Executive Summary

The Multi-Hazard Risk and Vulnerability Analysis (HRVA) for the City of Vijayawada, Andhra Pradesh study has been carried out as part of the Climate Risk Management in Urban under Disaster Preparedness and Mitigation Program of USAID-UNDP. It aims to reduce disaster risks in urban areas by enhancing institutional capacities of urban local bodies and to integrate climate risk reduction measures in the development programmes as well as to undertake mitigation activities based on scientific analysis.

This report provides findings of hazard risk and vulnerability assessment of the key natural hazards the city is exposed to namely – cyclonic wind, flood, rock fall, heat wave, and epidemics. Quantitative modeling techniques based on GIS methodology was used for mapping and analysis developed around standard public domain models. Based on these results, recommended action for various mitigation and adaptation was also provided in the last section.

City Profile: Vijayawada city is one the largest cities of Andhra Pradesh with an area of 61.86 sq.km and population of more than 10 Lakhs. It has a population density of 16, 518 person/ sq km with an annual population growth of 17.2% against the national average of 10.93%. The city constitutes about 3.91% of the total urban population of the undivided Andhra Pradesh State. The city being the transport junction (both rail and road) connecting north and south India thrives on commercial activities. Vijayawada city along with the contiguous urban areas in its outskirt forms the 34th largest urban agglomeration in the county.

Being located near the east coast of India about 70 km from the Bay of Bengal, the city is highly influenced by the monsoonal activities of the sub continent. The city receives rainfall from both southwest and northeast monsoon and has a marked high temperature in summer. The city experiences cyclonic winds (particularly during Sept-Nov months) and floods during northeast monsoon and heat waves during summer (April-May). The city experiences an average annual temperature of 27°C with high temperature peaking at around 45°C in the month of May recorded over the past several years.

City Assets: The city has more than 2,70,000 households and about 85% of the buildings in the city are under residential use. The city has several commercial establishments; about 12% of the buildings are in commercial use. The city has total road length of about 241 km. The city has 641 educational institutions and 937 hospitals. Other major city assets include power supply network (mainly overhead high and low tension lines), gas distribution system in a small portion of the city by Reliance group and water supply system. The distribution systems for gas, water (domestic and industrial) and telecommunication systems are mostly underground which are less exposed to natural hazards. The industrial units in the city are mostly agro-based due to the availability of agricultural produces in the surrounding areas and the commercial activities in the city.

Hazard mapping and analysis: The city is exposed and vulnerable at varying degrees to various natural hazards including cyclonic wind, flood, heat wave, and rock fall. In addition to this, the city has history of outbreak of malaria epidemics. The city also experiences wide spread vector borne and water borne diseases. For the hazard mapping and analysis, the hazards considered include cyclonic wind, flood, heat wave, rock fall and epidemics (selected water and vector borne diseases). Hazard mapping and analysis was carried out in GIS environment using hydro meteorological and biophysical data of the city. The hazard analysis was carried out based on its characteristics- both severity and frequency.
The city is exposed to cyclonic winds and some pockets of the city are vulnerable to these winds mainly due to the type of residential buildings. Historical cyclone events recorded in the city for the period 1877-2013 were considered for cyclone hazard mapping and analysis. Vijayawada Mandal was severely affected by the cyclonic storms of November 1977 and May 1990. As part of the analysis, hazard scenarios of maximum wind speed for key return periods (5, 10, 25, 50 100 years) were created. The 100-year return period Cyclonic Wind hazard map shows some pockets of the city (eastern and western parts) might experience extreme wind speeds over 151 km/hour. Correlating the high wind hazard zones with pockets where the residential structures are weak can help in better planning to protect the assets of the city. The slum pockets of the city have tin roofed houses and overhead power lines, which are highly vulnerable to strong wind hazard.

The flood hazard mapping and analysis estimated the frequency and severity of floods at different recurrence intervals (return periods), based on hydrological and bio-physical information. The city of Vijayawada, due to its geographical position, high rainfall variability, and topography has pockets which are exposed to flooding. The human activities like encroachment into the riverbed and canal area are key factors of flood hazards in the city. The key flood prone areas in the city include the banks of Krishna River and Budameru canal (drain) areas. People have encroached upon the channel of the Krishna River and the bunds on the river banks. The census ward numbers 1, 10, 41, and 42 are some of the most flood prone wards in the city.

The city experiences high temperature during summer months (April-May) some time lead to heat waves in the city. The historical data analysis shows an increasing trend in observed maximum temperature and minimum temperature in the city. One of the recent heat wave affected Andhra Pradesh and the Vijayawada city in particular. The city has recorded highest temperature in the range of 46°- 48°C. The heat waves not only affect the people with high temperature but also caused fire in transformers and thatched huts.

The landslide hazard analysis considered rock fall from the steep slopes and carried out rock fall susceptibility mapping. Analytical Hierarchy Process (AHP) based weighted ranking methodology is used for the rock fall susceptibility mapping. The susceptibility maps prepared were overlaid on the administrative map in GIS to understand the hazard at ward level. In Vijayawada 2% of total areas falling under high landslide susceptibility zone, 3% of total areas are falling in medium landslide susceptibility zone and remaining 95% areas falling under low landslide susceptibility zone. Rock fall hazard is in the three pockets of the city where there are steep hills (Indrakiladri hill, Machavaram, Gunadaa hill, Moghalrajapuram hill and Gollapalem Gattu hill) and which have considerable settlements.

Epidemic hazard analysis was carried for based on available historical disease incidence data for selected vector borne diseases - malaria, chikungunya, and dengue, and water borne diseases - typhoid, diarrhea, jaundice and viral gastroenteritis based on the historical reported cases. The disease incidence data shows that vector borne disease are mostly recorded during the rainy season and typhoid during summer months. The incidence rate of malaria is on decreasing while comparing the last 5 year incidence data. City needs to take additional precautions for vector borne diseases particularly malaria and dengue in heavy and prolonged rainy seasons.

Global climate change scenarios were used to analyze the trends in climate change impact in the city and surrounding region. Spatial distribution patterns in maximum and minimum surface air temperature and rainfall over Vijayawada Mandal were developed using HadGEM2-ES model data. The analysis indicate the likely shifts in spatial changes of temperature and rainfall during 2040s (2026-2055) and 2080s (2061-2090) with respect to baseline time-period (1961-1990). The analysis shows that temperature is likely to rise by about 1.25°C and about 2.50°C
respectively around the middle and end of this century. The rise in night-time minimum temperature could exceed 1.50°C and 2.80°C respectively by the middle and end of this century. The monsoon rain is projected to increase by about 0.5 mm / day (a total of about 60 mm in the season) and about 0.8 mm / day (a total of about 100 mm in the season) over the Vijayawada city, respectively by the middle and end of this century. On annual basis, the rainfall increase over the region would be limited to 0.15 mm / day (a total only 50 mm in a year) and about 0.37 mm / day (a total of 130 mm in a year) respectively by the middle and end of this century.

**Vulnerability Assessment**: Assessment of physical vulnerability to various hazards, and social vulnerability and environmental vulnerability in general of the city was assessed based on identified indicators and field observations. Economic vulnerability was estimated based on available economic indicators. Physical vulnerability is developed based on analysis of the building typology in the city and developing vulnerability functions separately to flood and wind storm. For social vulnerability, socio-economic indicators were considered and based on secondary and field based information. The poverty, gender, seems to have high influence in the social vulnerability in the city. There is good correlation between high social vulnerable groups to low income areas particularly slum settlements of the city. Analysis of social vulnerability based on Social Vulnerability Index (SOVI) of the city shows the environmentally vulnerable and high hazard areas particularly the flood hazard areas has high SOVI. The analysis of the land use land cover of the city shows a fast increase in the built up which increases the vulnerability of the region specifically for flood (due to increase in run-off) and heat wave (due to increase in temperature and built-up area against greenery).

**Risk Assessment**: Risk assessment is carried out using probabilistic methods for flood and windstorm while for epidemic hazard simple deductive method is used. For landslide (rock fall), adequate events database is not available for estimating the risk, and hence conclusions are made based on landslide susceptibility analysis. For flood and cyclonic winds, risk matrix by each hazard is developed based on estimated losses and damage attributable to each hazard.

Flood hazard risk assessment: Probable Maximum Losses (PML) for buildings (residential, commercial, and industrial) are estimated based on general occupancy for various return periods. This loss is of the order of Rs. 9.58 Crores for residential buildings for a 100-year return period event (worst-case scenario). In case of industrial and commercial buildings, the estimated losses are not very significant. The flood risk map shows high-risk areas along the Krishna River compared to the rest of the city with an Average Annual Loss (AAL) of about Rs. 32 Lakhs for residential buildings.

Cyclone wind hazard risk assessment: The PML for buildings are estimated based on occupancy and replacement cost. The estimated losses are of the tune of Rs. 89 Crores for residential buildings in a worst-case scenario (100 years return period) for cyclonic wind hazard. The estimated loss for utility sector, particularly electric network is the highest and is of the tune of Rs. 201 lakhs, Rs 325 lakhs and Rs. 588 lakhs for 25, 50 and 100 year return periods respectively.

Epidemic risk assessment: For the epidemic risk assessment, taking into consideration of the historic disease incidence data, malaria disease is only considered. Based on the reported case records, government spending and per capita income of the city, the probable loss due to malaria disease is estimated to be in the order of Rs. 9.57 Crores for the year 2013.

Climate Change impact on Health Sector: The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) concluded that climate change would have adverse impact on human health. As the city is vulnerable to climate related hazards, this would have significant implications unless appropriate mitigation measures are not adopted. The
temperature variation due to climate change would have adverse effects on both morbidity and mortality including cardiovascular, respiratory, and heat stroke mortality as well as increase in incidence of water borne diseases like typhoid and diarrhea. The changes in the rainfall pattern would increase the incidence of vector borne diseases – malaria, dengue and chikungunya. City’s minimum temperature, rainfall during the monsoon months has a high correlation with the malaria incidence in the city.

Based on hazard scenarios, exposure, and structural vulnerability the affected population and causalities are estimated. For flood hazard, affected population estimated for 100-year return period is about 2.55 lakhs and 37 injuries including fatalities.

**Risk Atlas:** Risk atlas is prepared as separate document, which is a compilation of all the base and analytical maps generated as part of this study. The risk atlas is presented at ward level, which would help to understand the spatial distribution of hazard, exposure and risk.

**Capacity Assessment:** The capacity in terms of response and relief with respect to knowledge, skill and awareness towards mitigation and adaptation measures are analyzed. The city administration has reasonably good infrastructure, knowledge and resources for disaster management. It is essential to enhance the knowledge about climate change impacts on disaster, and its adverse impacts on city to mainstream disaster management in city’s developmental planning. A comprehensive epidemic contingency plan is required for the city with long-term investments in health sector, considering impacts of climate change. At community level, awareness on Building Codes (byelaws), landuse restrictions, hazard zones etc., are needed. There should be sensitization program on hygiene and preventive measures for minimizing epidemics particularly during post-disaster situations. NGOs and community organizations need to be encouraged to be part of community capacity building activities.

**Recommended Actions:** Based on the city level risk assessment, recommended actions are suggested for the disaster risk reduction of the city. This includes both structural and non-structural measures. It warns mainstreaming disaster management in city development planning to reduce the risk and protect the life and assets of the city. While sector specific interventions are required, they should be based on community needs, future growth trends and risk scenarios of the city. It needs coordination among sectors, and an integrated approach to ensure mitigation, and adaptation measures would not cause any adverse impact. The mitigation and adaptation measures need to be phased appropriately and integrated into city's short, medium, and long-term plans.

**Cyclone adaptation and mitigation measures**

The economic losses of residential buildings and electric power lines are highest due to cyclonic winds. It needs the following measure to reduce these losses:

- Building codes (byelaws) for various types of buildings in general and residential buildings in particular need to be put into effect to reduce the cyclonic wind risk in the city. In a phased manner, the tinned/asbestos roof buildings should be evaluated by a certified structural engineer for their resistance to cyclone. This should be followed up by appropriate retrofit measures.

- The overhead lines in general, and electric power lines in particular, needs to gradually covert to underground cables to avoid damage and loss due to cyclonic wind.

**Flood adaptation and mitigation measures**

Flood risk management intervention is essentially required mainly to protect the residential assets of the city. Approach required for flood risk management for Krishna River and Budameru drain is different due to the nature of the flood and flood impact.
- Enforcing strict landuse is required in the banks of Krishna River to avoid encroachment of settlement in the riverbed. This has to be carried out in a phased manner with immediate steps towards restriction of construction of new houses in the river bed and in due course relocate the existing habitat to other parts of the city through some urban housing programs.
- Any structural intervention for flood mitigation in Krishna River to protect the city needs to be dealt at a watershed level. Local interventions may not be of much help to resolve the flood issues of the city, and may cause negative impact in the downstream.
- Taking into consideration of short lean time of the flooding in Budameru area, strengthening of Early Warning System (EWS) using telemetry system need be explored.
- The Budameru drain also has large number of encroachments within it’s channel and these communities are mostly affected during flooding. Enforcing landuse restriction taking into consideration of flood risk zone is required.

**Rock fall/Landslide adaption and mitigation measures**

- Creating awareness in the community towards risk of living in rock-fall prone areas and administration to develop suitable mitigation measures, if such habitats cannot be relocated.
- On a priority restriction of encroachment on high risk slopes need to be imposed.
- Slopes facing the main road need site inspection and need structural intervention to avoid rock fall.

**Heat wave adaptation and mitigation measures**

- Creating awareness among community towards energy efficient buildings.
- While developing building codes for residential buildings, it is also important to consider the heat wave risk. The design specifications should take in account of guidelines on the design of green buildings.
- Mandating green building designs for government and public buildings.
- Improving green cover in the city in a phased manner to develop heat syncs.
- Awareness for people to live-with heat wave situations like drinking of enough water, avoid alcohol consumption, suitable dressing, etc.
- Training masons for construction of buildings following building codes and design specification that covers features of green buildings.

**Epidemics adaptation and mitigation measures**

Health is a key sector that needs priority consideration as part of DRR activities both in short and medium term planning. This includes:

- Public awareness for improving hygiene and sanitation.
- Monitoring of commercial eating places to adhere quality standards, ensuring availability of good quality drinking water.
- Imparting hygiene and sanitation education in schools.
- Coordination with Public Work Department (PWD) for desilting drains to avoid waterlogging during rainy season.
- Landuse planning need to take into consideration of water logging issues during and after construction and developmental activities.
- Coordinate with railway department, and PWD and regularly fumigate railway yard, trains in the train yards particularly during rainy seasons.
• Periodic inspection across city to identify potential mosquito breeding places and take necessary steps before and or during rainy seasons

**Climate change adaptation measures**

• Landuse and infrastructure development plans of the city need to take into consider the climate change trends.
• The storm water drains of the city need to develop taking into consideration of the flood scenarios and the rainfall variations trends based on climate change scenarios.

**IT and Database Development**

• Spatial data for the city is presently used only by planning department. It needs to develop/migrate the spatial data available in various formats (Autocad) into GIS platform to help in using for various decision making processes including DRR activities. This should be a central database and accessible to various departments through defined data sharing policies.
• The city needs to have a mechanism to develop disease incidence data from both government and private hospitals. This can be done through an online module in the city portal where access can be given to users (government and private hospitals) to enter category wise tested and positive identified cases at their institutions. Similar to birth and death registry, registering disease incidence for identified disease need to be mandatory.
• Health contingency planning should be based on disease incidence data.
• Damage assessment report need to following the format developed and circulated by NDMA and need to be decentralized, in the case of city it would be at ward level. Mobile based application can be developed for ward officials to make online entry of damage information to populate this database in distributed manner.

**Mainstreaming integrated DRR in city development planning**

• The city master plan need to consider the disaster risk and integrate mitigation measures in the vision document.
• City with the support of the political representatives need to enforce landuse zoning and building codes based on hazard and risk maps.
• Implement incentives and disincentives for climate proofing – tax subsidy for houses with climate proofing and disincentives like climate risk penalties for people encroached in hazard risk areas.
• Awareness of political representatives will help regulating community encroachment in hazard prone areas.

As a part of medium and long term planning process, the city need design and develop proper storm water network to avoid situation of urban flash floods.