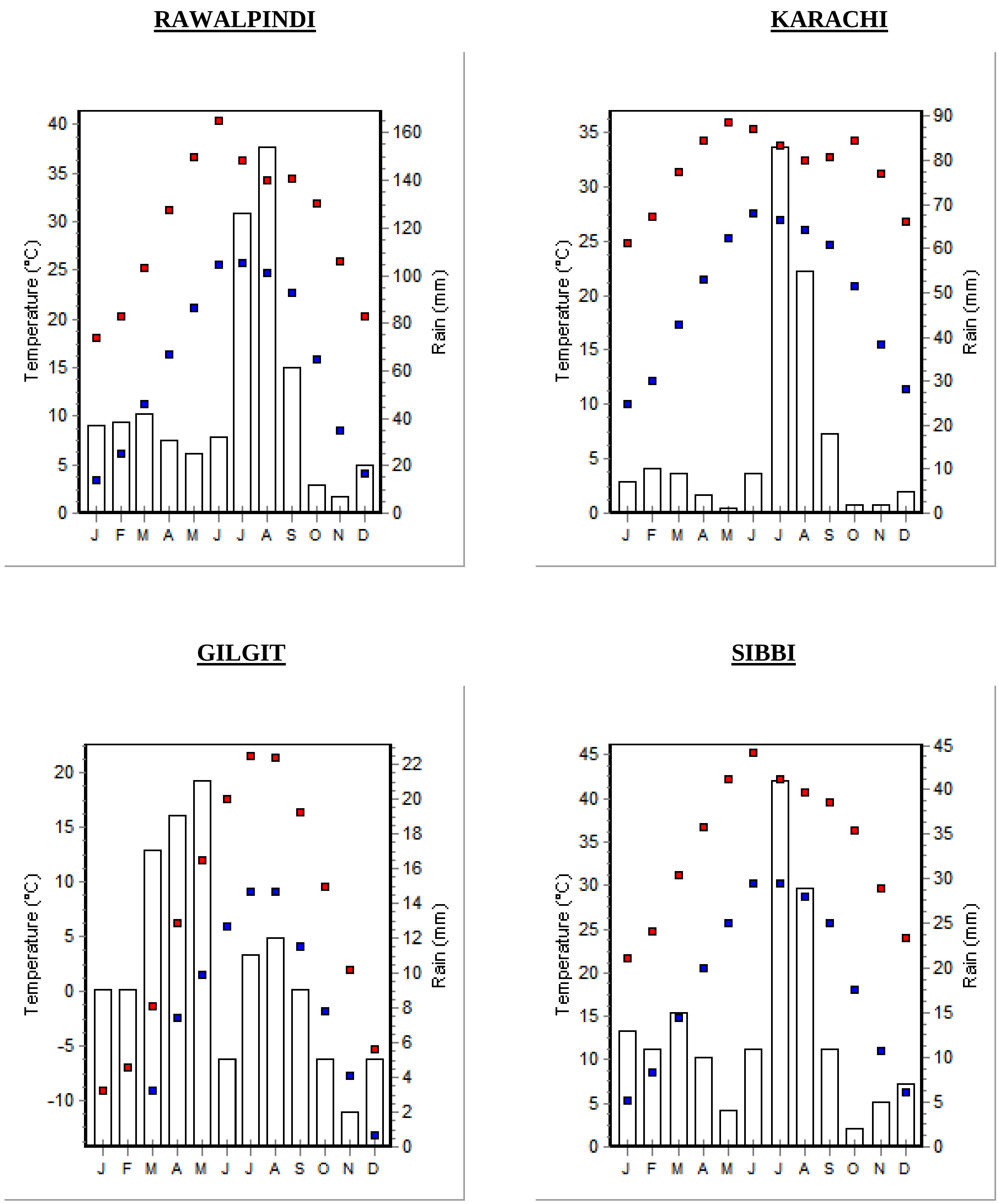

Figure 1.1. Mean Annual Temperature and Precipitation for different cities of Pakistan (1950 – 2000) (Data Source: World Climate Database)

effects of floods include the loss of economic and agricultural production and a decline of socio-economic welfare (Appleton, 2002), off site business interruption, reduction in property values, stock market effects and many other sociological and environmental effects (Rose, 2009). Among the flood impacts, health risk takes the lead. Floods have complex and far reaching effects on human life including deaths, drowning, displacements, irreparable injuries, and an increased incidence of common mental disorders. Prolonged cases of anxiety and depression for even months and years worsen the scenario (Hajat et al., 2005).

A natural disaster, either geologic or climatic, has its effects on the key macroeconomic variables as well, which determine the long run growth. These include; natural resources, physical capital accumulation, human capital accumulation and technology. Whether the net effect of a disaster on the macroeconomic variables is positive or negative, it depends on the type and location of the disaster, and measure of post disaster recovery progress. A sound institutional setup of the country is going to boost the net effects towards positive, reducing the financial crisis and human shock following a catastrophe (Aaron, 2006). Oh (2010) highlights a common observation in such natural disaster events, that is the inadequacy of critical infrastructure to endure the forces of natural catastrophes and the lack of mitigation strategies on the part of emergency-related organizations, industries, and communities, concluding that there should be an early identification of vulnerable critical infrastructure by the emergency-related agencies to significantly reduce the damage and impacts. Flow of process is mentioned in Figure 1.2.

In Pakistan we see extreme weather conditions. In summer temperature rises up to 50 degree Celsius in some areas. On the other hand temperature may fall below zero in northern

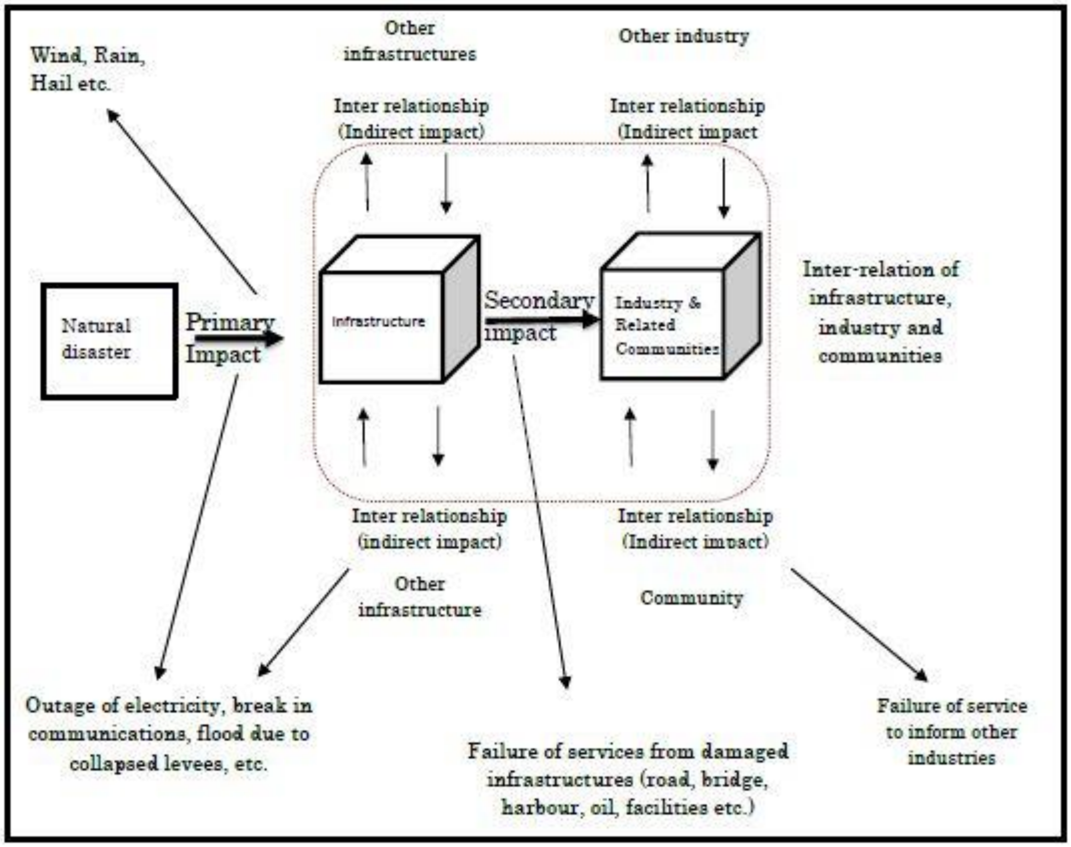

Figure 1.2. Direct and Indirect Disaster (Oh and Heskey, 2008)

areas of Pakistan. As far as rainfall is concerned, Pakistan faces extreme rainfalls due to monsoon patterns. Heavy rains during monsoon cause Pakistani rivers to overflow and flood the land. Even though monsoon is the major reason of floods in Pakistan, it is not the only reason. Flooding in Pakistan during 2010 was due to unusual shifts in the rainfall pattern during monsoon season. Monsoon rainfalls are the core basis of flooding in Indus basin whereas flooding in lower parts of Pakistan is induced by the Mediterranean waves and cyclones generated in Arabian Sea (Tariq, 2012). Though too much rainfall is a reason for major flood disaster but human interventions in the riverine system has turned this disaster into devastation. Geomorphologists suggest that the Indus River had a very dynamic regime in the past but the river has been constrained by embankments on its sides and barrages on its course which resulted in high sediment load which in turn caused significant increase in cross valley gradient leading to breaching and inundation of large areas (Gaurav, 2011). Sometimes floods may occur from dams burst due to extreme melting of glaciers, owing to high temperatures.

These devastating events and there impacts create an alarming situation to be worked on disaster management and flood predictions. There are many different stakeholders involved in the flood scenario and each decision maker has his own priorities to accomplish. Government sectors are interested in providing healthier and safer environment for people to live; knowing which populations are at risk, managing relief distribution and evacuation planning. Non-government is attentive in providing social welfare and assisting government. Private sectors have their own interests like Insurance companies planning their schemes, town planning concerns of acquiring a safe place to construct a society whereas Public needs to know what is happening and what is expected. Technical studies in this field are required to assist decision makers in their efforts to build a more resistant society through well designed system. Flood management issues are complex and time taking involving all the stakeholders with different preferences and less compromise (Levy et al., 2007). For the purpose, it is becoming a common practice to invite all participants for decision making and submit flood management plan to public for participatory discussions with research on public perception of floods and its management (Francisco, 1998). It can be reminded here that United Nations conference on Disaster Risk Reduction (2005) provided commendations to decision makers for disaster risk reduction, including flood disaster and also delivered The Hyogo Framework of Action (2005) which emphasized on improved compilation of information on disaster risk.

Flood mitigation in a developing country comes up as a big challenge for the institutions and administration. Asia being the world's most disaster prone region, with a high population, its exposure to natural hazards increases exponentially. Increased vulnerability to disasters is attributed to scarcity of resources and poverty level in populations.

The conventional methods of mitigating floods are related mostly to structural strengthening e.g. constructing dykes, embankments, floodwalls and levees or altering the river channels (e.g. widening, lining with concrete, or straightening by cutting through channel meanders to shorten the flow distance). But focusing on mere structural development does not address the issue completely as it has its own drawbacks e.g. siltation of river channel resulting decrease in carrying capacity, water logging, and drainage congestion triggered by embankments (Gupta, 2005); environmental degradation of structural approach (Burby et al., 1988); health issues arising from stagnation of flood waters for lengthy periods of time contaminating the ground water(Gupta, 2003); these are the factors which mainly contribute to encourage the non-structural approaches of flood mitigation adopted by developed countries e.g. USA, Japan, such as land acquisition, land use zoning and regulations, environmental restoration programs etc. (Gruntfest, 2000) (Bechtol and Laurien, 2005).

For the developing countries, flood mitigation is considered as an amalgam of hard and soft measures. Restoring the natural functions of rivers and floodplains, planning and management practices, involving the local communities in the river basin management, capacity development of the local institutions are some effective measures of sustainable flood management. The prime victim of any disaster event is the human population, therefore, if the community recognizes their potential being the direct hit of a catastrophe, they can rise up to alleviate the aftermath to a greater extent but not addressing their own vulnerability can bring them an intense loss. The idea of Community Based Disaster Management (CBDM) stems where potentials and capabilities of human populations to respond to emergencies is strengthened by providing them more access and control over resources and basic social services. As being on the front line, the local people of a disaster hit area serve as a repository of coping mechanisms, responding immediately to a crisis situation, where timeliness is extremely crucial. This approach of response reinforces social consistency and collaboration increasing the confidence level within people interacting in a community, ensuring a maximum participation in the development programs for disaster preparedness and mitigation.

Identifying the 2 main issues associated with CBDM approach, the findings include: A) the issue of sustainability, as the involvement decreases gradually because of reasons like partnership, participation, empowerment and ownership of the local communities. Many of the rehabilitation projects continue to diminish as time passes. While a disaster mitigation needs the participatory approach from communities in a very broad sense, which is consistent in strategic terms. B) Up-scaling of the initiative. Many of the best practices towards disaster mitigation applied at a small level stay confined to that local level. Dissemination of best approaches at a large scale stays a big obstacle. Summarizing the major challenges of CBDM, findings are: Firstly, sustainability of the efforts in the community level; Secondly, Integration of the CBDM issues in the policy making. The applications of CBDM need to go beyond NGOs, communities and local governments, for producing a sustainable impact. Nation and state level governments must incorporate CBDM in the policy and procedure implementation for enhancing responsiveness and operative governance (Shaw, 2004).

In this regard, evidence and studies reveal following measures being effective towards mitigation planning: Firstly, Local institutions (both formal and informal) play a critical role in sustaining the efforts; Secondly, Integration of community initiatives in the government policies and practices is important to up-scale the efforts; Thirdly, Local change agents play crucial role in grass-root implementation; Lastly, Synergy of grass-root efforts with the development policy is regarded as the measure of the success of project implementation (Shaw, 2006).

The NDMA in collaboration with UNDP, highlighted the following issues regarding flood mitigation in Pakistan, divided in four categories i.e. administrative, technical, financial and geographic.

Firstly, Administrative Constraints; (1) the approval of developmental schemes is a lengthy process, causing much delay and sometimes making it impossible to carry out ground level implementation, due to short working time available prior to the start of Flood Season. (2) Litigation issues (after approval/before construction/during construction), followed by difficulties in land acquisition effect the speed of workflow. (3) Incomplete scheme are always prone to flood damages resulting loss to national exchequer.

Secondly, Financial Constraints; the most important issue faced is shortage of funding that disturbs the implementation of important pre and post disaster development schemes. Consequently due to delayed provision of funds, actual river morphology changes requiring modifications in original scheme design. This happened in year 2007, when provinces demanded 130 billion (PKR) for next ten year time frame against which 30 billion (PKR) planning for ten years was made, 3 billion (PKR)/year, while actual provision of funds remained 1 billion (PKR)/year during 2008, 2009 & 2010. Then there stays a lack of operational and maintenance funds for regular maintenance of flood works, resulting in a gradual deterioration of structures and increased danger of collapse in the future events.

Thirdly, Geographical Constraints; steep slopes of northern areas, valleys and hilly terrain of the Khyber Pakhtunkhua (KPK), slopes of Federally Administered Tribal Areas (FATA) along with the critical law and order situation, partially hilly partially plain Punjab, coastal environments of Sindh, far flung deserts of Baluchistan, sandy soils of Azad Jammu Kashmir, all account for a very diverse topography of the country as a whole. To cater for every fact is a big challenge for the authorities while designing and implementing disaster management policies.

Lastly, Technical Constraints; a major concern in this regard, is the lack of inter-agency coordination. Every department works within a specified sphere with almost no data sharing with other similar governmental and non-governmental organizations. Additional barriers associated with inadequate reporting of flood susceptible areas, expansions in remote area coverage, system deficiencies in forecasting flash floods, increased emphasis in coastal area flood management as priority, proper registering of discharges at rivers, nullahs, streams, flood plain extent definition; existing at both federal and provincial levels may act as a big hindrance towards policy development. There exists a constant requirement of new construction machinery, refined construction techniques, project planning, designing, siting and implementation on modern trends, more skilled labor input, time intensive planning, institutional capacity building, enhanced coordination for effective mitigation measures.

Considering all these impacts caused by the flood and issues arising from them, and with such immense constraints in decision making and limitations in mitigation measure, advancement of technology and role of science is of extreme importance. Science has always paid its contribution to every matter related to human life and similarly in the case of disaster management, whether it is a post disaster analysis or pre disaster recommendations. Science and technology is helpful in every domain of it, from prediction to evacuation planning, from management to relief distribution, from emergency response to future developments.

Statistical analyses have always been of leading reputation when it comes to any study. Many studies were done in case of Pakistan to identify weaknesses and to make Pakistan technically upgraded and administratively resilient. A temporal analysis showed that rainfall in Pakistan is highly predictable. If extensive quantitative data is available on precipitation then the rainfalls estimations can be foreseen and if these rainfall forecasts are coupled with hydrological models then areas of high risk can be identified, with proper preparedness measures anticipated and actions taken to lessen their impact (Webster, 2011). Flooding behavior of the major basins and flood management at the national level can be investigated. Hussain (2011) investigates Annual Maximum Peak (AMP) flow through flood frequency analysis at 7 stations sited at the central watercourse of River Indus, namely Tarbela, Chashma, Guddu, Taunsa, Sukkur, Kotri and Kalabagh.

Many studies have been done on 2010 floods of Pakistan. Lau (2012) showed that the extreme flood events of 2010 were physically connected to Russian Heat Wave Wildfires. And

Warraich (2011) suggests that surveillance is of prime importance to timely identify disease outbreaks, food shortages and other requirement of affected population.

Tingsanchali (2012) identified that proactive disaster management requires more effort from all the participants including government, non-government, private and public; demanding more time, equipment and resources. The four step cyclic process for disaster management is described in Figure 1.3.

Studies are not only done on what was the nature of flood or its destruction, the applications of flood analysis has far more reaching advantages than just its mitigation and preparedness. Knowledge of floods helps in civil engineering works, water resources management and vulnerability of civil structures in the buffer of rivers (Herschy, 2002). The designs of flood prone constructions rely on these studies as well as extreme events. Arslan et al., (2013) worked on 2010 flooding and the basic goal was the prediction of floods and droughts on the basis of annual and monthly rainfall data of 900 days for all the provinces of Pakistan.

Statistical studies were further carried forward with the integration of location of data, hence a better visualization of data in terms of maps. Geographical Information Systems add greatly to the field of disaster management as it is famously said as 'Map' captures more information than thousands of words. Similarly remote sensing data helps greatly in quick analysis of affected areas and response measures. The introduction of these fields has changed the dynamics of disaster management. Chowdary et al., (2008) suggests that coupling of Geographical Information Systems (GIS) and Remote Sensing (RS) provides an exceptional substitute to conservative ways of mapping of water inundated areas as well as flood monitoring and damage assessment that leads to significant disaster management. GIS and RS are being used on global and country level to facilitate flood disaster management issues. Haq et al., (2012) developed a technique for mapping

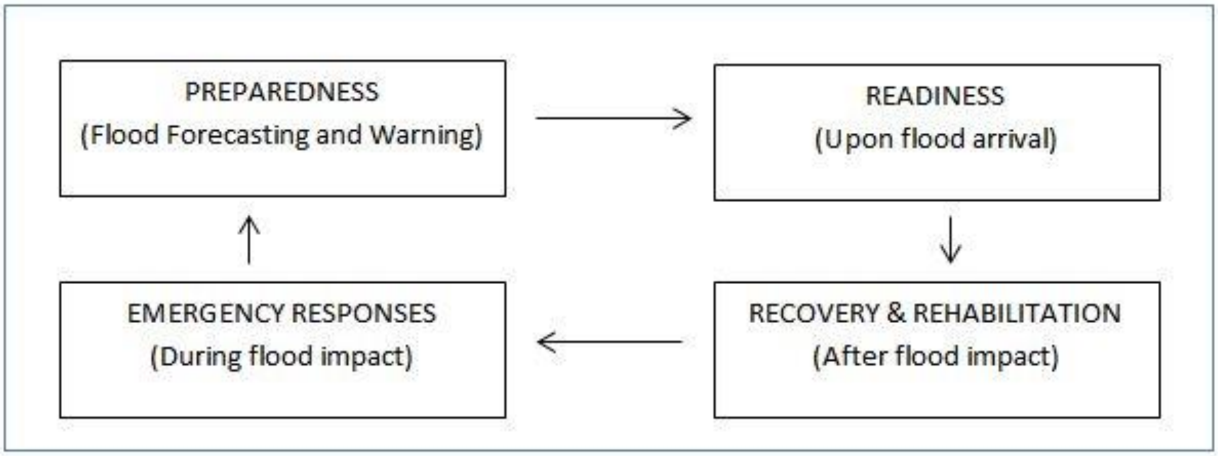

Figure 1.3. Four Step Cyclic Process for Disaster Management (Tingsanchali, 2012)

flood disaster extent and assessing flood damages which can serve as a guideline to improve the efficiency of flood disaster monitoring and management. Analysis of flood disasters, their frequencies and risk assessment have been done by Zhang et al., (2010) for Peral River Basin and Luan River Basin in China. The research primarily focused on utilizing water resource applications in ArcGIS. Arc Hydro tool which is embedded in ArcGIS was comprehensively used to obtain watershed features for flood disaster management by implementing spatial database in the tool. Study results provided in-depth information regarding post flood disaster assessment in critical situations.

Using GIS, a composite hazard index map can be devised incorporating all the variables like flood frequency, transportation networks, availability of high ground, population density, access to potable water and maximum risk zones can be identified and mapped on the basis of hazard index (Sanyal, 2006). The application can be extended to a form of Flood Hazard Mapping and Flood Shelters Suitability Indexing (Uddin et al., 2013). Zlatanova (2009) gives special attention to the use of Geo-information such as Risk Maps and Topographical Maps and discusses how this spatial information can aid in the need of emergency response systems. Satellite based remote sensing are valuable data sources to identify, conclude and evaluate the flood magnitude, destruction and effect. Nevertheless timely acquirement of datasets and their availability are important. Landsat images are freely available since November 2008 (Hussain and Shan, 2010).

GIS and Remote Sensing has been utilized for flood risk analysis at Kalu Ganga River, Sri Lanka by Samarasinghea (2010) who focused on risk of floods and vulnerability to forests, crop land, residential areas and many other vulnerable areas. Research was carried out on hazard and vulnerability analysis using hydro metrological data and risk analysis using remotely sensed satellite data.

Many applications of GIS and Remote Sensing have been done in case of Pakistan. In 1978, hydrology of Indus Basin was studied using Landsat imagery to calculate the flood extent of 1973 floods in Indus River basin (Moris et al., 1978). Flood zoning and flood insurance are assessed through a risk based assessment (Tariq, 2011). Annual peak discharges are analyzed and risk of flood in the Indus River Basin was estimated in 2011 (Khan, 2011). Ahmad et al., (2013) analyzed flood prediction techniques making GIS as base and using Ad hoc wireless sensor network architecture. In this study, ArcGIS Simulation tools are also used to identify pre and post disaster impacts and model is prepared for flood risk analysis and prediction for areas which are prone to flood disaster.

Liu et al., (2011) thoroughly analyzed the aftermaths and losses of 2010 flood disaster in Sindh and Punjab and describes that GIS and Remote Sensing plays key role in real time flood monitoring scenarios, also incorporating the submerged conditions of different areas which are hit by disaster. Flood extraction model was built using supervised classification and decision tree method. The research mainly focused on analyzing the statistical data using remotely sensed satellite imagery for affected population from floods in cultivated land areas of Muzaffargarh and Dera Ghazi Khan.

However, the recent flood disasters show that current warning systems which are stand-alone desktop based are not sufficient to fulfill all the requirements. As natural disasters are spatio-temporal events so web based GIS and RS can serve this purpose better by providing accessibility and dissemination of timely and accurate information which is vital for sound flood management systems. Even though GIS and RS are most important tools for decision support system, if support is extended to web it will pose a significant positive impact for planners and decision makers in providing timely and accurate information. Al Sabhani et al., (2003) suggests that for a GIS to be effectively used in flood management decision making, real time and up to date sources are needed to be utilized in the system. Zipf et al., (2004) developed a web based mapping application using inundation surface model at University of Applied Sciences Mainz, incorporating flood information for tentative area on northern upper Rhine. He further suggested that the web based integrated water shed model will provide an interactive graphical user interface with ease of access to the databases. Web based GIS will provide a platform to access the environmental database easily and take part in the environmental decisions that affect them directly. Satellite monitoring is another technique useful for obtaining data for real time flood forecasting, suggesting that the web based GIS system required for flood forecasting system should have real time rainfall data, a user friendly interface and easily available at different web platforms. One promising step in this regard is the Java programing language which has database applications suitable for watershed modeling. Flood information system extended to web based platform can provide up-to-date data and real time information prior to and after the flood disaster in order to illustrate vulnerable and affected areas respectively (Raltman et al., 2011). This will help the concerned authorities to take precautionary measures in time to avoid further loss.

Chan (2011) has found out that using Google Earth software for GIS and incorporating Digital Elevation Model (DEM) is extremely important for flood disaster management system. Google Earth Pro v.5 and KML files are crucial for observing disaster affected regions can be successfully integrated together into a web application. Research was focused on advance use of ArcHydro tool to monitor real time river flow movements causing floods and respective files can also be downloaded for future reference. Mioca et al., (2008) improved the flood forecasting of Saint John River by developing a web GIS based decision support system for flood prediction and monitoring which could perform data integration, online map interfacing and floodplain delineation; system being capable of dynamically displaying the observed and predicted flood extent models for the decision makers as well as general users. With the help of satellite imagery and DEM of the flood plain area, the user can access the web based prediction that models the flood events and can show how the water progresses for the next 1 to 2 days along the Saint John River.

1.2 RATIONALE

Reviews in Table 1.2. helps us understand that timely surveillance of everything involved is of paramount importance in solution to problems such as flood, whether it is pre-disaster or post disaster requirement. This is a time for some much-needed integration and collaboration. All stakeholders; Government, Non-government, Private and public must be advocated timely. Shan et al., (2009) defines the timely provision of flood extent, progress (nature) and impact information directly to all the disaster management authorities as of prime significance and suggests that 'Web' can help providing platform for developing quick response strategies, planning rescue operations and placing relief efforts. Such platforms can assist decision makers in their efforts to create more resilient societies through well designed management system.

With such power of Web technology, there is a need of a system that can pool in information from various sources and provide it to user as required. With human lives in danger, there is no time for a disaster management analyst to look into various bookmarks and collect information first and then analyze later.

The study aims to provide a facility where all the stakeholders are combined at a single platform, assessing what is required to them and using it for operations and services through an

Table 1.2. Overview of Bibliography

	PROBLEM		SOLUTION		
BIBLIOGRAPHY	**DISASTER**	**FLOODS**	**WEB**	**GIS/RS**	**MASH UP**
(Sabhani et al., 2003)		☒		✓	
(Raltman, 2011)		☒	✓		
(Mioca et al., 2008)		☒	✓	✓	
(Chan, 2011)	☒	☒	✓	✓	
(Zipf et al., 2004)		☒	✓	✓	
(Liu et al., 2011)		☒		✓	
(Sanyal, 2006)	☒	☒		✓	✓
(Karnatak, 2012)	☒	☒	✓	✓	✓

information portal for flood hazard support facility prototyping disaster management and rescue services using geospatial technology.

Geospatial web systems and technologies like US FEMA HAZUS and FEWS have been playing a major part in disaster mitigation and management for a wide range of disasters from that of Chernobyl, tsunamis in Indonesia (2004) and Japan (2011), Hurricane Katrina (2005) and the Denube floods (2013). As suggested by Gupta and Knoblock (2010), Geospatial mash-ups can be sound economic implementations of geospatial technologies as they reduces the overheard on data storage and management. Also, a Geospatial mash-up helps in seamless data integration from other portals with its increasing implementation in form of crowdsourcing web and dedicated software platforms in the global community.

1.3 OBJECTIVES

Development of an elaborate Web Infrastructure for Disaster Information and Mitigation is now a requirement for Pakistan while institutions across the world are already working on dissemination of useful information in the global community.

In light of the facts being discussed, objective of the project design is:

1. To develop a **Geospatial Mashup**, with the capabilities of data integration from heterogeneous sources like disaster management authorities, World Wide Web, ground observations through sensors and distress calls, processing and validating this raw information, and presenting it at one single platform.
2. To develop a system component that databases past floods, i.e. extents and affected areas, in order to derive useful products from them helping in disaster mitigation strategies.

1.4 SCOPE OF THE STUDY

The material output of this project will act as a disaster management portal forming the basis of a disaster response unit, connecting relief and rescue service providers, management and mitigation authorities, NGO's keen on providing aid as well as establishing immediate communications with the affected communities.

A variety of organizations would be benefited from the said project but those of prime importance and relevance are:

A. **The Cabinet Division** dealing with disaster response and mitigation at national level;

B. The NDMA (National Disaster Management Authority);

C. **The Indus river management authorities** at federal and provincial levels;

D. **NGOs and universities** offering aid to disaster hit areas

The Pakistan Insurance Associate and its affiliates can benefit from this project for ascertaining provision for insurance schemes and ranking high to low risk areas. **Note:** In Switzerland CAT-NAT is one portal which is made accessible to such organization through a username and password against monthly charges.

Chapter 2

MATERIALS AND METHODS

Effective preparedness, mitigation and planning following a disaster event, require information from multiple sources and working in the domain of Geographical Information Systems and Sciences, everything is centered on location and spatial extent. To combine information from different sources of spatial nature and integrating it with the relevant non-spatial data results in a product, that can efficiently support disaster management. Our approach, towards a system for flood visualization, follows the development of a Geospatial Mash-up, which integrates heterogeneous data, form heterogeneous data sources and presents them on a common scale. It will have a component to provide historical records to the audience on flood events in Pakistan. SMS utilities would be provided to generate disaster alerts and receive distress calls from disaster hit districts. Having said that, the system access rights would be provided based on the audience interacting with it and the nature of information.

Proceeding further, in the next sections, there would be a discussion on the project study area, datasets used and their sources along with the implementation framework of the project.

2.1 STUDY AREA

In the study area of complete Pakistan, the most significant entity related to floods is the river Indus.

The Indus River is located at 5182 meters elevation, on the northern slopes of Mount Kailash in the Gangdise Range of Tibet near Lake Mansarowar, close to the source of another major river, the Brahmaputra. Watershed area of basin is 944,000 square km, 60% of this area is in Pakistan. The tributaries of Indus are Sutlej, Ravi, Chenab and Jhelum. The Indus River then flows north-west, through the high plateau area of Ladakh into Kashmir. The river continues west-north-west past Skardu where it is joined by the Shyok at an elevation of 2730 m. Subsequently, the Indus partially circumvents the northern flanks of the Nanga Parbat-Haramosh Massif, where it first turns north along the Raikot Fault, then west, and finally south-west where the Gilgit River flows into the Indus from the west at an elevation of 1515 m. A number of past slope failures have wholly or partially blocked the river at times, even giving rise to catastrophic dam-failure floods downstream. Mangla and Tarbella dams control the floods in the Indus and Jhelum basins. Lack of control over the Ravi, Chenab and Sutlej rivers is the main reason of floods in monsoon season in these areas. Chenab has the history of more floods in Pakistan. Under the Indus water treaty, India has the rights of the waters of Sutlej and Ravi which is the main reason of the very little flow in these rivers. The floods in upper and lower Indus basin have different natures. Due to lower river bed than the surrounding areas the water returns to the river after spilling out in floods but water stays in the surrounding areas for months in the lower region, thus causing lots of troubles. WAPDA annual report (2000) shows some of the main features of Indus river system as shown in Table 2.1.

Climatically, country lies in the sub-tropical and temperate zone with its longitude stretching from Arabian Sea in south to the great Himalayan mountain ranges in the north. Most of the regions in Pakistan are arid and semi-arid with quite significant spatial and temporal variability in climate. Since the northern part of the country is mountainous region, it has humid to arid climate. The south and south east have coastal temperature with narrow strip along the coast whereas, in between this range of mountains and coast, climate is tropical continental type.

Table 2.1. Main Features of Indus River System (WAPDA Annual Report, 2000)

	Sutlej	***Ravi***	***Chenab***	***Jhelum***
Origin	Tibet	Himachal Pradesh(India)	Himachal Pradesh(India)	Kashmir
Discharge to	Chenab	Chenab	Indus	Chenab
Length(km)	1500	900	1240	820
Basin area(km2)	122,000	40,000	67,500	63,500
Avg. annual flow (km3/yr.)	3.05	4.46	25.17	24.33
Dams in India	Bhakra, pong	Thein	Salal, baglihar	-
Dams in Pakistan	-	-	-	Mangla
No of barrages	2	2	5	1

Pakistan is situated in Asian monsoon zone which receives immense rains as a result of seasonal currents, originating from Bay of Bengal. These Intense rainfalls are caused by the combination of Jetstream which are very high in atmosphere above northern Eurasia leading to concentrate monsoon over northern Pakistan along with “La-Nina” which is related to high sea surface temperatures and huge amount of moisture over the Indian ocean. Farooqi et al., (2005) gave a view upon climatic change by describing that Green-house gasses emission have been one major component of the climatic change, changes in weather patterns; especially over Asiatic zone, along with ENSO (El Nino Southern Oscillations), tropical cyclones and fluctuation in monsoon pattern, further adding that one of the main reasons behind changes in weather pattern is fluctuations in temperature of the region either due to green-house gasses effect or the monsoon pattern changes. A 50 year temperature variation trend has been shown for the region in Table 2.2.

There are two seasons of precipitation in Pakistan. One is the summer or monsoon precipitation and other is winter precipitation. (Mainly resulting from western disturbance winds entering from Iran called secondary wind disturbance and from Afghanistan called primary wind disturbance). Floods, droughts and intense rainfall play a role in shaping the overall climate.

Salma et al., (2012) describes that owing to the global climatic changes, spatial shift in the rainfall patterns have made this region unreliable and unpredictable in this perspective. This variability in rainfall patterns has been observed globally whereas decreasing trends in rainfall along coastal regions of Pakistan and arid plains have also been observed (IPCC, 2007). This

Table 2.2. Temperature Change during 1951-2000 (Farooqi et al., 2005)

	Region	***Trend during last century***	***Range (^oC)***
1	Over the thermal low region	Increased	0.2 to 1
2	Coastal areas (Baluchistan)	Decreased	-0.5 to -1.5
3	Monsoon belt	Generally decreased	-2.0 to 0.0
4	Northern mountains	Generally increased	-1.5 to 1.5
5	Thar region	Increased	0.3 to 1.0
6	Sindh coast	Generally increased	0.0 to 0.5

variation in rainfall is mainly associated with westerly wind disturbance and monsoon winds as shown in Table 2.3.

Rainfalls do not occur throughout the year. Baluchistan and KPK regions receive maximum rainfall from December to March while Punjab and Sindh receive 50-75 % of rainfall during monsoon season. Annual rainfall in the Himalayan region is between 760mm and 1270mm and about 72% of the annual flow in the Indus River is from these mountains. Northern Sindh and Baluchistan receives the lowest amount of rain (Tariq et al., 2012).

Though it is hard to relate any specific weather event to human induced global warming phenomenon, there is strong evidence from various sources that we are in an era of changing weather patterns, attributed by an increase in severity of extreme weather events. It is expected that trend of heavy rainfalls in northern Pakistan and surrounding regions will become more frequent and intense in future. During the last 3 consecutive years, heavy monsoon rains in Pakistan lead to immense flooding. Floods generally occur in various forms e.g. flash floods, coastal floods, riverine floods, urban floods etc. depending upon the rainfall intensity and geography or terrain of the vulnerable area. However in Pakistan monsoon hazards particularly lead to riverine and flash floods which normally occur between July and September. Geography also plays an important role in the nature of floods. The fluvial floods in the Indus plain are more destructive due to flat terrain, surrounding dense population and maybe the economic development. They are also called as **Riverine Floods** and are the most common type of floods in Pakistan. They tend to occur in main Indus River System and its tributaries (Ravi, Sutlej, Chenab, Jhelum, and Kabul) and other secondary rivers as a consequence of torrential monsoon rains. **Flash floods** are also destructive as they can take lives more frequently and they commonly occur along the mountainous regions adjoining the Indus river basin e.g. Gilgit Baltistan, Kashmir, KPK,

Table 2.3. Rainfall Change during 1951-2000 (Farooqi et al., 2005)

Region	***Annual basis***	***During monsoon***	***During winter***
Coastal areas	Negative	Negative	Positive
Quetta region and south eastern Sindh	Positive	Positive	Positive
Western Baluchistan	Negative	Negative	Negative
Monsoon belt	Positive	Positive	Mostly positive
Northern mountains	Positive	Positive	Negative

Baluchistan and southern Punjab. Pakistan also encounters hill torrents and urban floods which tend to occur in hilly areas and congested cities as a consequence of cloud burst leading to heavy monsoon rains. Coastal floods are seen in south eastern part of Sindh and Makran coast due to tropical storms. Some floods also occur due to breaching of river embankments and canals e.g. The Shadi kor dam in Pasni also caused floods due to its breaching on February, 2005.

Historically Pakistan has faced 13 major floods since its independence in 1947. The 63 years of data on losses from these floods is being utilized for future preparedness and mitigation measures by generating risk maps. The risk maps generated by NDMA using this data illustrate 25 districts as highly vulnerable to floods (11 in Punjab and 14 in KPK). A flood based human loss details for 61 years (1951-2011) are shown in Table 2.4. Federal Flood Commissions annual report (2008) has outlined the embankments and spurs at provincial and national level as mentioned in Table 2.5.

Out of all the floods that have occurred hit Pakistan, 2010-flood is still the most devastating disaster in the history. The floods of 2010 were induced by heavy rainfall, affecting 78 districts of Pakistan and more than 20 million people. Flood 2011 occurred only in southern part of Sindh and eastern part of Baluchistan owing to heavy monsoon rains, rendering up to 9 million people as victims of flooding. 2012 floods were caused by hill torrents from Koh-e-Suleiman range due to very heavy rainfall.

In last three years Pakistan has come across with lethal flood losses due to inconsistent monsoon behavior. Experts take this behavior in a larger context of climate change which is frequently more prominent in Pakistan. Last 20 years data depicts that monsoon impact zone has

Table 2.4: Historical Flood Human Loss 1951-2011 (Zaidi, 2010)

Year	Fatalities	People Effected
1950	2190	10,000
1956	160	11,609
1957	83	4,498
1973	474	9,719
1976	425	18,390
1978	393	9,199
1988	508	1000
1992	1008	13,208
1995	591	685
2001	219	50
2003	484	4,376
2004	85	47
2005	59	1,931
2007	989	2.0 million+
2010	1781+	20 million
2011	434	8.9 million

Table 2.5. Flood management in Pakistan (FFC, 2008)

Province	Embankments(km)	Spurs(no)
Punjab	3334	494
Sindh	2422	46
KPK	361	185
Baluchistan	602	650
Total in Pakistan	6719	1375

been shifted from its original catchment area of Kashmir to approximately 100 km westwards towards Indus and Kabul basins. Many interventions are being carried out to reduce the risk posed by disasters. Khan (2013) suggests that proactive management of natural disasters needs an identification of the risks, the developmental strategies to reduce those risks, and the formulation of programs and structure to make those strategies work. There are three possible approaches that can be used to map and manage the areas affected by flood. The first approach is using a historical worst case scenario that happened in that flood plain. The second approach is maximizing the meteorological factors that could happen in area producing the worst possible flood due to worst possible storm. The third step is to use historical information and records on past flooding to relate probability of occurrence versus magnitude. No structure other than important bridges should be allowed to build in the flood plain area while taking flood proof and flood protection measures.

Such efforts are being made by collectively or in isolation on international, national, province and district levels. However there is a strong need to give them sound directions and guidelines to align their activities accordingly in order to help facilitating with appropriate disaster management system.

2.2 DATA SOURCES, QUALITY AND LIMITATIONS

An overall detail regarding the datasets and corresponding data sources used is provided in the Table 2.6.

The data we have identified for use is divided into 3 categories;

1) Base Data
2) Real Time Feed
3) Ground Observations

Table 2.6. Overview of Datasets

DATASETS	***DATA SOURCE***	***DATATYPE***	***USAGE***
VMAP0	National Geospatial Intelligence Agency	Topographic records	Transport, vegetation, elevation etc.
LANDSCAN	Oak Ridge National Laboratory	Ambient Population	Population extent
NIGHTLIGHT	Defense Meteorological Satellite Program	Population (Night)	Population extent
FLOOD EXTENT MAPS	DFO	Flood Extents of past floods	Visualization of past flood patterns
DISCHARGE	Dartmouth Flood Observatory	Discharge	Discharge feed
MODIS	Land Processes Distributed Data Archive Center (LP DDAC)	Flood	Flood extent
CENSUS POPULATION 1998	Census Dept	Population	Tehsil level estimated population for 2010

2.2.1 BASE DATA

Refers to the data, which has to be fed once in the system, to provide the underlying map basis. This data is used for the representation of spatial reality of the study area like road networks, settlements, population extent, historical records, topographic details, existing infrastructure etc. The datasets which have been used as base data include:

(***VMAP Vector Data Set***), Short abbreviation of Vector smart maps. It is based on multiple sets of data which use vector product databases and have various applications in geo information systems, military IT simulation as well as for the production of military digital and analogue maps. Based on scale Vmap datasets are classified into four levels; VMAP0 (level 0), VMAP1 (level 1), VMAP2 (level 2), Urban VMAP.

The VMAP product used in our project is VMAP0. It was acquired by online web sources, as the product is entirely in the public domain.

VMAP0 is a low resolution (1:1,000,000) dataset with global coverage. The data is structured following the VPF (Vector product format). The entire coverage has been divided into four data sets:

1) North America (NOAMER) v0noa
2) Europe and North Asia (EURNASIA) v0eur
3) South America, Africa, and Antarctica (SOAMAFR) v0soa
4) South Asia and Australia (SASAUS) v0sas

This dataset comprises of following data: boundary lines, elevation lines, utility lines, transportation lines, population areas, industrial areas, physiographical areas, hydrological areas and vegetation areas.

Vamp0 is a low resolution database derived in large part of the world. It has limitations regarding data source and scale, which have to be kept in mind in order to properly exploit the data. The collection of features in Vmap0 dataset is based on topologically structured coverages, originally extracted from feature separates. It becomes very costly to overcome these overlaps and gaps in the coverages. Since the data is not accurate, it captures only one quarter to one third of global road data and for regions such as Europe, it covers only 12% of the road network. Some license limitations related to the vmap0 dataset usage are also encountered. The vmap0 specification does not permit cross coverage topology and it does not require precise geographic co incidence of feature between coverages.

(***Moderate Resolution Imaging Spectro-Radiometer***), MODIS is NASA's extensive program for global high resolution imagery, freely available, using two sensors namely Terra and Aqua. Each sensor provides daily full coverage of the surface of earth. Terra is the preferred sensor to acquire imagery in morning while aqua acquires images in afternoon. The Terra and Aqua sensors have significant potential for various operational applications in applied hydrology in a number of ways. Flood characterization, flood detection, warning systems, flood disaster response and damage assessment, flood disaster prevention and mitigation, all these are the areas where MODIS contributes in different ways (Anderson et al., 2003). MODIS imagery at 250m resolution has been used to monitor spatial extents of the Southeast Asian Flood 2000. Khan et al., (2011) coupled hydrological modeling for flood inundation mapping with satellite remote sensing for Victoria Lake unguaged basin. Terra sensor based MODIS imagery was utilized to generate the flood inundation maps

The data has a variety of spatial, spectral and temporal resolutions. With a viewing swath width of 2,330 km it views the entire surface of the Earth every one to two days. Its detectors measure 36 spectral bands in which 7 bands are designed primarily for the study of vegetation and land surfaces. These bands include: Blue (459-479nm), green (545-565nm), red (620-670nm), near infrared (NIR1: 841–875 nm, NIR2: 1230–1250 nm) and short wave infrared (SWIR1: 1628–1652 nm, SWIR2: 2105–2155 nm). It acquires data at three spatial resolutions: 250m, 500m, and 1000m. The data formats which MODIS supports are Hierarchical Data Format - Earth Observing System (HDF-EOS) format. HDF-EOS is the standard data format for all EOS data products. Both the Terra and Aqua sensors find their applications in applied hydrology in a variety of techniques. Strengths if MODIS imagery include free availability over the internet, the results fall within the acceptable, near to real range, time series data is available during floods, data comprises of various spectral bands and in different spatial resolutions and it excels in providing reliable data to support flood detection in ungauged areas where no other resources for flood monitoring are available.

The data we have used in our study is MOD09A1 500m, which uses the MODIS satellite image acquired by Terra instrument, freely available from NASA's Land Processes Distributed Data Archive Centre (LP DAAC). The said product is obtained via LP DAAC's data access web Modis Reprojection Tool (MRT web) (https://lpdaac.usgs.gov/data_access/mrtweb), which provides us the capability to select the tiles of our area of interest for desired time period and mosaic them. The files in Geo tiff format were downloaded from LP DAAC's FTP link.

Full name for MOD09A1 is "Modis/Terra surface reflectance 8-day L3 global 500m sin grid V005". These datasets are taken every 8 days and composed together to get a product called MOD09 with minimum of atmospheric distortions. Atmospheric corrections for distortions such as thin cirrus clouds, aerosols and gases were implemented during its production (Vermote and Vermulen, 1999).

The spectral description of MOD09A1 surface reflectance comprises of 7 bands ranging from 620-679 (nm) to 2105-2155 (nm) wavelength (Donglian et al., 2011). This product is approximation of the surface reflectance for each band as it would have been measured at ground level after removing atmospheric scattering and correction. MOD09A1 also has quality assessment flags and bands to cater for various image distractions such as clouds, mountain shadows and cloud shadows.

Apart from the usefulness of the dataset, there are few limitations too. MODIS has inherent limitations in observing sea ice and snow. Also, it cannot detect microwave energy through clouds and hence cannot observe the surface when cloud cover is present. The visible bands of MODIS are only used during the day, when reflectance is the dominant mechanism for detecting ice and snow however the thermal bands are used during both day and night to measure sea ice surface temperature by emittance.

(***LandScan***), A global population database product by ORNL (Oak Ridge National Laboratory) through integration of GIS and RS, Land Scan is the finest global population data ever produced at a resolution of less than 1 km. Its population distribution model uses accurate census data usually up to district levels and four primary geospatial data input datasets including night time light data (night light data), roads (key indicator of population distribution), land cover and slopes. Two models of land scan data have been released yet. One is land scan 1998 and the other one is land scan 2000. Based on the cultural and geographic variability, the world has been divided into several different regions and each region is considered to have unique settlement features. For each region, the population distribution model calculates a "likelihood" coefficient for land scan cell. The applications of land scan include the Kosovo refugee example where it has been used for visualizing population migration and changes in settlement patterns using the details on known deaths and number of migrations to and from the region.

Land scan has wide applications in emergency planning and management tools, using its spatially and temporally refined population data. Land scan is constantly updating population data, which is an important aspect in saving lives at the time of calamity. Land scan has a crucial role in monitoring flood hazard assessment and emergency response, for estimating number of people at risk (Bhaduri et al., 2002). Migration of populations from one to another place can be well estimated using multi temporal LandScan data (Morjani et al., 2007).

Landscan data for the year 2010 was obtained from the Food and Agriculture Organization of the United Nations (FAO-UN)

Land scan data used has a grid cell size of 30 arc seconds and represents an ambient population distribution over 24 hour period. It has a spatial resolution of 1km and provides ambient population per pixel. All data is geo-referenced in the geographic projection WGS 1984.

The land scan data is not accurate as compared to census data since it approximates population on the basis of lights which are illuminated only at night time. The approximation of population based on only night light data cannot give us precise results since there are other factors involved that should be catered such as economic development and poverty levels in certain countries.

(***DMSP Night Time Lights Data - Night Lights***), A database being maintained by the United State Air Force Meteorological Satellite Program, that records and quantifies the amount of "stable light" produced in night hours through satellite observations. DMSP operates satellites in sun synchronous orbits with night time overpasses in the 7pm to 9pm range local time. With a swath width of 3000 km and fourteen orbits per day, each OLS is capable of generating a complete coverage of night time data in twenty-four period. The operational data collections have a spatial resolution of 2.7 km. The OLS is an oscillating scan radiometer with two spectral bands. The visible band ranging from 0.5-0.9 (um) and thermal infrared band ranging from 10.5-12.5 (um). Main applications of the DMSP images include most importantly, the estimation of population since persistent light at places is an indicator of the presence of human settlements (Pestalozzi et al., 2012). In terms of disaster management, there are possibilities for night light data to detect the impact of a disaster on human populations including the indirect impacts. Forestry and Forest Products Research Institute et al., (2001) developed an early fire detection system using imagery from DMSP-OLS and NOAA AVHRR in “ANDES” project (Asia Pacific Network for Disaster Mitigation using Earth Observation Satellite). Takashima et al., (2004) used the night light data for estimating inventory damage for a large scale earthquake disaster.

Night light data set can be an effective tool towards mapping the disaster impacts on urban settings and human populations by comparison of stable lights produced before and after the disaster event. Also it can help to assess any infrastructural loss due to fire outbursts or power failures as triggered by a disaster, as well as changes in spatial extents of a disaster hit area.

Ten rasters for the period of 2000-2010 were downloaded from online sources, for the extents of Pakistan.

The 2000 night time light datasets are cloud free composites processed specifically for the purpose of change detection. The production was considered to be more automated and accurate than the methods used for 1994/95. The processing included automatic cloud detection and a modified light detection algorithm to capture dim lighting. Human settlement was separated from the fire, based on their low brightness and illumination as compared to fire.

Past analysis have shown that there are significant differences between various spatial measures of urban extent and the spatial extent of lit areas in the night lights data (Welch and Zupko, 1988). The lighted areas detected by the OLS are consistently larger than the geographical extents of the settlements they are associated with. The large spatial extent of the lighted area as compared to the actual developed area is referred as “blooming”. Its caused by the coarse spatial resolution of the OLS sensor and the detection of diffused and scattered light over areas containing no light source, large overlap in the foot prints of adjacent OLS pixels and the accumulation of geo-location errors in the compositing errors Usable observations might get reduced by solar and lunar contamination (Elvidge et al., 2004).

(***Flood Extent***), The most common type of flood maps is flood extent map. It shows the inundated areas of a particular flood event. It may be any historical event or may be hypothetical event with a specific return period. The extents of single or multiple past flooding events can be depicted via flood extent map. Flood extent map provides an approximation of the extents of probable maximum flood events. Since these maps are easy to depict, they can often be supplemented with point information on other flood parameters such as velocity or depth parameters (Moel, 2009).

Flood extent map were acquired from Darthmouth Flood Observatory (DFO) in a vector format. The map shows extents of all the major floods in the history of Pakistan. Initially the data was available on global level which was then clipped to Pakistan level.

(***Tehsil Level Census Data***), Tehsil level population records for the year 1998 were acquired from PCO, Islamabad.

A Census is based on house to house survey therefore it estimates the population accurately but projecting population for 2010 from 1998’s records is prone to statistical errors. Using census records for disaster management cannot give human loss estimate as people are counted only at their residence. The Census data quality depends on the law and order situation in certain parts of the country. Access of enumeration and supervisory staff in troubled areas, security of census documents in sensitive areas, distortion of population figures due to linguistic and ethnic feelings in certain areas, political linkage of census data in terms of representations in assemblies and distribution of financial resources among provinces make census a sensitive issue.

2.2.2 REAL TIME FEED

This includes the data from online web sources, which is being maintained on a regular basis at the source, and is subsequently being integrated in our system through web scrapping. The web scrapping technique helps system maintaining automated updates on the data giving us near real time estimates.

(***Discharge Updates from DFO - Dartmouth Flood Observatory***), An initiative of Dartmouth College, the Dartmouth Flood Observatory maintains worldwide satellite record of large flood events and stores a substantial amount of the records in its archives. Observatory provides data on flood detection, indexing of inundation maps, surface water records and global flood records. DFO also maintains global satellite river discharge measurements at river gauges, called River Watch, which is updated daily, at 13:30 MST (Mountain Standard Time), acquired using NASA's AMSR-E (Advanced Microwave Scanning Radiometer- Earth Observing System Sensor) and AMSR-2 (Advanced Microwave Scanning Radiometer 2).The River Watch gives the percent runoff along with flow status at each discharge gauge classified as low, normal, flood, major flooding. The discharge data for Pakistan is incorporated in the system using web scrapping.

As the data is being scrapped from the web source, quality depends on the daily updating of records at the source website and also the internet facility available.

2.2.3 GROUND OBSERVATIONS

As there is no better information than what is present on ground at that time, incorporation of ground observations for decision making at the time of disaster is of primary importance. A system that is capable of storing archived data along with the real time feed about dynamic datasets when combined with the observations from ground turns into a comprehensive decision support system for disaster management.

The idea was to prototype a sensor observation system which can feed in with the desired observations in real time and making the updates available on the portal to the user for visualization and analysis (flow mentioned in Figure 2.1.) As it is useful for us as a research community to have live and proper records of water level fluctuations/ rainfall etc. in lakes and rivers.

For that purpose, it was planned to prototype a geotechnical component for water inundation level, using a **water depth sensor** which would provide depth indications, incorporation of these ground observations in the system architecture and then making this information accessible on the system. Successful implementation can help extend the system by incorporating multiple other sensors for temperature and precipitation.

Second approach was to incorporate distress calls in the system based on **SMS updates**. System would have the capability of receiving distress calls from disaster hit areas and generating warnings, helping the disaster management organizations in streamlining their rescue and mitigation efforts.

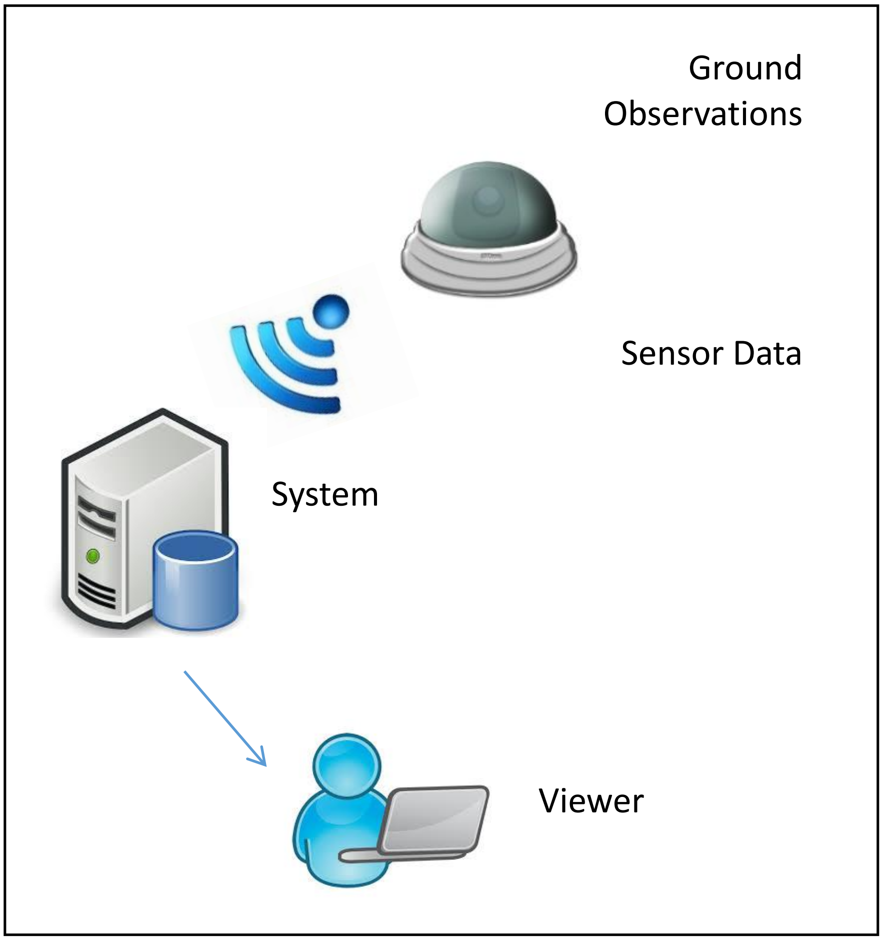

Figure 2.1. Illustration – Sensor based Ground Observation

2.3 ANALYTICAL FRAMEWORK

Mash-ups, and the basic theme which goes behind them has been made quite clear by far. Mash ups generically are used to combine data from multiple sources and create new web services and web pages, consolidating information with an easy to use interface and to merge or overlay entities in the hope of obtaining a comprehensive product which will be more useful or interesting, and which will present a broader perspective than the individual entities on their own.

Three different types of Mash ups are there as per definition:

1. Consumer Mash up.
2. Data Mash up.
3. Business Mash up.

One reason for rapid success of mash-ups was the introduction of different API, (application programming interfaces) like Google Maps API or OpenLayers Javascript API. These map APIs are used by programmer to access maps, and are further combined with other data sources so that something new and unique can be created. A Web mash-up differs from a distributed portal in a sense that distributed portal just gathers the information while mash-up makes something new from that information which is more facilitating and interesting.

Mash ups make web based data more useful, allowing for the reuse of existing applications and rapid application development. Development of a mash up does not necessarily involve extensive IT skills or higher application development costs. Ability to incorporate content that the users were previously unable to develop themselves, due to time or resource constraints, tailors applications to suit user's needs.

Everything comes with a compromise so does technology. Apart from the extreme usefulness, some things are to be taken care of. Mash ups often involve inserting foreign scripts into website which can allow the publisher of the script to hijack your webpages. It's important that you trust the source of the scripts. All the scripts should always be validated before use. Even if reliability of the content source is established, a potential problem is scalability. For example, checking for whether or not, the providers of the map we are incorporating would be able to support the traffic, our site would generate in two years. Security of these contents is another issue, especially for enterprises with very sensitive data. They need to be sure that the contents they are incorporating do not pose a security threat in any way but since there are no defined mash-up standards, this only makes it increasingly difficult to design and implement security mechanisms. While taking about integration of tools in the system, soft wares which can be accessed with a web browser are the only ones which can be included in a mash up, which implies that installed desktop applications cannot be easily incorporated.

Most data sources are not yet built on a service-oriented architecture (SOA), so drawing in the information is not easy. Although mash ups can be created without SOA, they are greatly facilitated by it. Also, the continued support by the owner of the mash up service or API cannot be guaranteed and the end user might have no control over the quality and features of the content.

Some of the examples we have, of Mash ups include:

(*MapLarge*), Spatial Mash-up that uses Google Maps API and other locational data to display information.e.g.it can display seismic activities related to the location on the map.

(Reference: http://www.maplarge.com/Japan-Earthquake)

(*GIS Doctor: Extent Tracker****)**,* Leaflet app where the coordinates of several locations are reported back on the fly. The current code updates the coordinates onscreen on the fly. The page has seven divs that report different attributes of the getBounds() attribute for the map object. (Reference: http://www.gisdoctor.com/leaflet/Bounding_Box.html)

(*MissingKidsMap****)**,* It uses the Google Maps API along with information from the National Center for Missing and Exploited Children (NCMEC) to display a current map of the origins of missing children in the United States, Canada and the United Kingdom. Clicking on a marker or rolling over the name of the missing child on the map opens up an information balloon with case details on the missing child.

(***Web Mapping Service***), Web Mapping Service or shortly known as 'WMS' is a standard protocol that serves with geo-referenced images over the internet that are generated by some map server using data stored in a map database.

Web Mapping Service reformed the Online Mapping experience, especially with the introduction of Google in 2005. The idea was not just helpful in making maps available online only for viewing in a quick and easy manner rather it produced the possibility of creating a mash-up through different Application Programming Interfaces (APIs) like Google or OpenLayers; leading many to proclaim the "democratization of mapping". Web Mapping Services impacted the Map World with vast benefits including possible areas for future development. Special emphasis was laid upon the technical developments as well as development of Base Maps and Map Types from pre-rendered tiles to editable map styles in different viewing modes. While the first maps produced with APIs were mostly static point maps, new features have enabled dynamic and interactive applications with "GIS-like" functionalities, often supported by third party implementations. Figure 2.2. shows the process flow.

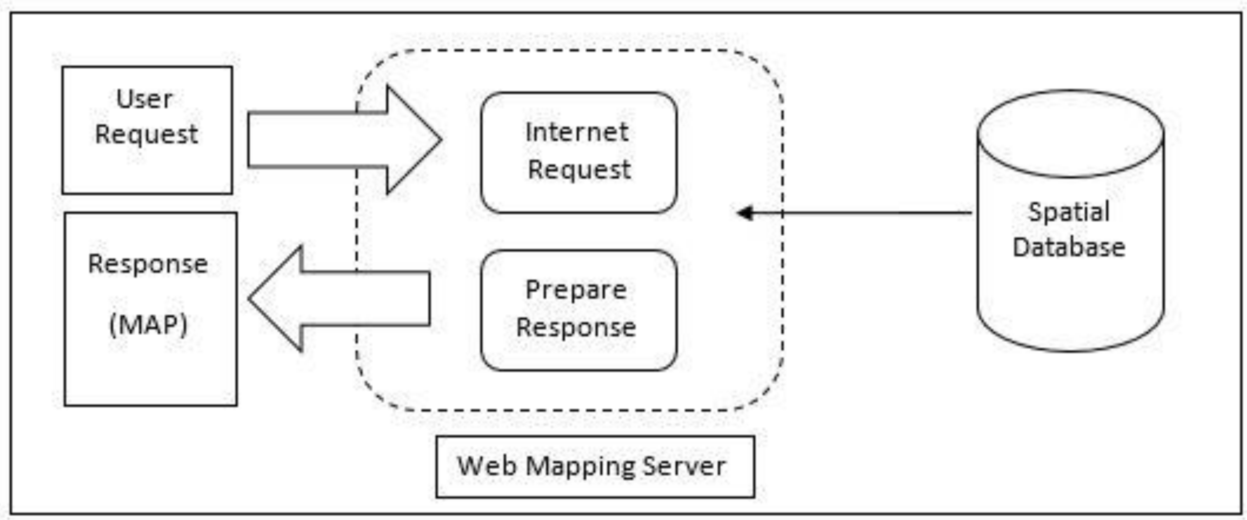

Figure 2.2. Web Mapping Service Architecture

With a desire to make a Geospatial system for Pakistan, there are two important factors that are to be considered; first being the Economy, with people working hard just to make their both ends meet and extensive development required in the basic infrastructure of life, an expensive solution can't proposed for research in the development of disaster planning and mitigation; second factor is the further extension of the prototype system since a stagnant system is not a solution with new technologies being invented every single day and considering the changing dynamics of disaster, floods and its associates.

Therefore, a solution is required which is **Economically Efficient** and **with a capability to be extended** as the problem's complexity and its counter technological solutions continue to progress with time. Considering preferences mentioned, Free and Open Source Development (FOSS) is the only solution. FOSS will provide with free software to be incorporated in the system with thousands of people from spatial and IT domain adding to new solutions to it every single day. Before proceeding further, a review of FOSS is presented.

(***Free and Open Source Development***), Free and Open FOSS pools the conception of open source software and free software. Free software relates to the user's freedom to run, copy, distribute, study, change and improve the software (Stallman, 2009). While Open Source development pertains to any software, code or tool that is freely and publicly available. Some of these softwares are available even with the source code which can be studied, changed, improved or shared under open source license. Open source software is generally distributed under licenses approved by the open source initiative (OSI). There are numerous open source softwares and tools e.g. Mozilla Fire Fox, Google Chrome, Apache HTTP Server, Moodle, Thunderbird and various androids apps. In field of GIS and Remote Sensing some of the common open source softwares include ILWIS, ENVI, GRASS, QGIS, SAGA GIS, uDig, FalconView, TerraView and many more.

The history of open source goes back in the era of 1950’s and 1960’s. However, the official free software movement was launched by Richard Stallman in 1983, by starting GNU project. The GNU Project has resulted in a large number of open source software over time and gave birth to the GNU General Public License (GPL), which is so far the most popular open source license model.

The invention, practice and research of FOSS have developed noticeably in recent past, primarily owing to its better-quality and economic factors. There is an exponential growth in the number of open source projects since 2000 (Deshpande and Riehle, 2008). The use of open source web mapping is growing in other disciplines, such as medicine (Boulos et al., 2010), astronomy (Terazono et al., 2009) and sociology (Ball, 2009)

The biggest and most attractive advantage of open source softwares as compared to commercial software is that there is no longer need to worry about licenses and their management. These products can be used from any location at any time without any tracking or monitoring. The softwares or tools can be installed or uninstalled as many as times, as desired. Open source solutions are also easily portable and compressed requiring much less hardware power to run the tasks. There are no expenses involved with support on using these solutions freely and readily available on internet. On the other hand commercial softwares can only be modified within the limited scope, provided by the original vendor. Not only this but open source softwares are also easy to integrate with various database servers and web servers. Accessibility to source code makes it easy to translate the language of the application unlike most of the commercial softwares (James, 2013).

Keeping in view all the above mentioned advantages, we opted to make an open source application which can benefit and ease users at its maximum.

(***System Architecture***), Figure 2.3. illustrates the basic Web GIS architecture in a very simplified form. A spatial database acts as a data store, from where the data is accessed by the GIS server upon a client request through webserver.

Process flow (Figure 2.4.) for a mash-up starts with the collection of base data from mentioned sources. The data is processed for extents and projections in GIS software. Prepared base data along with the real time ground observations and SMS updates is then imported in a spatial database, from where, a GIS mapping server accesses the data and using some mapping API, serves the data as a web mapping service. Central system then allows for visualization of this information in preferable form through Graphical User Interface (GUI) to the user. Users are of different types, Administrative and Public. The research has the consideration that the system is made for National level Disaster Management.

From here, the major components of the system to be developed are identified and listed as:

1) Spatial Database
2) Mapping Server
3) Base data preparation
4) Ground observation through SMS updates
5) Ground observation through sensors
6) Real time feed from web sources
7) Mapping API

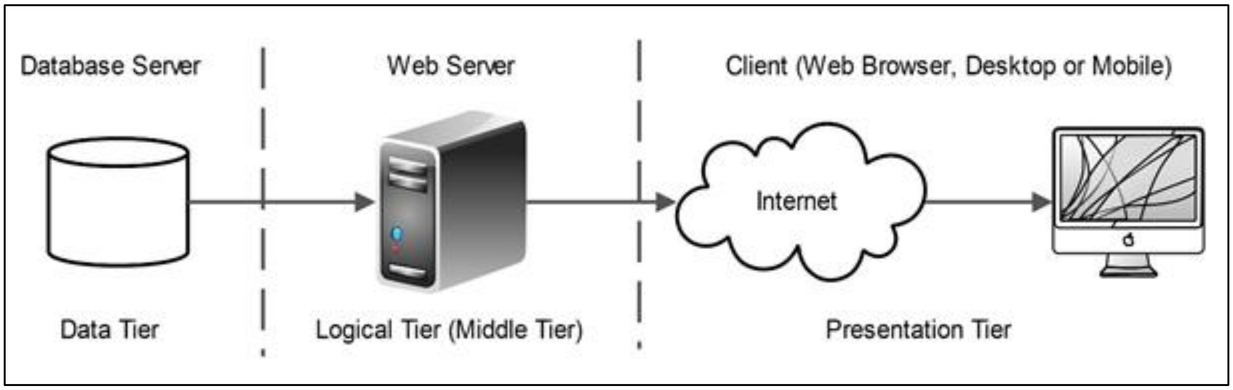

Figure 2.3. Web-GIS System Architecture

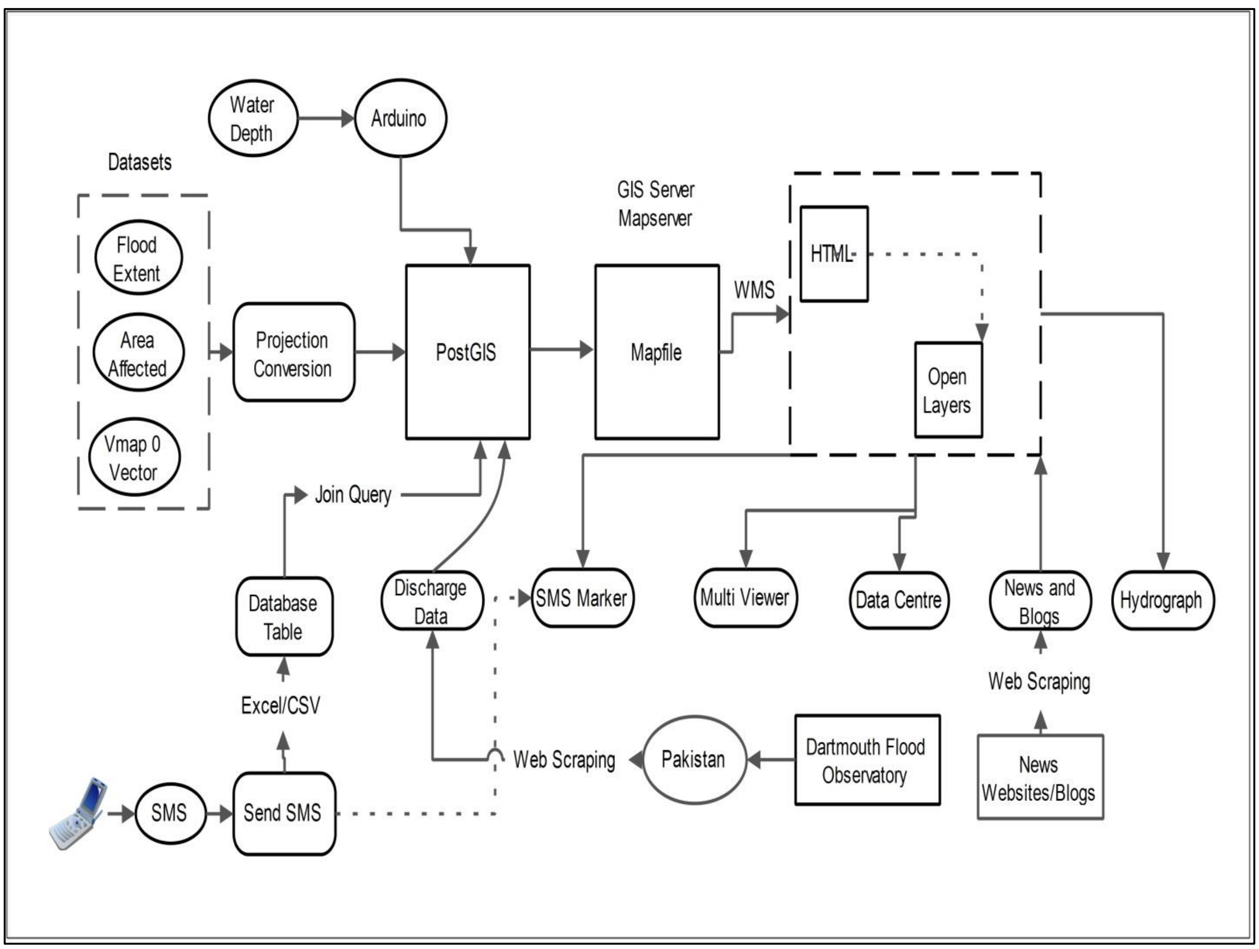

Figure 2.4. Process flow of Flood Web Product

Here onwards, detailed description would be provided regarding each component and their integration to maintain a process flow and to systematically develop a system for spatial visualization.

2.3.1 SPATIAL DATABASE

Being more of cartographic tool for geographic data representation, one of the major tasks a GIS needs to be capable of, is management of huge data volumes. Database management system (DBMS) is therefore the kernel of a GIS (Riguax et al., 2001). Traditionally the role of a DBMS has always been that of an effective and simple warehouse for huge volumes of accounts and business data. The querying scenarios are limited in those cases and the DBMS is designed to efficiently manage that. But, in scenarios involving addressing a spatial query, such a DBMS fails as it does not provide spatial data support and hence cannot manage to answer the spatial query. Need of a database tailored to handle spatial details therefore becomes immediate (Shekhar and Chawala, 2003).

A spatial database management system (SDBMS) is a collection of software that manages the spatial database structure and controls access to data stored in a database (Riguax et al., 2001). It defines special data types for geometric objects and allows the storage of geometric data (usually of geographic nature) in regular database tables. Also, it provides special functions and indexes for querying and manipulating that data. Apart from being a store of information, a spatial database has in it, the capabilities of an efficient analysis tool as well.

The role of SDBMS in the idea of geospatial mash-up is evident. Mash-up works on integrating multiple sources of information i.e. base data, ground data, data from web etc. All this data needs to be stored in a system, from where the mapping server can access it and present for visualization. A spatial database therefore links the data to the web.

Working on the idea of a geospatial mash-up for flood visualization in Pakistan, our choice of SDBMS was PostGIS.

PostGIS (pronounced post-jis) is a spatial database extension of the **PostgreSQL**, an open source relational database management system. It adds several spatial data types to the PostgreSQL and over 300 functions for working with these spatial types. It's the most powerful open source spatial database engine. To the PostgreSQL, it provides functionalities, similar to what Oracle Spatial/Locator provides to Oracle or what the geometry/geography types packaged in Microsoft SQL Server 2008+ add to the SQL Server. PostGIS has been developed on the PostgreSQL object relational DBMS, which offers transactional support, gist index support to index spatial objects and a query planner out of the box for PostGIS.

The main reason for choosing PostgreSQL as the foundation for PostGIS is the extensibility ease it provides, for developing new types and operators and for controlling the index operators. PostgreSQL is known to have many unique features which the other competing databases lack. It offers the ability to choose from a list of languages to write database functions and build aggregate functions; other than the commonly used built in SQL, PL/PGSQL and C, it offers an extensive platform for other languages including PL/Perl, PL/Python, PL/TCL, PL/R, PL/SH and PL/Java. Working with these languages requires additional environment installs. It provides support for arrays i.e. a table column in PostgreSQL can support arrays of strings, geometries, dates or any other user defined data type. Also, it offers object multi inheritance and ability to define aggregate functions.

In the domain of spatial data storage and handling, there are many other alternatives to PostGIS database including MySQL, Oracle Spatial, Microsoft SQL Server 2008 with spatial functionality, SpatiaLite, RasterLine, ArcGIS Geo-database etc. The choice of PostGIS to proceed with the work was made after a comparative process. The main idea was to go with the theme of Open Source GIS, as belonging to the academic community open Source GIS would save us from "re-inventing" the wheel. Ease of extendibility, stability, interoperability, quick learning are some of the strengths PostGIS possesses when compared with other competitors as the Figure 2.5. shows (Ballatore et al., 2011). It has support for both open source and commercial tools, numerous toolkits and application frameworks all of which use it as core data storage and manipulation tool (Obe et al., 2011).

Working with PostGIS started with the installation of PostgreSQL 9.3. pgAdmin 3 is the administrative graphical user interface (GUI) which is used to set things up in the database.

In the GUI, first step is to connect to the database server. Once the connection was established after specifying the host and port, new databases were created for vector and raster data. Required extensions were then added to the databases to enable them spatially. The base data was first adjusted for spatial reference and required extents in ESRI's ArcGIS and then loaded to the PostGIS databases using the shapefile loader plugin and raster2pgsql raster loader executable respectively. The datasets were then visualized in Quantum GIS using the capability of QGIS to load data from PostGIS database. After getting all the data prepared in databases, next step was postGIS-Mapserver connectivity. Mapserver work on the mapfiles and QGIS has got an extraordinary capability to generate mapfiles which saves user from excessive coding. The required dataset needs to be opened up in QGIS, adjusted for symbology,

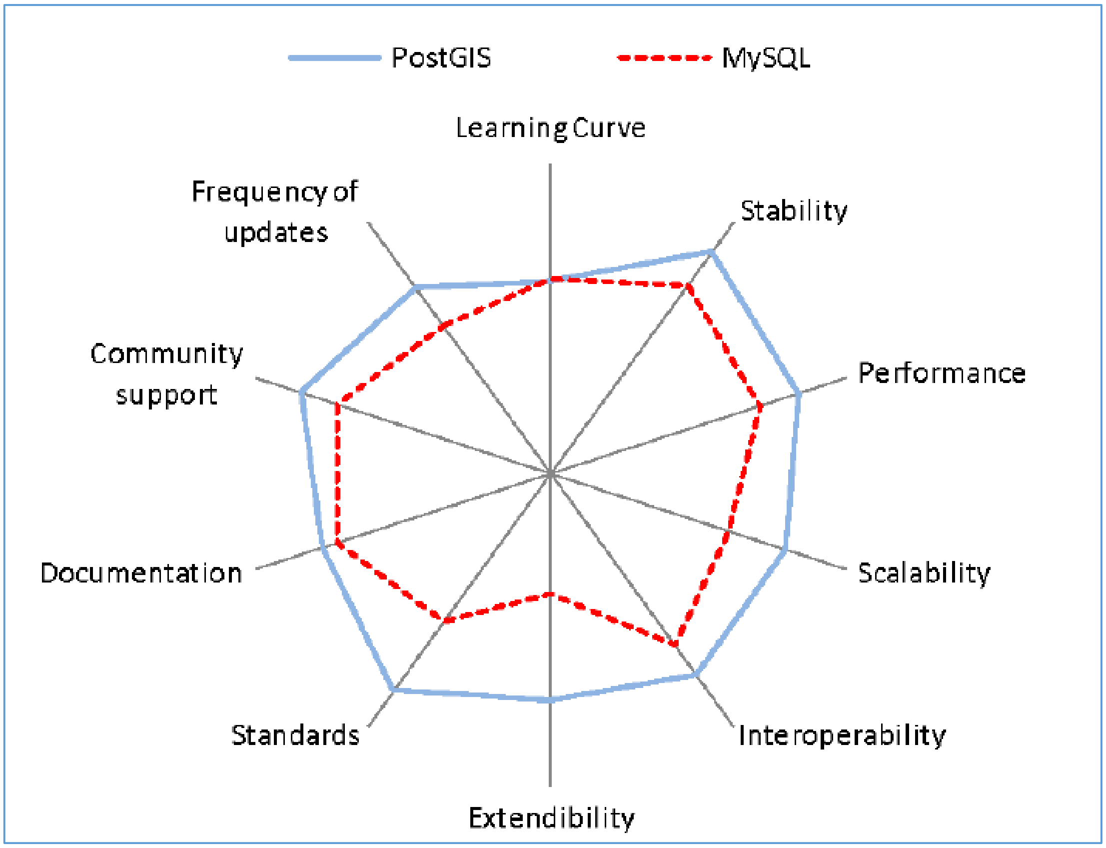

Figure 2.5. PostGIS - MySQL comparison (Ballatore et al., 2011)

and through the Mapserver export option, a mapfile can be generated which after the required adjustments, is ready to be used by MapServer.

Using this facility, a single mapfile was generated with all the required datasets, and the connectivity between PostGIS and MapServer was established. From MapServer, the data was then overlaid in OpenLayers and multiple other functionalities were added as per the requirements. The process flow with in a spatial database is shown in Figure 2.6.

Spatial DBMS is the core of any GIS. A GIS needs to access the information out of the SDMBS before carrying out any spatial analysis. It would therefore not be wrong to conclude that GIS is designed as a frontend of the SDBMS (Shekhar and Chawala, 2003). While GIS performs analytical functions, it's the SDBMS which actually drives that analysis efficiently and adds to the GIS effectiveness.

2.3.2 GIS SERVER

Web mapping servers act as a framework to publish a GIS application online. Generally, these servers include functionality to query spatial DBMS, projection support, integration with other geographic libraries as well as vector and raster support. Moreover, interoperable web standards have been developed by the OGC in support of web mapping, including WMS, WFS, web coverage service (WCS), geography markup language (GML) and styled layer descriptor (SLD).

WMS and WFS are widely used services to request maps and get information about the geographic features. These OGC standards have allowed numerous projects to be published online since the beginning of the FOSS movement (Sanz-Salinas and Montesinos-Lajara, 2009).

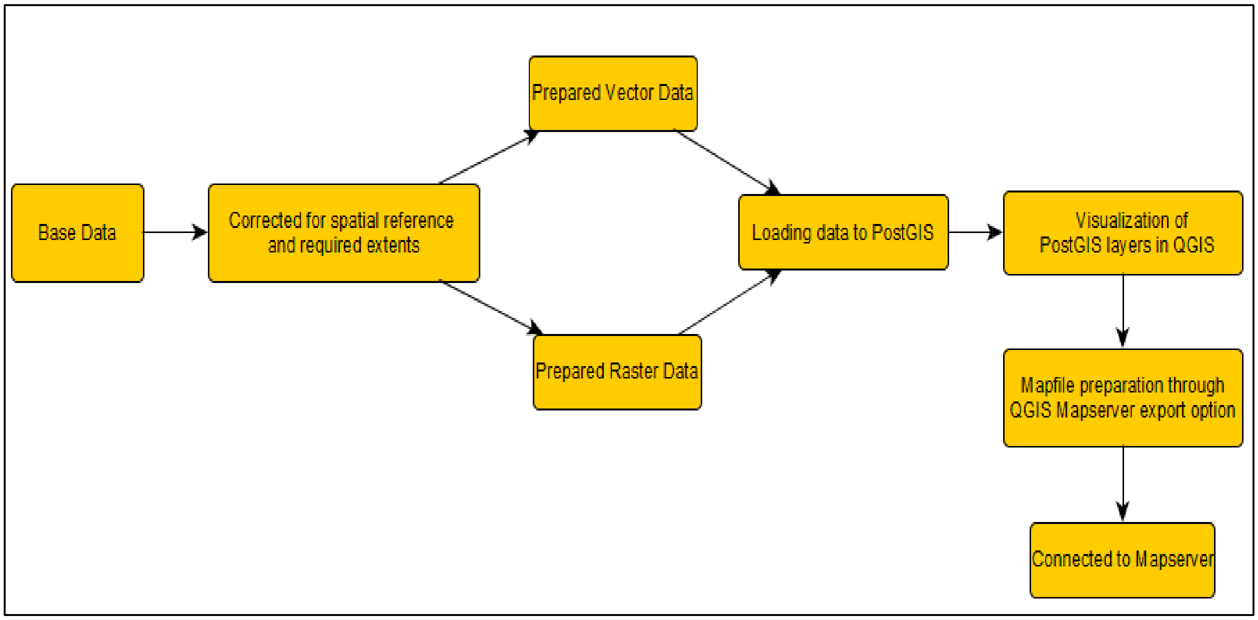

Figure 2.6. Process Flow SDBMS

(***MapServer***), desribed by Kropla (2005), is a widely used open source web mapping project for developing interactive and interoperable web GIS applications. Fully compliant with various OGC standards such as WMS, WFS, WCS and SLD, MapServer supports an extensive variety of vector and raster formats. MapServer runs as a common gateway

interface (CGI) application with Apache and Microsoft web servers. MapServer has strong cartographic support and dynamic capabilities. A map file defines styles and symbology that are used to render a fully customized map. MapServer also has built-in support for many scripting languages such as Perl, Java, .NET, PHP and direct databases support for PostGIS, Oracle Spatial and MySQL.

(***GeoServer***), developed more recently than MapServer, is a popular open source GIS project. It has a web administration tool to configure its spatial and non-spatial options. Apart from WMS, WCS and WFS, it additionally supports the editing of feature services on the client side using WFS-transactional. GeoServer is built on Java technology and runs on an integrated Jetty web server. A significant feature of GeoServer is the use of SLD, an OGC standard to render the visual style of the map. Other features include an integrated OpenLayers, Google Earth support for overlays using keyhole markup language (KML), GeoWebCache for tile mapping and wide support for many DBMS like PostGIS, ArcSDE, Oracle and DB2. A detailed description of GeoServer and its applications are covered by Erle et al., (2005).

Ballotore et al., (2011) researched on the comparison between different open source geospatial web mapping technologies that includes Web GUI libraries, AJAX libraries, Web Mapping Servers, Spatial Libraries, Object Relational Mapping and Spatial Database Management Systems. They researched through acquiring answers to a questionnaire from community associated with all these communities as developers and users. Total of 301 questionnaires were used to finally produce the result which were in form of Radar Chart. Radar Chart represented the minimum score at the center whereas the maximum score was at the outer side. The comparison between different Web Mapping Servers is as described in the Figure 2.7. from the research.

Considering the different factors compared in this research and presented in form of radar chart, MapServer is the obvious choice as considering Performance, Scalability and Community support, Documentation and Stability, it has the maximum score.

The only drawback of MapServer is its Learning Curve which scored less than that for GeoServer. But considering the advantages especially the robustness, MapServer is selected as the obvious choice.

Map Server was used in the system as the sole service provider. The idea was to issue services for datasets available in database and send the services to Front End of the web system which in this case is OpenLayers. The complete work of mapserver is done in a single file called Mapfile which has a ".map" extension and is based on a simple language similar to C. Mapfile is the heart of Mapserver in which objects and their attributes are defined in such a way that map visualization properties are determined. It contains entire symbology, fontset, visualization, spatial queries and attribute of the map. Elements of a mapfile generally include Cartographical symbol construction with map server, Geometry transformation, Class, Cluster, Display of the characters in map server, Expressions, Feature, Fontset, Grid, Include, Join, Label, Layer, Leader, Legend , Map, Output format, Projection, Query map, Reference, Scale bar, Style, Symbol, Templating, Union layer, Web, Xml map file support. The labels used in project mapfile include: Map, Output Format, Legend, Web, Metadata, Symbol, Style, Layer, and Projection. In our system, MapServer was used to serve shapefile data (vector data) stored in database as a Web Mapping Service.

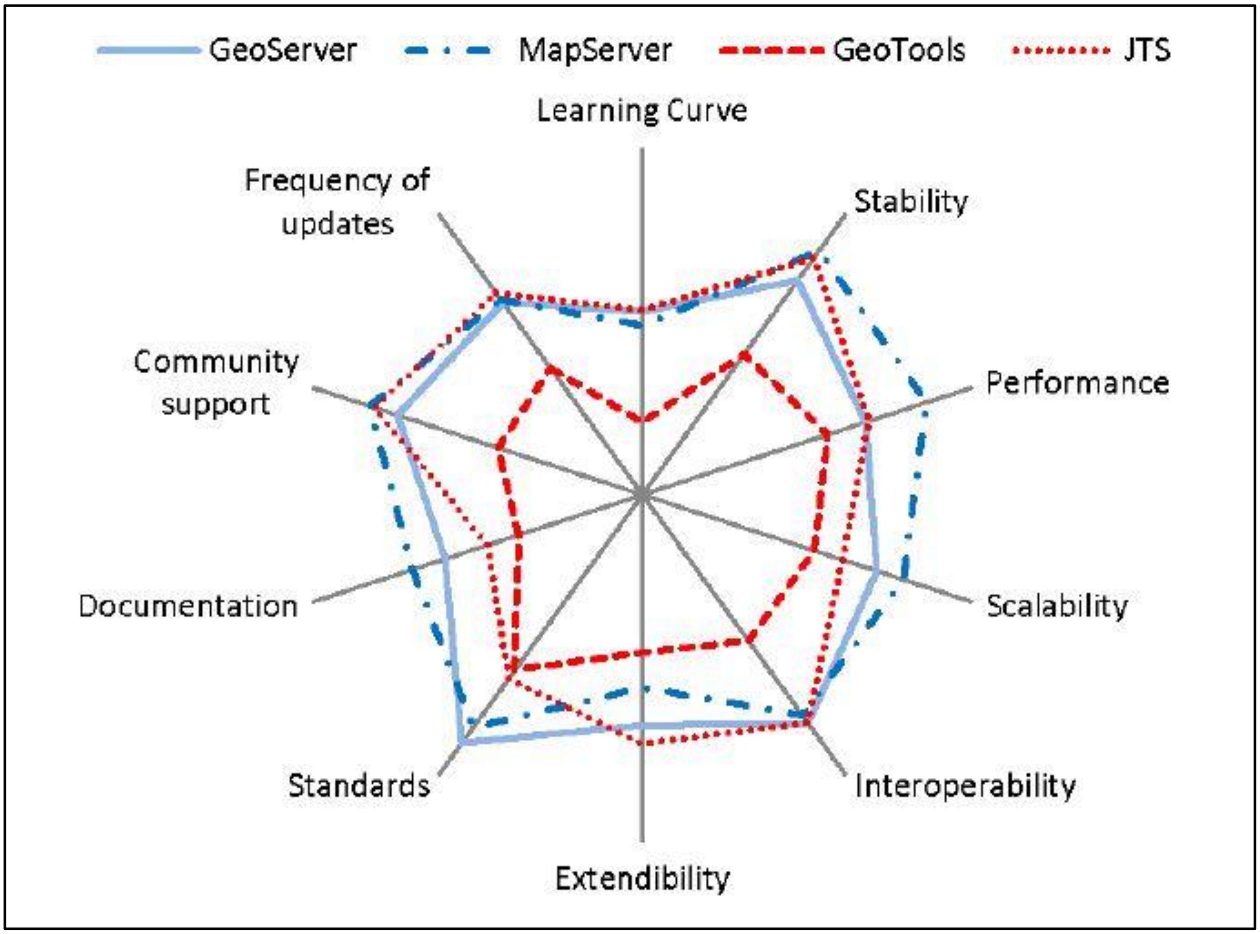

Figure 2.7. Comparison between different Web Mapping Servers. (Ballotore et al., 2011)

PostGIS - MapServer connection was achieved using syntax:

```
CONNECTION
    "dbname='project' host=localhost
    port=5432 user='postgres' password='user'
    sslmode=disable"
    DATA 'geom FROM "pak"
    USING UNIQUE gid USING srid=4326'
    PROCESSING
"CLOSE_CONNECTION = DEFER"
```

The purpose of Web Mapping Service is achieved using 'Map Server' as the server to provide with map services from data that is stored in PostgresSQL (PostGIS). The Client side is handled by the OpenLayers JavaScript Library. All the request are handled by the built in capabilities of MapServer.

Map Server proved to be the right choice as it provides with the robustness required to play with multiple datasets from different sources and conversions of different projections and justified to be the perfect solution for the problem of Spatial Mashup.

2.3.3 BASE DATA PREPARATION

After completion of data download, the first step was to process the data for use. ESRI's ArcGIS software was used for this purpose, because of the hands on experience on it. In a Geo database, the vector and raster data were added, clipped on the extents of Pakistan and assigned geographic coordinate system of WGS 84 as mentioned in Table 2.6. MODIS imagery obtained was used for producing flood extents for the year 2003-2012. Detailed working is explained.

Table 2.7. Base Data Processing

DATASET	***PROCESSING***
VMAP0	All layers clipped on Pakistan extents, coordinate system WGS 84
Landscan	Clipped on Pakistan Extents
DMSP Night Light	Clipped on Pakistan Extents, coordinate system WGS 84
MODIS	Water Masking for pre peak and post flood events
Census Population 1998	Excel to .shp export in ArcGIS

(*Working with MODIS*), In our study, we were supposed to produce water masks using MODIS imagery for pre flood period, peak flood period and post flood period for five years in which there was heavy flooding in Pakistan. Those years include 2003, 2005, 2010, 2011 and 2012. Thus, 15 water mask maps were prepared showing results in two classes: Land and Water. Water masking is one of the efficient ways of representing the extent over which water was distributed over an area prior to, during and after the flood event. The process flow is shown in Figure 2.8.

According to the surface reflectance curves, water shows maximum reflectance in VIS (Visual infrared) band which is band 1 in MODIS's case (620-679 nm) whereas water has lower reflectance than vegetation in NIR (841-876nm) band which is band 2 in this case. (Donglian et al., 2011) In order to identify water related pixels in a MODIS raster, there are different indices that are used. (Rogers and Kearny, 2004) Normalized difference water index (NDWI) and normalized difference vegetation index (NDVI) have been used in past to identify surface water features. Xiao et al., (2005, 2006) used two indices: Land surface water index (LSWI) and Normalized difference vegetation index (NDVI) in an algorithm to calculate the distribution of paddy fields in southern china and southeast of Asia and derived flood maps. Ji (2005) successfully used Normalized difference water index (NDWI) to find water features using MODIS imagery.

But there are a couple of problems that pertain with this approach. 1) NDWI's calculated from different band combinations (near infrared, short wave infrared or visible) can generate different results. 2) NDWI thresholds vary depending on the proportions of sub pixel water/non water components. Research shows that main reason behind using NDWI to detect water is that Short wave infrared (SWIR) band is quite sensitive to the moisture content in the soil (Gao, 1996; McFeeters, 1996; Jackson et al., 2004; Rogers and Kearney, 2004; Tong et al., 2004). Various

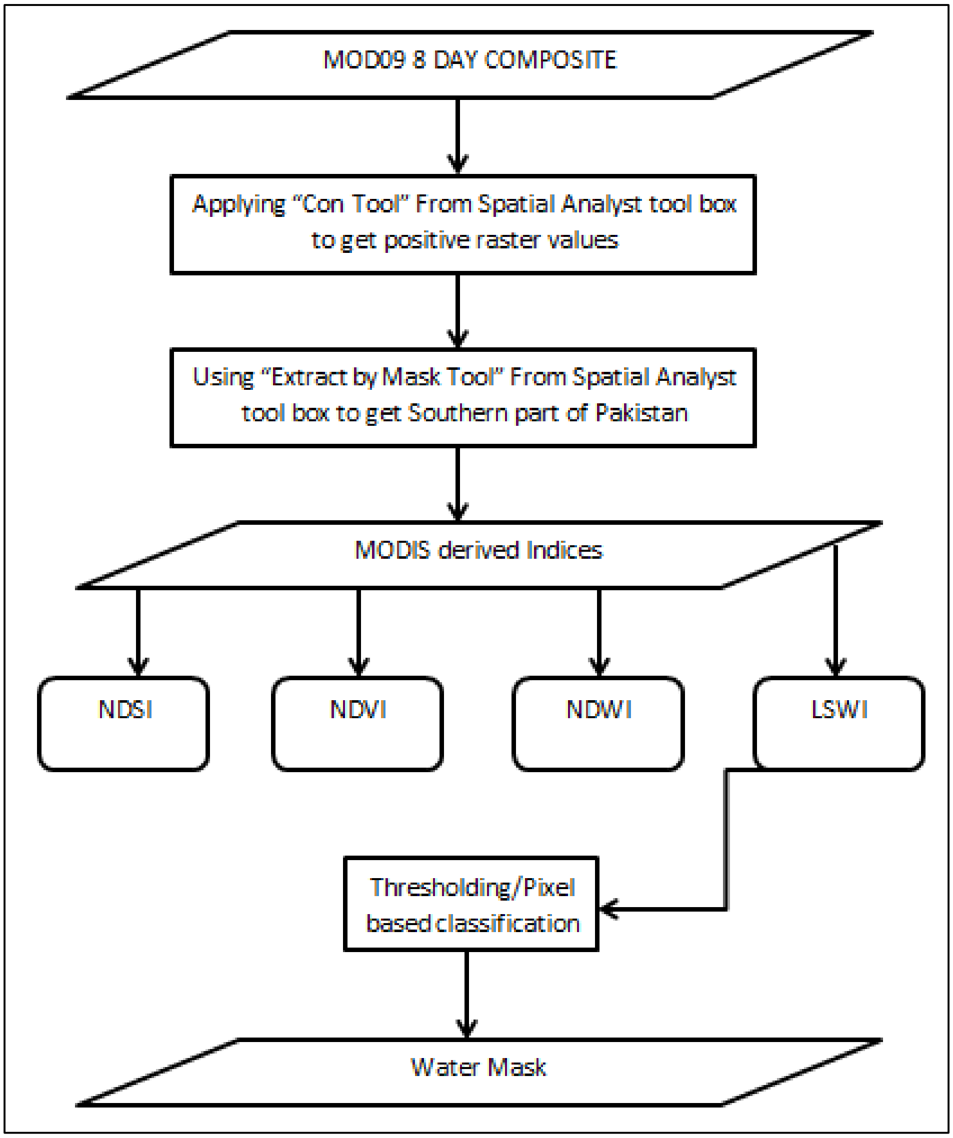

Figure 2.8. MODIS – Process Flow

studies have been conducted to detect water in the soil using spectroscopic characterization of SWIR.

Owing to the strong research support, NDWI was used to identify water features in the imagery. In the results that were obtained from NDWI, water pixels were getting confused with snow pixels on the northern part of Pakistan. Snow shows large surface reflectance values in the visible spectral bands and possesses the potential of having an impact on the NDVI and LSWI values (Hall et al., 1995) (Hall et al., 2002). To minimize the effect of snow, snow masks are developed in general practice. Normalized difference snow index (NDSI) was calculated for each 8 day composite using surface reflectance values from the green and NIR bands and then applying the threshold i-e. NDSI>9000 to identify pixels covered by snow.

In order to precisely delineate water pixels from the MODIS raster, we used different band combination using formulas of four indices. We calculated Normalized difference vegetation index (NDVI), normalized difference water index (NDWI), normalized difference snow index (NDSI) and Land surface water index (LSWI). The results from each raster were compared on the basis of which index best represents the water features. We found out that Land surface water index (LSWI) gave the best results out of the four indices. The results obtained from LSWI clearly indicated the water courses, water bodies and any pixel containing flood water. By using pixel based classification approach on LSWI, a threshold value was determined marking the boundary between water related pixels and non-water pixels upon our understanding in the raster calculator. This resulted in a raster that has only two classes with pixel values 0 and 1. 0 shows “Land” and 1 shows “Water”.

2.3.4 GROUND OBSERVATION THROUGH SMS UPDATES

Occurrence of disasters, especially natural disasters is an event usually beyond human control. The maximum we can do is to provide mitigations, manage and somehow minimize the loss of life, loss of property and infrastructure, loss of social stability and human suffering (Singhal et al., 2014). Use of Information and Communication Technologies (ICTs) can support the practice of disaster risk management (DRM) both in times of crisis, and in times of planning and reconstruction. The revolutionary potential of ICTs lies in the ability to instantaneously connect vast networks of individuals and organizations across great geographic distances, as well as to facilitate fast flows of information, ideas, capital, and products. Use of ICTs as essential tools for cooperation and collaboration is increasing tremendously (Williams et al., 2014).The ease of Short Message Service (SMS) for information exchange and high penetration of mobile phone technology worldwide makes the role of mobile phones crucial in coordination and control. The usage of mobile units to send geo-referenced updates on disaster situation, stocks of relief supplies, human loss and other time-sensitive information continues to multiply (Dlinskaya et al., 2013). Fajardo et al., (2010) made use of SMS technology to record locations of people in need, while developing a mobile disaster management system for Philippines. SMS processing has also been used for getting direct updates on human and property loss from the population affected in the Haiti earthquake 2010, as part of the use of digital for effective response (Dlinskaya et al., 2013). Use of SMS service in the aftermath of Indian Ocean Tsunami 2004 helped people connect to displaced families and for coordination with relief providers (William et al., 2014).

While proceeding with the idea of geospatial mash-ups for floods, SMS update integration in the system was an important component as the community directly affected by a disaster or the people on ground are the most reliable sources of information in real time. This requires the system to receive SMS updates sent from multiple locations, store it in the SDBMS, retrieve and present them on the map as information popups at the respective geographic locations. The possible options for achieving this capability are either using a dedicated GSM modem, a GSM mobile phone, or using SMS gateways or APIs.

To enable our system to incorporate ground level updates using SMS technology, we used the SMS gateway provided by the website 'sendSMS.pk'. Free user account was registered on the website which enabled receiving and sending texts on and from the account. To retrieve the received messages from the account, inbox was exported to excel sheet format. The excel sheet was then exported to .CSV (comma separated format). Next step was to feed the data into the SDBMS. The .CSV file was then imported into a database table inside PostGIS. The messages being received on the system do not contain exact location information in terms of geographic coordinates; rather they convey the exact district and tehsil name along with the relevant update. Manual geo-location is therefore required for extracting the location to be presented on map. For its solution, the idea was to spatially join the database tables of tehsil layer and received messages on the basis of tehsil name mentioned in the SMS table.

The output of this spatial query is accessed by MapServer through mapfile and the SMS location points are displayed on the OpenLayers basemap. Further the Openlayers Get Feature Info function is used to show the SMS information as a pop-up on the particular location. Figure 2.9. shows the workflow. The SMS processing part has been kept totally manual. It supports the idea of database administrators who would work on SMS screening, database import, manual geo-location of messages using spatial joins and showing the information as a pop up on the base map, as the prototype system is practically extended and implemented.

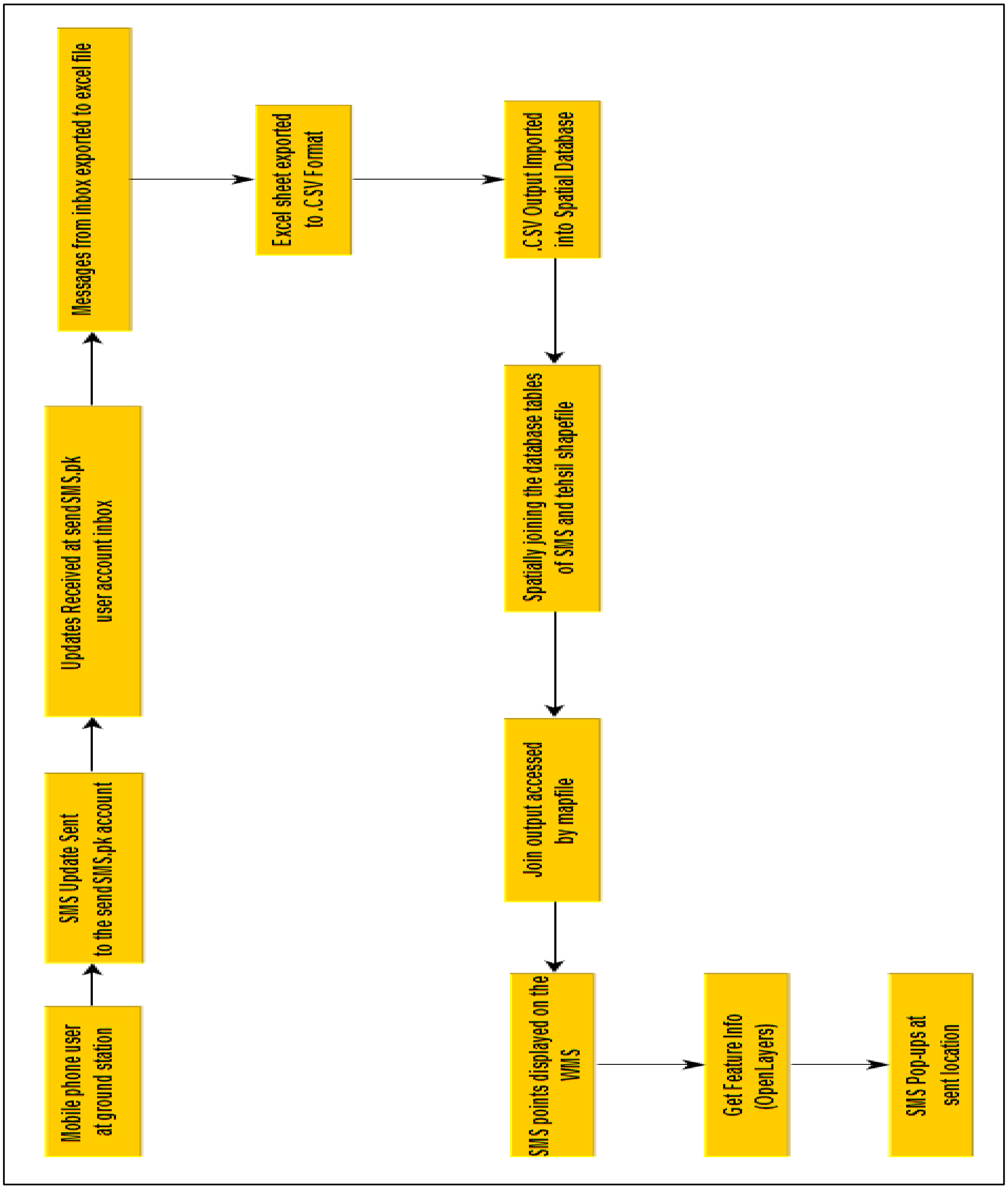

Figure 2.9. SMS Updates

Such manual SMS processing has also been practiced in the Haiti earthquake response 2010 (Dlinskaya et al., 2013).

2.3.5 GROUND OBSERVATION USING SENSORS

(***Real time water depth sensor***), Numerous water depth sensors are used worldwide to know about the depth or level of water in particular channel. Use of such sensors help maintain a constant contact with the data, therefore identifying the problem, as it occurs and maintaining the quality of data. Furthermore if this real time sensor is incorporated with GPS, its efficiency increases exponentially because it permits fewer trips to the station. Thus less money spent and therefore increased efficiency (Mike, 2009).

We have used Water Level Advance sensor which is a simple indicator to indicate the water level at 4 stages i.e. empty, low, medium and full by using respective LEDs. This circuit requires only 12 volts to function, which can be supplied either by battery or a power supply. To assemble the circuit, negative terminal of the battery has to be connected with the lowest level of the tank by a wire. Whereas the other terminal will hang up to the maximum level of water.

(*Arduino*), Arduino is an open source electronics prototyping platform. It can be incorporated in many projects because it is easy to adapt and flexible to use. Arduino was 1st introduced in 2005. It was designed to provide a cost effective and easy way to create various devices which interact with the environment using actuators and sensors. In the beginning Arduino was excessively used in robotics and motions detectors. With the passage of time it has been incorporated in almost all fields of science and technology. It comes with simple development environment that runs on personal computers. Arduino programs are usually written using C and C++.

Arduino can be interfaced with a variety of sensors and can thus sense the environment. It consists of a microcontroller on the board which is programmed based on Arduino programming language and development environment. Arduino can communicate with various softwares or programs running on the computer. Arduino board can be bought preassembled or you can build it manually according to your requirements.

We have used Arduino to fetch the real time discharge data, which has to be then fed to our database. Hence it will help in giving the real time discharge data on our spatial mash-up online about the particular locations, in which the sensor has been installed.

In this project Arduino was used alongside Water Level Sensor, which has a Wading Rod attached to it marking four different levels of water depth. When a certain water level is achieved, the circuit gets completed and signal is passed on to the system that respective level of water depth is achieved. Alongside passing the signal to the center station, there are Light Emitting Diodes (LED) which mark the level of water according to assigned color coded bulbs, where white is Low, Green shows medium, Orange shows High and Red marks the Extreme Danger situation. Global Positioning System Sensor is a small device to estimate the Coordinates of a position in form of Latitude and Longitude. The purpose of attaching the GPS with Water Depth Sensor is to Geo-Locate the depth information. The complete packet of information is displayed on a Liquid Crystal Display (LCD) Screen as well as passed on to the data center, where data is processed, ingested into database and then made visible to for the analyst on the Web System. The complete process flow is described in Figure 2.10.

The process compliments the idea of integrating a Real Time Ground Information on to web system for flood mitigation as ground happenings are the primary delimiters of decision making in such processed. If a single sensor is smoothly prototyped with the system that indicates a whole

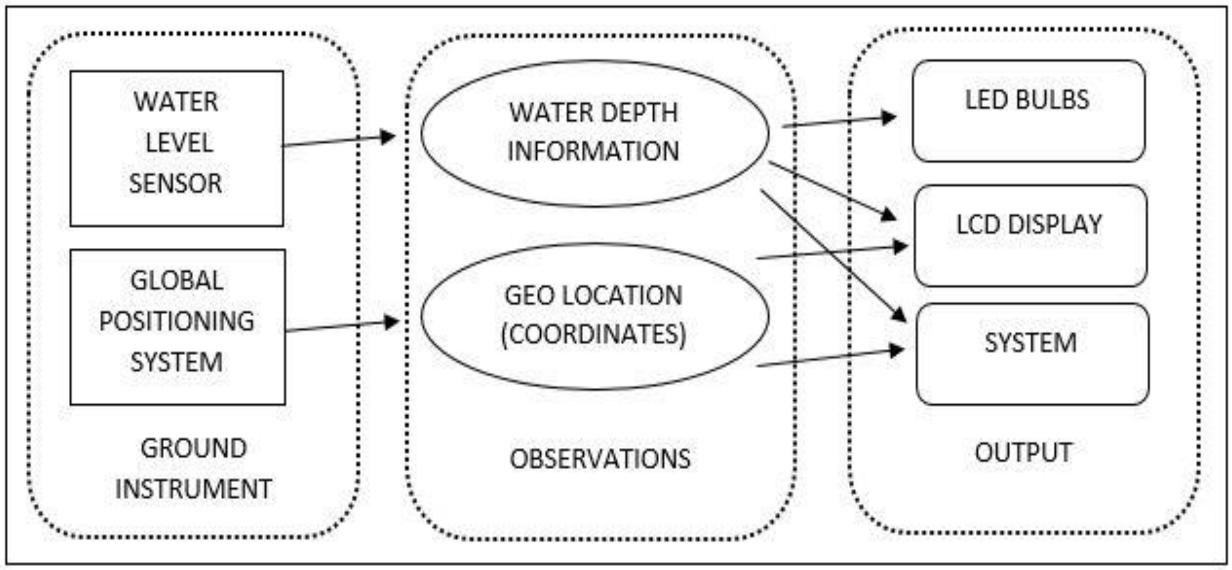

Figure 2.10. Real Time Ground Observation Architecture

assembly can be made to give depth information of various location on the disaster mitigation web system may it be River Streams, Households, Agriculture Area or Storage places etc. To successfully imply the protyping; a Virtual Machine was established as the Data Center/Web System and it was connected to a system which acted as the Ground Station as described in Figure 2.11.

2.3.6 NEAR REAL TIME FEED FROM WEB SOURCES

Web scraping, also known as web harvesting, is a computer software technique which is used to extract information from various websites. At times, there is a requirement to extract data from the 3^{rd} party web sources on the internet, which normally can only be viewed through a browser. These websites do not offer the download of displayed data in local storage. One option is to manually copy paste the data to a local file in the computer which is a very tedious and time consuming task. The second better option is to automate the process using a web scrapping software, which will accomplish the task within a fraction of time.

Web scraping can be done without doing web crawling. On the other hand, for web crawling you have to do some sort of web scraping. Web crawling deals with iteratively searching and fetching web links staring from a list of seed’s URL.

We have used web scrapping to fetch the data about the river flow status and runoff at discharge gauges from DFO website. For scraping the news, it is important to know the format of that website, as scraping is at its most powerful peak when it is site specific.

Once the format of the site is exactly known, more can be dug into the document hierarchy by examining the html source and finally a way can be designed to extract the prescribed information.

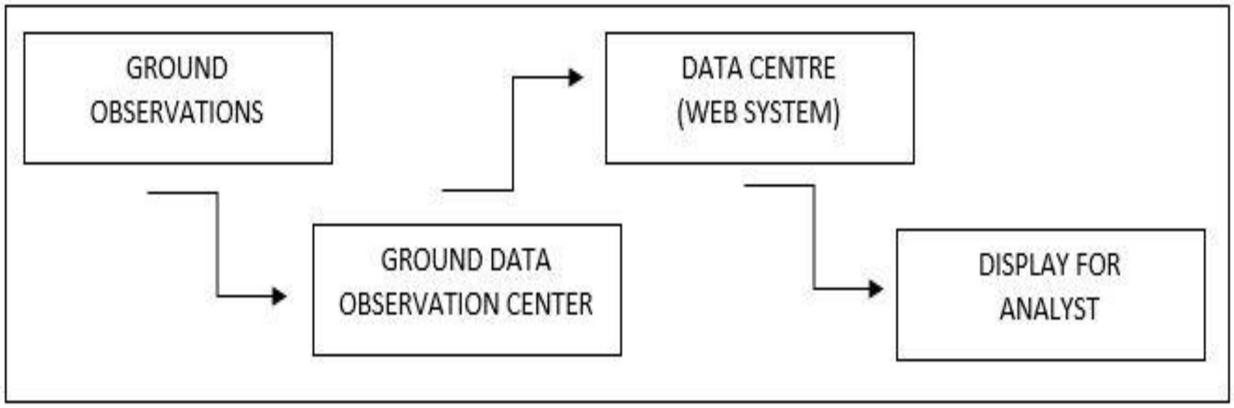

Figure 2.11. Real Time Ground Observation Process Flow

2.3.7 MAPPING API

OpenLayers is an open source, client side Javascript library which is used for making interactive web maps and is viewable in almost all web browsers (Hazzard, 2011). Since it is client side library, hence no serve side special softwares or settings are required. It was originally developed by Metacarta in June 30, 2005 as a response to Google Maps. OpenLayers is an API that allows you to develop your own maps in an interactive way. Instead of developing mapping application from scratch, you may use OpenLayers to make mapping part easy to develop and interactive to use. The library was originally based on Prototype Javascript Framework.

All the web applications operate following the Client/Server Model which constitute of a map client e.g. OpenLayers which communicates with a web map server e.g. WMS or Google maps. OpenLayers also allows having multiple backend servers that can be used by the map product by creating and adding a layer object in map. OpenLayers can communicate through several protocols. Creating the simplest map via OpenLayers require following things:

1) Including OpenLayers Library files.

2) Creating HTML element.

3) Creating map object.

4) Creating layer object.

5) Adding layer to map.

6) Defining the map's extents.

OpenLayers as described previously is an Open Source Client Side Application Programming Interface (API) used worldwide to construct beautiful web mapping applications.

OpenLayers comes up with a variety of already made functions which makes more robust than other programming interfaces of such kind.

Similarly, we used OpenLayers as our client side interface of web mapping application. The most prominent feature of OpenLayers used is its capability of bringing various Base Layers over which many overlays can be made of base datasets as well as any other spatial, geometrical or geo-located datasets. The Base Layers chosen for our system was of Google which are of four different categories listed as Google Streets, Google Hybrid, Google Physical and Google Satellite.

One of the main and most difficult problem faced in use of OpenLayers was the change of Projection System. Before getting into conversion, it's important to know that what is EPSG? As we are already familiar with what is World Geodetic System (WGS84). EPSG Geodetic Parameter Dataset is a collection of definitions of coordinate reference systems and coordinate transformations which may be global, regional, national or local in application. The EPSG Geodetic Parameter Dataset is a structured dataset of Coordinate Reference Systems and Coordinate Transformations, accessible through this online registry. The geographic coverage of the data is worldwide, but it is stressed that the dataset does not and cannot record all possible geodetic parameters in use around the world. The EPSG Geodetic Parameter Dataset is maintained by the Geodesy Subcommittee of OGP's Geomatics Committee. EPSG stands for European Petroleum Survey Group. They publish a database of coordinate system information plus some very good related documents on map projections and datums. The Projection Engine uses a modified version of the EPSG model.

EPSG 4326 is a representation of WGS84 in EPSG format. Hence, base datasets which are in WGS84 are in EPSG 4326 whereas Base Layers of Google follow EPSG 900913 or EPSG 3857 (both are same). So, it is required to convert the projection from EPSG 4326 to EPSG 900913 or

3857, so the overlay of base datasets is perfectly over the base layer. For the purpose, following settings were made:

In the layer selection code, Spatial Reference System (SRS) was selected as to be 3857 like:

var province = new OpenLayers.Layer.WMS("PROVINCES" , "http://localhost/cgi-bin/mapserv.exe?map=C:/ms4w/Apache/htdocs/project.map" ,

*{layers:"province", **srs: 'EPSG:3857'**, format: 'png' , transparent:true }, { visibility: false});*

Secondly, projection system in a Metadata for a WGS84 file was mentioned as to be EPSG 3857 in MapServer's Mapfile:

METADATA

"ows_enable_request" ""*

'ows_title' 'PROJECT-MAP'

'ows_onlineresource'

'http://localhost/cgibin/mapserv.exe?map=C:/ms4w/Apache/htdocs/project.map'

'ows_srs' 'EPSG:4326 EPSG:3857'

"wms_sld_enable" "true"

"wms_feature_info_mime_type" "text/html"

END

The following actions resulted in a perfect overlay of Base Datasets from PostGIS over Google Base Layer.

Another component produced using OpenLayers was the Geo-Location of the Mouse Tip. The concept was that as user scroll the pointer over the map, the user will be prompt of the coordinated he is scrolling over in a window. The task was completed using another function of Open Layers which gives the X and Y location of the mouse tip which is converted back to EPSG 4326 from EPSG 900913 or EPSG 3857 so it is in terms of Latitude and Longitude which is normally used. Otherwise the result of EPSG 900913 or EPSG 3857 is in Easting and Northing.

OpenLayers provides many in built control to be provided in the web mapping application. In this project, Controls like Layer Switcher, Pan Zoom Bar, Scale Line, Scale, Permalink, Keyboard Defaults, Editing Toolbar are used.

One of the main features in the web mapping application is the idea of a Pop Up incorporating all the information of the Layer. The core of Spatial Mash-Up is bringing together information from various sources, the concept behind Pop Up is to make available all the information collectively in a single pop up instead of making user to visit different tables and places to get the desired info. The task was achieved using the WMSGetFeatureInfo function of OpenLayers in which many settings are required both in Server side Mapfile of MapServer as well as OpenLayers function. In Mapfile, requests are to be enabled for Get Feature Info.

Others components include the inclusion of Marker to mark a place with a note about any particulate nature. OpenLayers was also helpful in achieving the concept of a Multi Viewer for parallel visualization as it provides with the capability of constructing two map viewers asynchronously.

2.3.8 MULTI VIEWER

Multi-Viewer is a very productive and efficient approach for allowing more than one displays together on a single screen.

With the passage of time personal computers are becoming more powerful and fast. Due to their increasing efficiency, one is now able to perform more than one task simultaneously on a single system. Thus multi-tasking has become a norm. The best way to deal efficiently with multitasking is the use of multiviewer. In case of GIS tasks, we almost always face cumbersome tasks, dealing with huge amounts of data and analysis processes. Multi-viewer can enhance the analysis capabilities in GIS by avoiding toggling back and forth to different windows and tabs, to get the work done.

There are many advantages of multiviewer. Having multiple screens or tabs for multiple tasks is quite distracting. It also wastes a lot of time toggling back and forth to different tabs or screens. On the other hand, viewing multiple processes on one screen can keep up with visual continuity and increased productivity. It also saves the expenditure for multiple monitors. However sometimes it may seem complex because it takes up all the display space.

Chapter 3

RESULTS AND DISCUSSIONS

After a continuous effort of 6-7 months, we were able to implement the idea of a Geo Spatial Mash-up. Product prototype has now been developed which takes data inputs from various sources, including base data, data from ground observations and the real time feed from online sources, integrates them in a database, and presents them for visualization. Upon each click on the map, at any point, the combined information from all the underlying layers opens in a pop up, which is the heart of a mash-up.

Geotechnical component of water sensor combined with a microprocessor in a circuit gives the water depth which would help tracking the rising water levels in the river and provide timely flood indications.

Further strength is added by the SMS based distress call concept, which brings the system closer to the most important project audience – victims and people on ground. SMS processing would offer a better potential to the rescue and relief service providers to expedite their work, keeping them rightly informed at the right time.

System also provides the discharge and water flow status information for the river gauging stations, scrapped from web sources which are being updated on a day to day basis, making it 'near real time'.

The desired product has been prototyped which can be further extended to work as a complete system in the maximum benefit of Pakistan.

Chapter 4

CONCLUSION AND RECOMMENDATIONS

4.1 CONCLUSIONS

Pakistan has been a home to some of the most disastrous flood events in the history of mankind. Undoubtedly, much work is being done on flood early warning system and flood disaster management in Pakistan during the previous few years. But there lies a major lack of coordination between all these organizations working on disaster management with mostly overlapping roles and responsibilities. At this point, with the current infra-structure and socio-economic culture and where we as a nation, have already suffered beyond limits, there is a need to integrate the individual efforts to offer one best solution.

This project design was an initiative, to integrate all that it takes to build an effective solution for flood management, equally beneficial for all the stakeholders, from qualified spatial analysts, rescue service provider, disaster management bodies, to general people. It needs much more refinement and has a room for further extension based on time specific needs.

4.2 RECOMMENDATIONS FOR FURTHER RESEARCH

Based on the practical implementation of a mash-up, we recommend a system, which is completely automated. It would be a tedious task to fully automate the system as it involves extensive computing. A great deal of spatial functionalities can be added to the system to extend the analysis capabilities.

The product can have different versions i.e. different system access levels depending on the type of audience interacting with the system to maintain security. It is important to identify the needs of all user communities and providing them system access accordingly.

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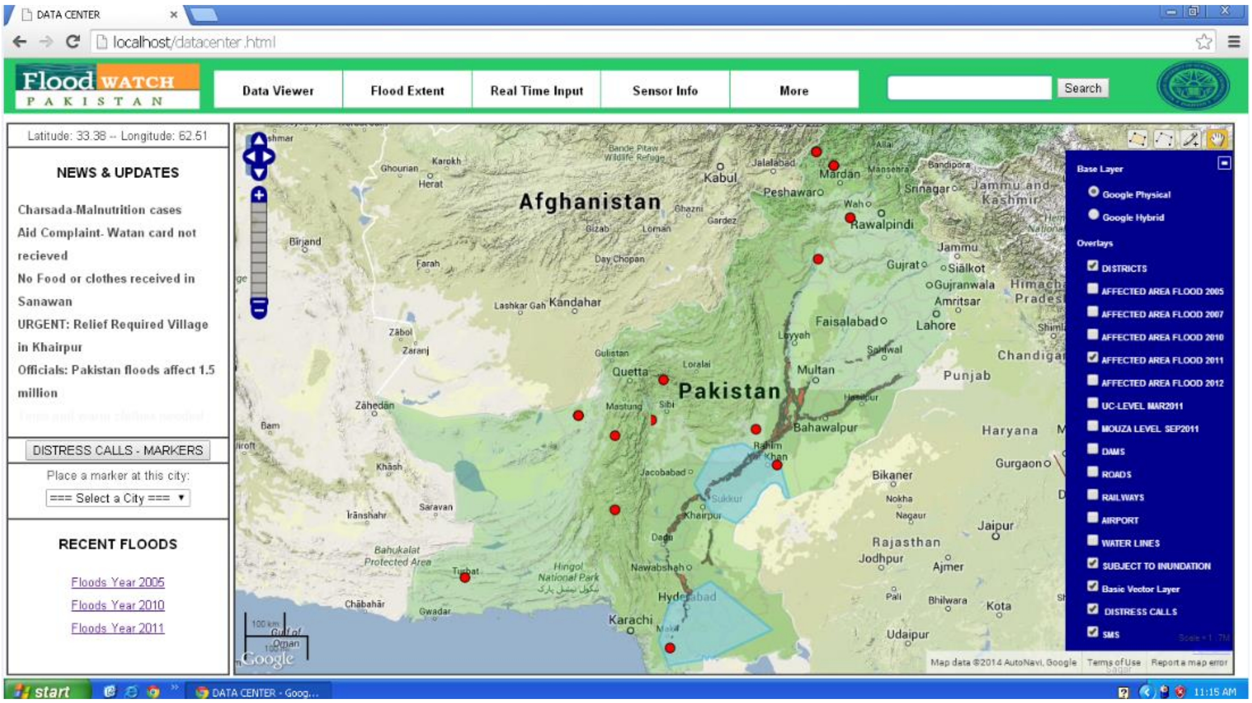
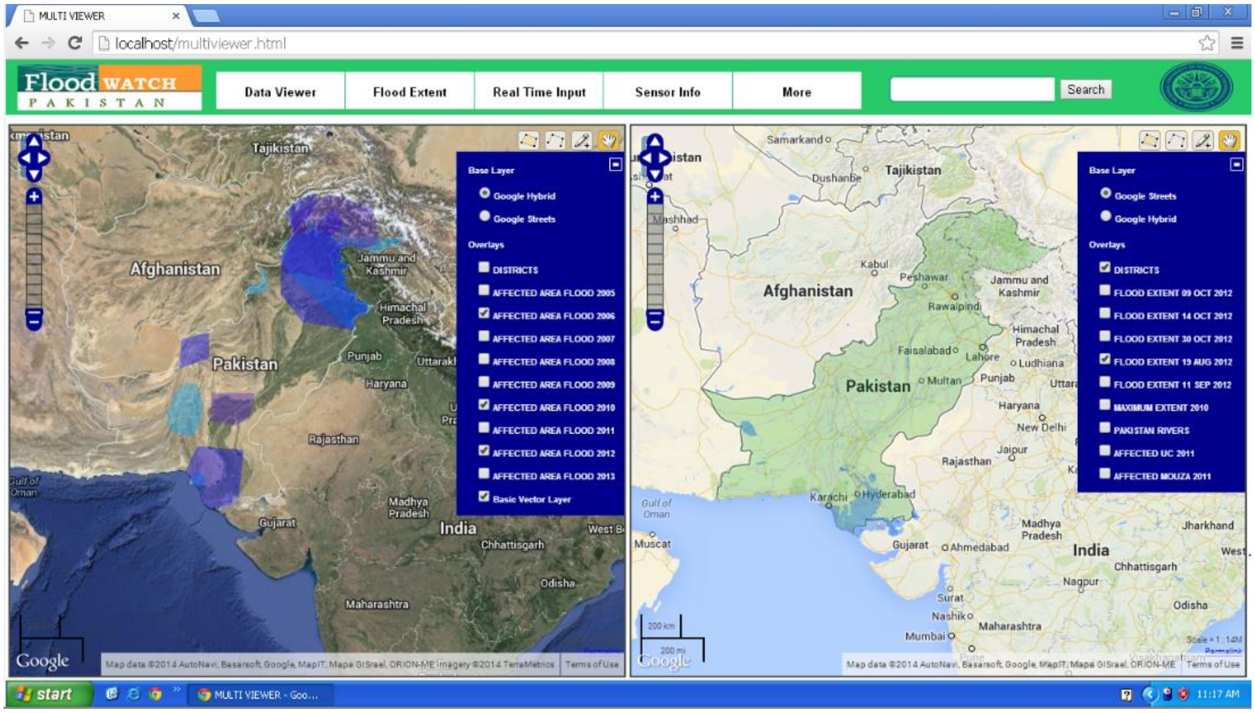
APPENDIX

APPENDIX: 1 - GRAPHICAL USER INTERFACE OF WEB SYSTEM

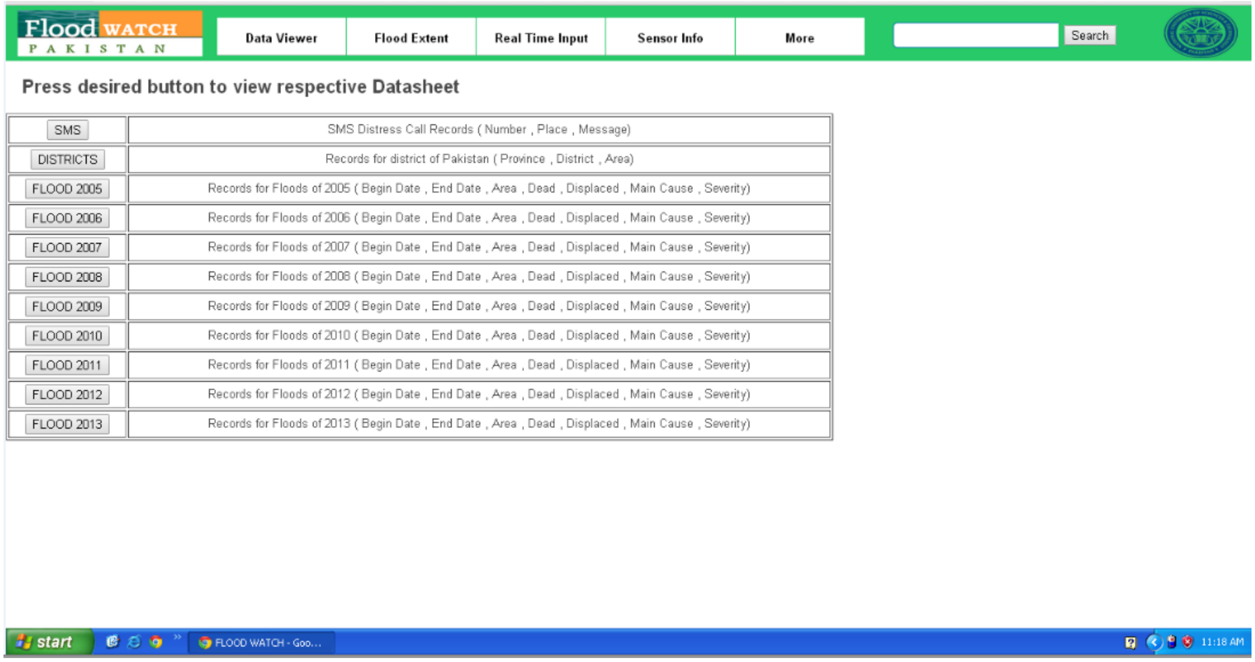
FRONT END:



MULTI VIEWER:



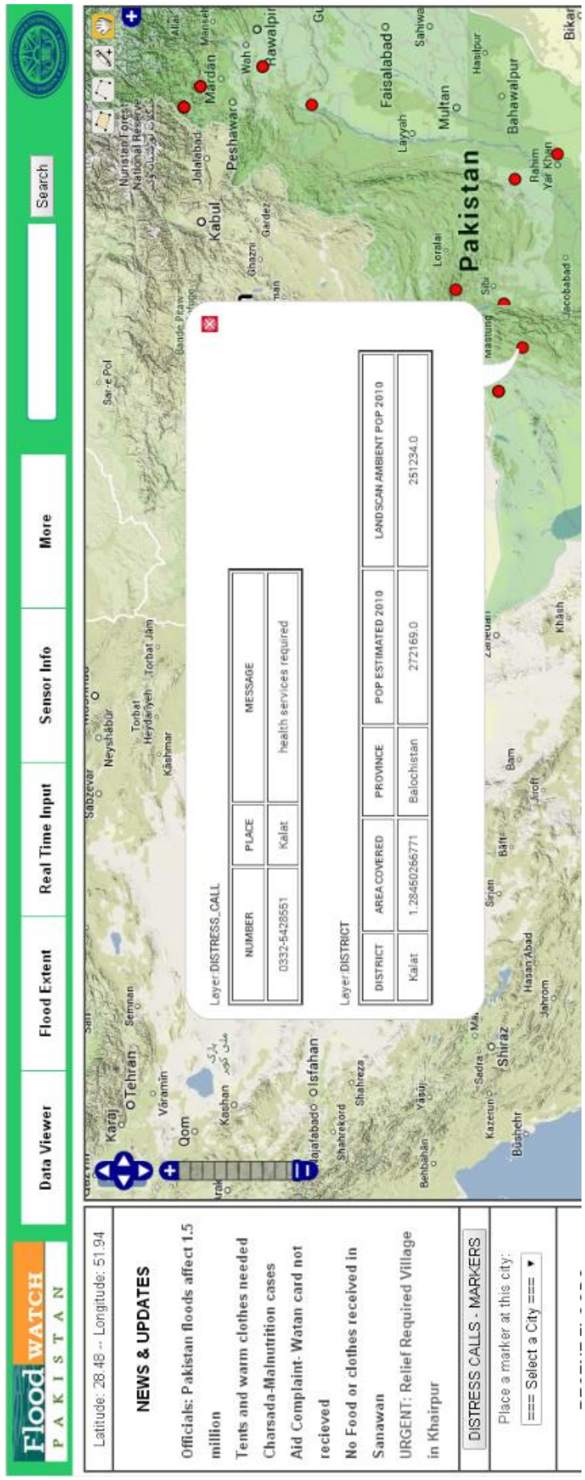
DATA SHEETS:



DATA SHEET - DISTRESS CALLS

Number	Place	Message
0300-5118159	Nushki	aid not received
0332-5428551	Bajaur	food required
0333-5531345	Malakand	clean water
0321-5043231	Attock	blankets
0300-5118159	Nushki	aid not received
0332-5428551	Bajaur	food required
0333-5531345	Malakand	clean water required
0321-5043231	Attock	blankets required
0321-5305430	Mianwali	death toll rising
0300-5118159	Rahim Yar Khan	health services required
0332-5428551	Thatta	aid not received
0333-5531345	Harnai	food required
0321-5043231	Dadu	clean water required
0300-5118159	Rajanpur	death toll rising
0332-5428551	Kalat	health services required
0333-5531345	Kech	blankets required
0321-5043231	Khuzdar	health services required
0321-5305430	Bolan	blankets required

INFORMATION POP UP:



APPENDIX: 2 – PROPOSAL FOR FUNDING OF IMPLEMENTATION ON PROJECT

Natural hazards and disaster management has been a critical issue for Pakistan, particularly since the country was hit by the cyclones in 1992, 1998, 1999, 2004, 2007 and 2010, floods in 2003, 2005, 2010 and 2011 and the devastating Azad Kashmir earthquake of 2005. One thing of significant importance in the midst of all this is the creation and disbanding of a variety of various state owned organization their shuffling and reshuffling. This is suggestive of a great deal of confusion among state machinery on how to understand, mitigate and subsequently manage a natural hazard.

With a globally every changing scenario of climate and related natural hazards like floods and cyclone there is a growing tendency on one hand toward trying to understand and control the natural environment. On the other hand organizations both government and private are putting in their two pence’s by developing means and methods to counter the growing threat of natural hazards. This later requires fortifying our mechanism and approaches towards how these threats are handled.

Strahler (2010) suggests that the study of natural hazards are their mitigation emanates from physical and human geography and its management is efficient and proper with significant use of one of the outcomes of neo-geography i.e. Geographic Information Systems.

This research aims to signify the potential of geospatial technologies coupled with an understanding of the physical and social factors that contribute to efficient management of natural disasters along the Indus river basin. In the process we aim to develop a geospatial web portal (of the kind Google maps are) that provides timely and significant information on disaster risk and prevention strategies. This will at the same time aim to include an elaborate understanding of the causes and consequences of natural hazards in Pakistan through a research based survey of both the natural and anthropogenic causes. These causes shall then be mapped accordingly from district to district basis for the entire province of Khyber in the first phase, followed by Punjab, Sind and Baluchistan subsequently. Over that the information generated will be accessible to the research community as well as the national disaster management and mitigation agencies for use in their efforts.

The portal will also have component providing historical overlook to the general public on natural hazards in Pakistan and their significant impact. It will bear a component on SMS messaging utilities for generating disaster alerts and receiving distress calls from selected districts in the first phase and after a successful implementation lead to a nationwide implementation of the same.

Having said that some of the component of the said portal/system shall have global access rights while others shall only be available to selected partners keeping the nature of the information a deciding utility.

Pakistan is heavily reliant on its natural resource particularly water. This helps the largely agrarian economy of the country which resides in the fertile plains of the Indus river basin and its tributaries to both the east and the west. The ancient civilization of south Asia bear evidence to that and so does the current population distribution patterns. Out of the total ~80 million ha of land area ~18 million ha is cultivated of which ~12 million ha lies in the Indus River basin. On one end it speaks of the great connection of the country’s population to its water resources it hints one on the excessive proximity that a majority of the population has with the meander belts of the rivers. On the other end it signifies that without doubt many of Pakistan’s people reside in close proximity to flood prone areas. Similarly in the northern mountainous regime in the Himalayan and

Karakoram piedmonts a vast majority of the population resides prone to frequents, mudslides, floods, flash floods, soil creep, and GLOF (Glacial Lake Outburst Floods).

A variety of national and international organizations therefore continuously are in the process of streamlining information and releasing it to a wider audience at the time of a disaster. However, this reliance on international organization and lack of professional expertise at local level has been observed to result in delays in disaster assistance and lack of information on mitigation works required.

The proposed project thus with the creation of a web based disaster management and mitigation portal shall suggest developing expertise in the areas of **i) archiving information on natural hazards and disasters ii) providing information and forecasts on natural hazards and disasters (specifically floods) iii) suggesting maintenance and establishment of mitigation mechanisms iv) big data management and analysis, v) sms alert system generation and cataloging system vi) geo-localization and classification of vulnerability levels and vi) evolving socio-hydrology of the Indus River basin system**.

In order to achieve the above the system therefore will be highly reliant on the use of computers and elaborate ground surveys. The first phase where archiving information is necessary is based on survey of national and international archives and analysis of satellite remote sensing data. In the second part the forecasting focuses on modeling from scratch a selected river meander belt evolution. The third part relies on the findings from the first two sections and additional satellite remote sensing data analysis of the state of various levees along the river basin, leading to suggestions on improvement of protection mechanisms as well as suggestion on protective measurements in Shyok and Shigar basins as an indicator of what needs to be acquired at the state level. While this being done the nature of the information catalogues by this system is expected to surmount normal conventional storage schemes and a component on big spatial data management and representation shall constitute a part of our work however this will be a preliminary exercise and does not entail a necessary inclusion at the early stages. Ushahidi and Sahana are two disaster management systems capable of implementation of a disaster relief portal for small organization, these two have been widely employing smsyn and frontline sms for sms delivery and reception. An integration of either of the two systems for bulk sms generation and processing in line with the needs of a disaster mitigation portal shall be prototyped for the ICT at first and subsequently if the confidence is high extended to the rest of the national territory. Once the distress calls are received it is pertinent to categorize that information and delineate hazard level as well as prioritize assistance needs. The system design requires that human dimensions be a vital part and hence a last but not the least would be a component on the socio-hydrology of the Indus river basin as how human resettlement (based on census and satellite remote sensing data) contributes to exacerbating or alleviate threat of natural hazards.

It is pertinent to mention that as this research will have a material output in the form of disaster management portal it will pave the way for the establishment of home based disaster response unit at NUST and easy communication with affected communities as well as those providing assistance. In addition to this it aims to produce publications in the area of data management and disaster mitigation, on communities at risk and their problems, big data analytics and disaster and socio-hydrology of Pakistan.

The final part of the research (socio-hydrology) to some extent relies on a hypothesis and hence it is being noted here despite it being applied research in general.

"Ignoring the changing resettlement patterns has led to increased affects of natural hazards and disasters in parts of the Indus River basin."

Goals/Objectives (please quantify your objectives (relevancy to National needs in case of Applied research)

1. **Development of national disaster information and mitigation web infrastructure**, in the light of the fact that an elaborate system here in Pakistan is missing, while universities and academic institutions across the worlds are moving towards hosting and disseminating such information to a wider global community. The EM-DAT and DFO are two examples of a basic level implementation of such systems. It is pertinent to mention that this system by no means will disseminate raw information but process data for mitigation and rescue purposes only to onboard state organization. Individuals on the other hand will have access to the academic/research related components only;
2. **Develop means and methods** and provide suggestion for seamless integration of global geospatial data (such as the one created and disseminated by NOAA, NASA, GODDARD etc.) into the created web portal;
3. **Survey the causes of natural disasters** and identify the effects of human negligence and incompetence in making these disasters more damaging;
4. **Explore (at quantitative and qualitative scales)** the needs and possibility of implementation of a big data management infrastructure for disaster management and mitigation at national level;
5. **Develop** a system that can generate sms alerts on a regular basis if a catastrophe is expected and inform the local communities on what precautionary measures to take, while at the same time be able to identify and geo-locate distress call SMSs from the same localities. Note: This component shall be prototyped for a selected region initially and might require additional expertise and financing for a large scale implementation.

6. **Develop a data distiller,** a data reclassification component that is capable of identifying calls as high, medium and low priority based on the source where the call is being generated form and on the basis of existing disaster analysis that have been carried out.
7. **Survey and research** on the socio-hydrologic parameters of the Indus river basin. Here we will be keen on assessing the effects of various small dams and water redistribution schemes on resettlements.

IDENTIFY END USER/ BENEFICIARY INDUSTRY AND FACTORY AS WELL (if applied research)

There is a variety of organizations that can benefit from the said project but those of prime importance and relevance are:

1. **The Cabinet Division** as it is chartered with disaster response and mitigation at national level;
2. **The NDMA (National Disaster Management Authority)**;
3. **The Indus river management authorities** at the federal and provincial levels;
4. **NGOs and universities** keen on offering aid to disaster hit areas across Pakistan;
5. **The Pakistan Insurance Associate and its affiliates** can benefit from this projects for ascertaining provision for insurance schemes and ranking high to low risk areas. **Note:** In Switzerland CAT-NAT is one portal which is made accessible to such organization through a username and password against monthly charges.

The general perception about natural hazards in Pakistan have gained significant strength in the last decade with the inclusion of media in everyday life of a majority of the population as well as the fact that a large number then previously ever recorded in human history has been affected in Pakistan. According to estimated published by the Pakistan meteorological department

(2010) and EM-DAT (2010) ~ 9.5 million people were affected by the floods of 2010. Similarly ~5.1 million people got affected in the 2005 Kashmir earthquake of which more than a 100,000 deaths were reported in the Pakistani region (EM-DAT, 2005). Hyndmann and Hyndmann (2010) suggest that a majority of the natural hazards are results of human negligence the obvious lack of information on their recurrence intervals their modeled future extents and population boom in hazard prone areas. If we consider Pakistan in this context we find that at large we are devoid of any serious understanding and educated consensus on how to mitigate them. Geospatial technologies have by far and large helped enhance our understanding of the real world, how the natural processes unfold and how and to what extent they affect or can affect our lives. This research in its core aims to explore geospatial technologies and their possible contribution towards understanding and mitigating these events.

The project aims to harness the power of modern day computing technologies. It is based on using web, image analysis and geographic information system to gather, share and efficiently use geospatial information. It will be reliant on the survey of existing federal and provincial archives to develop a concise historical database of natural hazards to have hit Pakistan and make that information available to the national research community.

Additionally, it will develop archive of maps and databases using aerial photography, satellite imagery and field surveys to contribute to the already existing archives and provide that information to a wider base of users including academicians, planners, managers and social welfare organizations. Considering we are already heavily reliant on foreign agencies and need to establish data sharing protocols for information sharing our disaster responses suffer greatly due to this approach (Afsar et.al. 2013, Afsar, 2014). In this context there is also a dire need to ensure capacity building in such analysis and information retrieval hence the project aims to focus on a couple of workshops in this regards using its team members to share their learning experiences. Additionally, the project aims to provide for an initial ground on the use of sms technology for information sharing such as pre-disaster alerts and distress calls cataloguing and filtering for response priorities. It means that the system will have a user/distress profiling system which is capable of ascertain the needs of individuals based on existing flood analysis by the support teams and subsequently delineating necessary actions on its parts to provide that assistance. It is pertinent to mention that the system and its developers might not be fully in a position to offer direct assistance but shall rely on establishing effective communication with the state disaster response organizations. Hence, providing them a much needed support and helping them not disclose their strategic capabilities in the wake of these hazards. As these components shall be prototyped on selected areas such as Shigar and Shyok basins and the ICT it is therefore necessary to understand that scaling or preliminary studies on scaling these projects to an ever growing national database would be required. In this context big data management and its use in disaster information storage, analysis and mitigation shall form a research component of the project. Where the objective would be of finding how to integrate big data in a project as such can be achieved seamlessly, if requirement develops at a certain point in the future. The last component relies heavily on the understanding of a combination of pull and push factors effective in human resettlement. For instance it is of interest to our work to identify which are the push factors for a certain community in a risk free zone while what are the pull factors for a certain community in a risk prone area. Once this has been peculiarly identified our findings can contribute to future settlement planning in the country and our resource redistribution plans.

Akhtar (2011) reported that each year ~20,000 people are killed by floods and ~75 million people are severely affected by floods as a natural hazard alone. Many other disasters to hit

Pakistan are more or less related to floods or are a cascading effect of the hydro-meteorological cycle in the region. For instance, slope failure resulting in massive landslides and soil creeps. According to ADRC Data book (2002) around 38% of the world disasters have been recorded in Asia since in a span of 25 years from 1975. Around 57% of the total causalities related to natural disaster have as well will be recorded in the same region since 1975. Being in a zone of shifting ITC (Inter-tropical Convergence) it is therefore highly prone to hydro-meteorological hazards and related damages.

Geospatial technologies have been widely employed in disaster response and management. There is a wide implementation in the form of spatial mash-ups, crowd-souring web platforms and dedicated software platform available for use by the global community. Disasters ranging from that of Chernobyl, tsunamis in Indonesia (2004) and Japan (2011), Hurricane Katrina (2005) and the Denube floods (2013) are some of the examples of where geospatial webs have played a vital role in disaster management and mitigation. The US FEMA HAZUS and FEWS are another set of valuable examples of geospatial technologies in disaster management and mitigation. Gupta and Knoblock (2010), suggested that their more economic implementations of geospatial technologies possible in the form of geospatial mash-ups. This later significantly reduces overheard on data storage and management at the host system but rather enables the developers to seamlessly integrated data hosted on other portals. In a way enabling the use of information from the entire world. In a survey of recently published literature on floods and natural hazards a variety of suggestions were found by authors advocating on the use of web, GIS and RS, and spatial mash-ups in disasters. Sabhani *et.al* 2003 believed that GIS and remote sensing renders disaster mitigation efficient through disaster hit area identification and need assessment. Raltman (2011) being in the age of web advocated the use of web for information sharing and gathering using web technologies. The use of web and GIS coupled with GIS/RS technologies or simply the geospatial web has been advocated by Mioca *et.al.* (2008), Chan (2011) and Zipf *et.al* (2004) for flood disaster management and mitigation. Karnataka *et.al* (2011) believes that all three technologies know to the user and developers of distributed GIS i.e. WEB, GIS/RS and spatial mashups can effectively help in visualization, management and mitigation of floods and all other types of natural hazards.

While the role of Geospatial technology on the web remain significant it is worthy to mention that the tools and methods present in the form of image analysis utilities, data management and processing tools and modeling environments have made disaster management and mitigation far more elaborate and compatible with modern day needs. Munir *et.al* (2013) in an analysis of the FEWS (flood early warning system), implemented in Pakistan in comparison with the real observed flood extent of the 2010 floods concluded that such environments are highly efficient in predicting the flood extents. However, the model results due to some administrative constraints were never shared with the relevant authorities and action not being taken until very late. Additionally, satellite remote sensing data from a variety of sources such as the Goddard data sharing portal, the USGS earth explorer and the LAADS web have made the job of following these natural disasters and their occurrence details much easier. The availability of technologies suits such as ERDAS imagine, ArcMap, GRASS-GIS, PostGIS, Spatial SQL, Mapserver and many other off the shelves commercial and open-source utilities have eased the life of communities in search of easy to use utilities in the fields natural hazards.

Pakistan can broadly be placed in two physical sub-regions one that is dominated by arid climate and lies to the central dividing Suleiman-Kirthar ranges while another that is to the east and constitutes the fertile plains of the Indus and its tributaries. It is these eastern tributaries broadly inundated by regular floods. The floods source out from rapid glacial melting as was observed in 2005 and excessive rainfalls as were observed in the summer of 2003, 2010 and 2011. Broadly speaking the cause being a rather complex and anomalous hydrologic cycle of the region. Many open-source models and utilities are available such as Avulsion, CREST, Channel Oscillation, HydroTrend (specifically concerned with climate driven hydro-meteorological trends) and a series of D-8 (flow direction based hydrologic routing models). These models however, are mostly used independently and their abilities have not been harnessed at a broader scale. A web implementation and real time processing abitlites of these models can provide for effective round the clock information availability on expected flood disaster extents in the future.

In a document published by CNN in 2012 it put forth a survey of seven ways mobile technologies have changed life in Africa. Of the seven highlights disaster management was the third most important in the list after education helping people track lost ones during disaster related migratory behavior and advanced information on the rather pertinent African hazard of drought. Napean (2010) in a document on the effective use of mobile technology and SMS significantly highlights the role of SMS and related technologies in broad scale management activities with particular focus on the generation of short codes and information sharing. The GSM (Groupe Spatiale de Mobile) (2012) worked in with smart PLC in developing an elaborate disaster response platform for Philippines which is regularly hit by floods and cyclones. This network made broad use of mobile technologies and the fact that around ~90% of the country's population is connected to the state mobile communication systems. The system in discussion therefore plans to make efficient use of available technologies to make the portal highly efficient.

A recent and new dimension that constitutes in part disaster management and mitigation is socio-hydrology. The concept is based on the fact that changing human population dimensions are critical. For instance it can be that of the indices of the effects of human movement on increase/decrease in vulnerability. As is the case of the Indus river basin after the first water repartition agreement it was decided to avoid mass migration to the Indus river basin in the east from the vicinity of the Ravi, Sutlej and Beas tributaries. In doing so a series of link canals were put in place. However, with time the efficiency of these canals and many other which are just plain irrigation channels have severely suffered. This leads to migration of people at large towards disaster prone area. This research project aims to explore these changing vulnerability patterns of communities and map them accordingly.

Our work shall focus on a multi-level approach where setting up a geospatial data management system is of utmost important. With an ability to catalogues and generate short messages to a list of mobile users, garner information on distress level and display that information on a map, generate modeled maps and real-time surface water maps and maps of communities at risk on a regular basis.

In order to do this the research has been divided into the following chunks:

1. **Survey (focused) of users understanding of geospatial technologies** and that particularly present on the web, some simple examples are that of the Google maps while more focused examples are the Dartmouth flood observatory and the Fargo Flood information portal hosted by North Dakota State University. This shall be helpful to us in shaping our approach toward our online application design and at the same time will lead to a UCD (User-Centered Design) for the entire system. This information shall also be published as a research in a journal of good academic reputation;
2. **Survey of state level disaster achieves** being hosted at various provincial and national libraries and those that can be mapped using freely available satellite imagery. This

information shall bear a detailed record (chronology) of flood primarily in Pakistan followed other moisture related hazards (landslides and slop failures). The information shall be stored on the web portal for free viewing by academia and general public to help generate awareness on floods at national level. This information shall be particularly put forth to k-12 institutions in the country which needs to either explicitly or implicitly make such material a part of their curriculum.

3. **Development and implementation of meander rate migration model** (preliminarily executed by the PI during PhD research work) reliant on high resolution digital elevation models and channel avulsion and later migration indices counts. This model shall than be incorporated in the existing database to help ascertain possible channel migration direction and rate for the future in a selected area. *The study area for this purpose shall be a selected segment of the river south of Tarbela reservoir west of Islamabad where the river tends to meander frequently uncontrolled (It is pertinent to mention that site selection and procurement of necessary elevation data might extent to a period of ~ 6 months)*. Once the model is ready it shall constitute a part of the entire portal however state wide implementation may require extensive resource both human and financial and may not be possible due to data constraints too. The model development and outcomes shall be published with a general of good reputation hosted by the European Geophysical Union;
4. **Integration of SMS pooling and generation utility** is another important aspect of the disaster management and response system being envisioned here. To do this we shall work on seamless integration of frontline SMS technology in our web portal. This shall be exactly prototyped for the rural and urban localities of the same area that the river avulsion/lateral migration model will be incorporated for in the previous segment. A small

component on community training and sample drills will be documented and communicated where necessary to narrate successes and failures. Any information generated or received through this component shall only be available to restricted audiences;

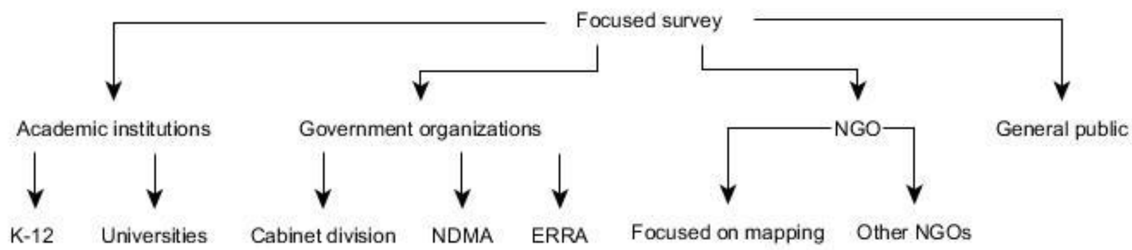
5. **Research on system scaling** will be the next component in case where the developers and user find the system useful and fully implementable at the national level. This scaling component would however be a virtualization exercise and may focus on suggestions based on previous work done in the field or by the team itself. Care however, will taken to ensure publication of our findings;
6. **Changing demographics of the Indus river basin and water repartitioning** will be the last but a significant and elaborate component. This shall be composed of a survey of population census records and mapping these records with changing levels of canal efficiency. The canal efficiency shall be mapping using elaborate free satellite remote sensing datasets. With agriculture a key potential pull factor for most of the communities in Pakistan if the canal efficiency in irrigation a region decreased it is evident that those communities previously placed there will move to either naturally safer or more dangerous locations. This later shall be explored using information generated in this component and that retrieved in the second research component of a survey of historical natural hazards. Once the maps have been produced these maps will be hosted on the portal for restricted audience;
7. **Compilation and presentation of results** will be the last but not the least of the components. This will be obviously an ongoing process in the form of conference presentations and research publications in general but it is believed that an elaborate

conference on the subject where research finding can be shared with a broader national community will be vital.

As at no stage research can totally be inductive or deductive, or structured as planned a set of approaches have been planned in the form data gathering, pre-processing, processing and representation tier for each of the above mentioned components. It is by no means avoidable to change these mentioned schemas as per our evolving needs. Details of the methodologies to be adopted for every task as follows:

Survey (focused) of users understanding of geospatial technologies: The survey methodology has been organized such that there are going to be four major focus groups. These namely are academic institutions, government organizations NGOs and the general public. These will be questioned using a basic questionnaire application for android which will be carried by the field agents on their personal phones. In cases where online coordination is possible individuals shall be surveyed through an online portal. The focus will be on asking short precise and a few questions only that defines a user's ability to understand and interpret a map online or in a given situation a paper based map document.

The academic group of institutions has been further divided into K-12 and Universities where we shall get to streamline the user centered design needs for each of these institutions types. Similarly, three government organizations that shall remain the focus of this disaster mapping and information sharing exercise are the Cabinet division the NDMA and ERRA. These organization as shall be the focus of certain disaster assistant components of the portal hence the nature of questions shall focus on their professional institutional needs of a disaster management portal.

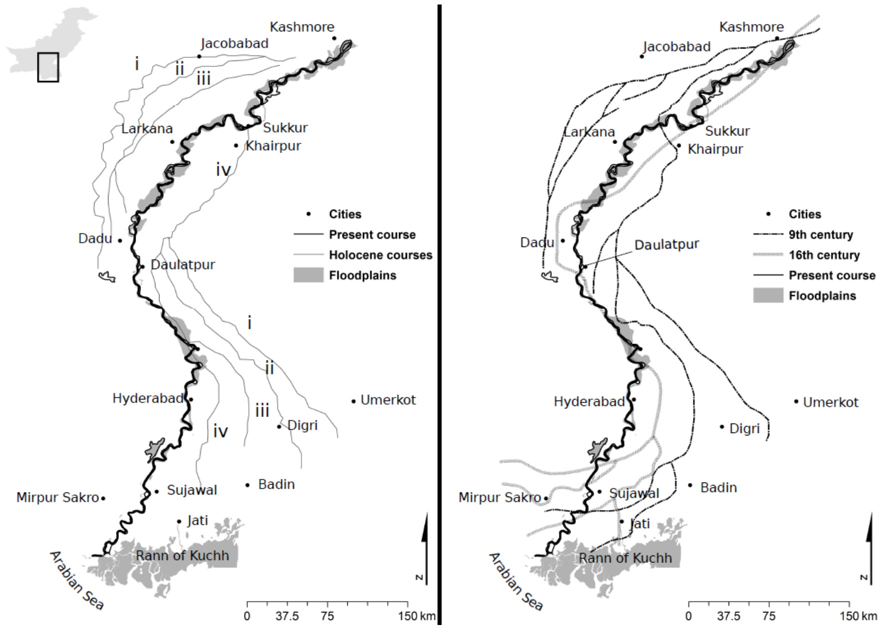


The third group of the NGOs has been divided into those that are already focused on mapping such as IMMAP and UN based organization while those that are working on disaster relief such as save the children but do not have specialized or well know mapping units. It will be vital to survey and include their needs as these institutions will be the ones benefiting the most from any focused disaster mitigation and assistance related information being provided online. And the last but not the least will be the general public. The focus of survey for the general public will be more of how aware they are of geospatial information concerning disaster management.

Survey of state level disaster achieves: There are masses of information lying around national archives and libraries without proper utilization or awareness of their log keepers. It is vital to convert those information sources into a digital archive. Initially, as it is not know where and of what context the information is being stored the best starting point shall be the provincial ministries and their affiliate provincial libraries and achieve offices and museums.

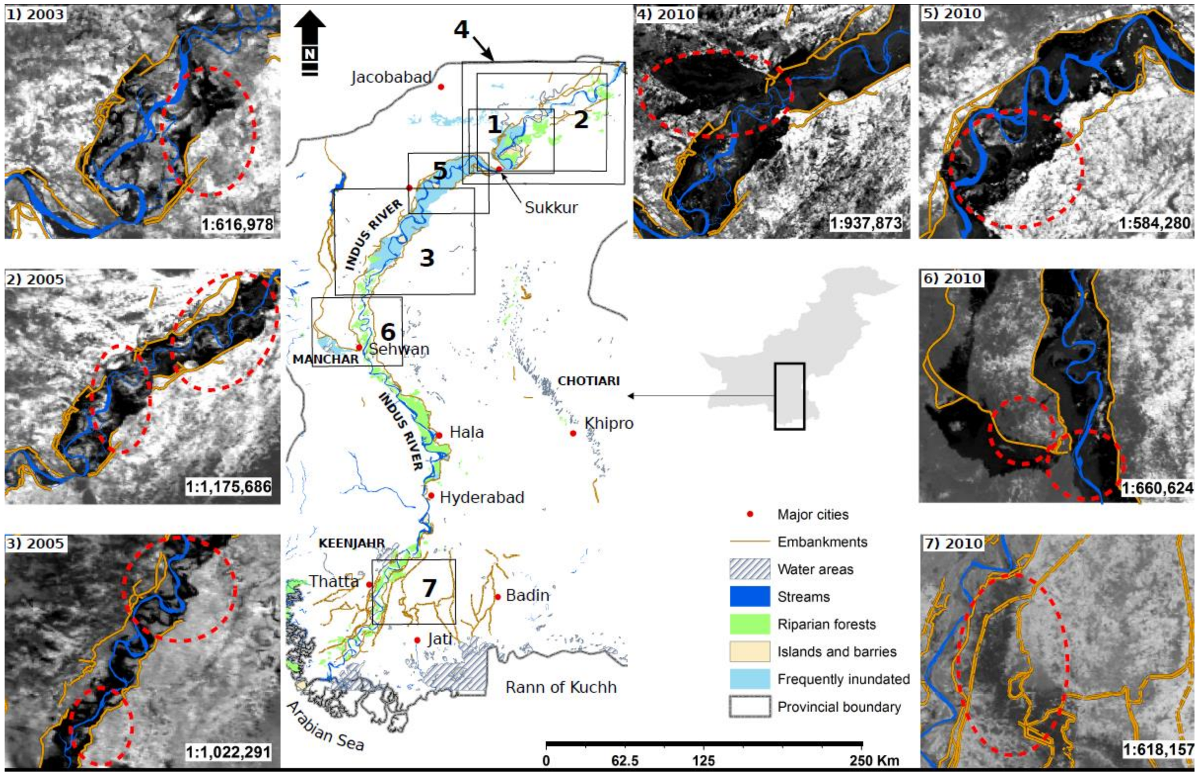
To enhance this collection however, it is considered vital to survey online databases and records on disaster occurrences in Pakistan particularly the hydro meteorological ones and map their extent, damages caused etc. using satellite remote sensing data available. These records can then be provided online for visualization and academic uses in K-12 institutions and universities. As well as the general public who have minimalistic understanding of natural hazards.

Development and implementation of meander rate migration model: Channel migration along the Indus river basin has been a constantly disturbing factor for river managers since long. Holmes (1968) suggested that the Indus river basin in Sindh alone bore marks of old stream flowing on either side of the river towards the north east and the northwest. However, since the river has been controlled and its discharge and flow direction anthropogenically modified this seems to aggravate the concerns in the times of floods. River bends are known to migrated either in the normal direction of the meander or straighten. While the later can be thought of as relieving the former however can lead to levee destruction and subsequent damages to the nearby population.

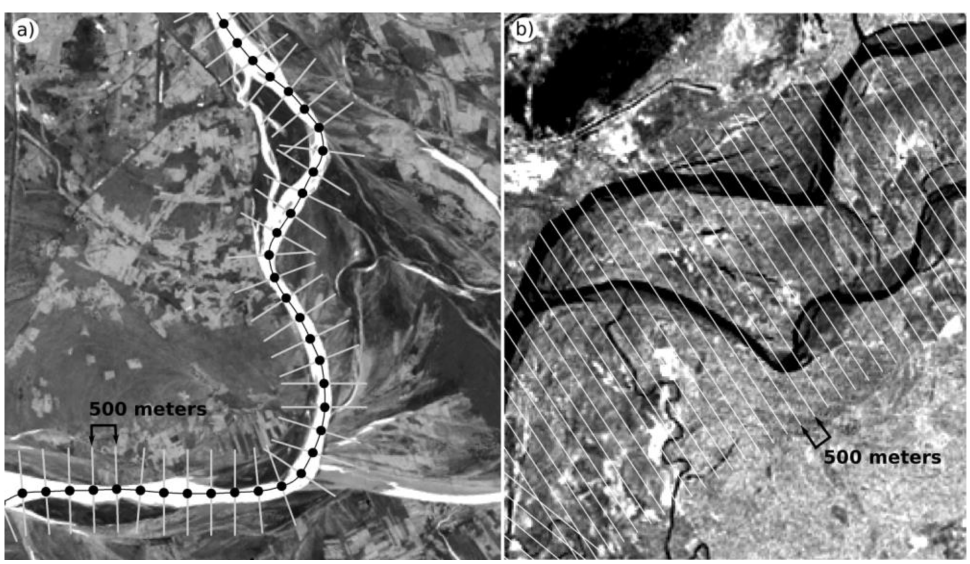


In this regard an understanding of the meander behavior is vital. GIS and remote sensing therefore can be vitally used to model the possible directional shift based on historical records as well as topographic information of the meandering region.

The information used to do so shall constitute of extensive field surveys in an area close to the PIs position primarily to reduce cost and save time. The effort however, shall be to scale the model to a broader implementation for entire Indus river basin. This later however, is conditional to the success of the designed model and time constraints.

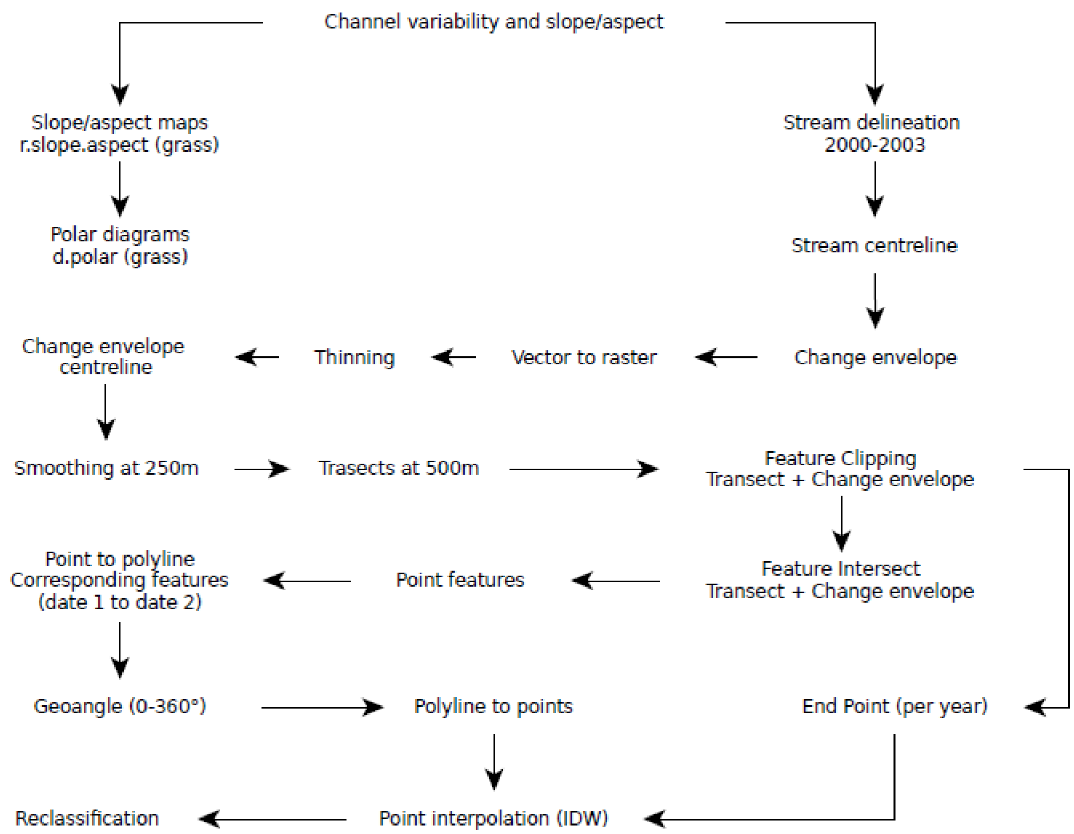


The focused methodology for the task includes, i) channel migration patterns mapping using satellite remote sensing records, ii) Calculating channel migration rates using GIS iii) estimating future channel migration rates. This later will require a complete survey of the topology, channel sediment characteristics and their role in allowing or disallowing migration at a certain rates, as well as that of the riparian corridor and its kind.

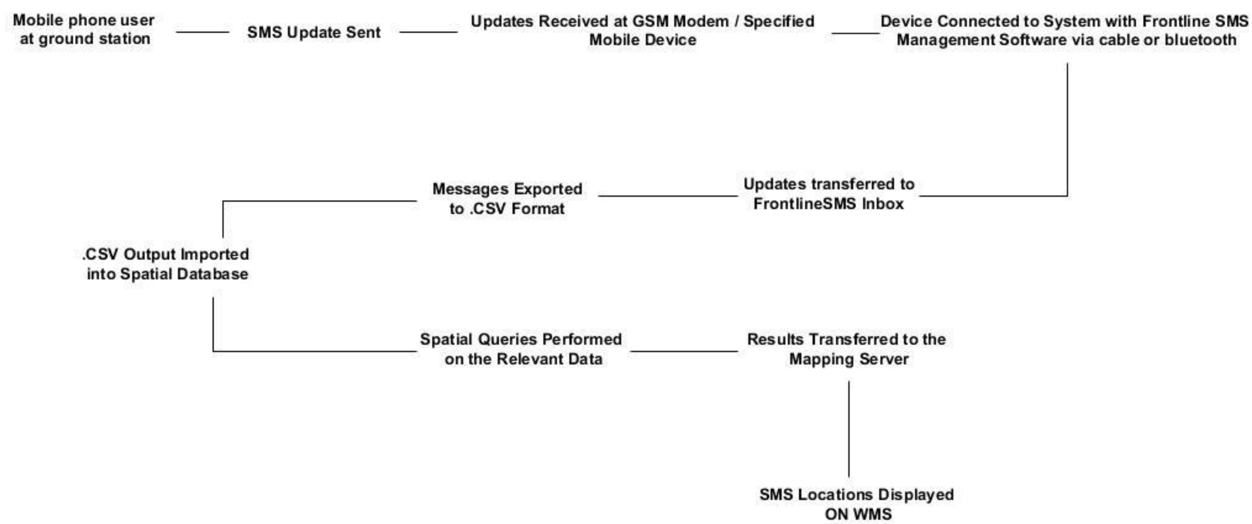


A quick illustration of how the entire process might shape up in a GIS is shown above. The approach shall be observing channel migration rates at every 500 meters to provide for best results.

An integral component to this model will be the efficient use of GIS and for that a methodology has been illustrated in the following figure. This shall include for instance stream delineation and stream slope maps followed by stream centerline delineation, channel change envelope mapping, casting transects at 500 m and then after following a process of cleaning records converting the GIS layers to suitable point type features for rate of lateral migration as a function of elevation, slope, soil types, and riparian vegetation cover extent and type etc. This methodology is subjected to obvious improvements during the due course of our work.



Integration of SMS pooling and generation utility: SMS technology as mentioned has been widely employed in real-time information pooling on natural hazards as well as hazard mitigation and relief operations. However, in Pakistan its use for the said purpose remains minimalistic. In this regard we plan to integrate frontline SMS utility in our a web mapping application which shall be able to identify risk level and individual's position and possible assistance that can be provided to that person or group. As for its first ever implementation we do not remain highly convinced on being able to geo-locating individual due to limited state policies and resources on mobile tracking etc. However, the idea is to gather information from mobile phone users on their distress level using SMS on a local GSM model attached to the central server. When the information is received this will be mapped automatically on to the map available for viewing by the concerned assistance provider. This module needs testing for ICT first before a national level implementation is envisioned.



Research on system scaling: An intermediate by important component of our workgroup's focus is system scaling. Many technologies available today either fail to use multi-core systems to their best efficiency or require adequate scaling in other scenarios. It is therefore necessary to work on the possibility of scaling the generated information and models for a broader audience. This will be a purely research oriented component and hence findings shall be shared as a research document only.

Changing demographics of the Indus river basin and water repartitioning: There is a sure need to survey the canal efficiency in Pakistan its impact on population changes. Particularly the effect on migration of poor local communities from one part to the other in search of more fertile lands. We plan to use satellite remote sensing derived vegetation indexes from 1998 to 2014 or whatever be the final year at the time of presentation of our findings be. These vegetation indices will provide vital information on canal efficiency to its far of reaches and whether the far flung communities due to the canal failure (i.e. to irrigate its far flung reaches) are moving towards urban area or close to the river banks. These maps will be vital for river managers and irrigation planning agencies to ensure that communities do not come across many push factors at their local communities and other pull factors near hazardous areas are controlled.

S#	Task	Starts	Ends
1.	**Survey to establish a user centered approach**	**August-2014**	**December-2014**
2.	**Survey of archives**	**August-2014**	**February-2015**
3.	**Meander shift modeling**	**October-2014**	**October-2015**
4.	**SMS pooling and generation module**	**January-2015**	**June-2015**
5.	**Research on system scalability**	**June-2015**	**December-2015**
6.	**Changing demographics of the Indus basin**	**December-2015**	**May-2016**
7.	**Compilation and presentation**	**June-2016**	**August-2016**

The compilation of results and their final presentation is the last part of the entire work plan. As has been mentioned previously, the entire project relies on regular publications of our findings in journals of good reputation. Additionally, it will be viable to share the findings in an internally organized workshop session for academic and general public.