Thiruvananthapuram City, Kerala

Hazard & Vulnerability Assessment Report

Sunil

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Hazard and Vulnerability Assessment Report - Thiruvananthapuram City

This report was prepared with co-funding of the 'Govt. of India (GoI), United Nations Development Programme (UNDP) and USAID Climate Risk Management Project in Urban Areas through Disaster Preparedness and Mitigation' which is a sub-component of the 'GoI-UNDP Project on Enhancing Institutional and Community Resilience to Disasters and Climate Change" (2013 –2017)".

Hazard and Vulnerability Assessment Report – Thiruvananthapuram City

First edition 2015

Government of Kerala

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CONTENTS

List of Tables

List of Figures

List of Annexures

1. INTRODUCTION

Natural hazards by themselves do not cause disasters – it is the combination of an exposed, vulnerable and ill-prepared population or community with a hazard event that results in a disaster. Climate change will therefore affect disaster risks in two ways, firstly through the likely increase in weather and climate hazards, and secondly through increases in the vulnerability of communities to natural hazards, particularly through ecosystem degradation, reductions in water and food availability, and changes to livelihoods. Climate change will add yet another stress to those of environmental degradation and rapid unplanned urban growth, further reducing communities' abilities to cope with even the existing levels of weather hazards [1].

Thiruvananthapuram City is home to nearly eight lakh people inhabiting 215 km^2 of land. With the current rate of urbanization and development, the city and the adjoining urban sprawl is expected to witness a massive growth in its population. Thiruvananthapuram city is historically vulnerable to various natural disasters. The city is prone to naturally triggered hazards like flood, drought, coastal erosion[1], lightning and earthquakes and human induced hazards like petro-chemical accidents, transportation accidents and epidemics.

Understanding the disaster proneness of the city and undertaking appropriate risk management activity is essential to the wellbeing of the city dwellers. Increasing frequency of urban flooding, severe droughts and windfall[2] of trees in the recent past has proved disastrous to life, property and livelihood in the city.

The 35 km long coastline is vulnerable to various hazards particularly during monsoons. Of the 100 wards in the city corporation, 14 wards have coastal line as boundary.

The city has experienced minor earthquakes. Lightning, which is of common occurrence during north east monsoon season claims several lives and causes damage to property almost every year. The rise in anthropogenic hazards such as industrial mishaps, road accidents are also of major concern. Windfall is a common event in the city causing substantial damages to life and property.

1.1. HAZARD, VULNERABILITY AND RISK ASSESSMENT

Hazard, vulnerability and risk assessment is the combined process of quantifying the spatio-temporal return probabilities of various hazards, the expected degree of damage that a given element or set of elements-at-risk is exposed to and the expected monetary losses when a given area is exposed to hazards within a given period of time. This forms the most fundamental and primary activity in the disaster risk reduction cycle (Figure 1) and hence has to be a continuous process.

In the context of HVRA, the terms hazard, vulnerability and risk has specific definitions, they being:

- Hazard (H): is the probability of occurrence of a potentially damaging phenomenon within a specified period of time, within a given area.
- Vulnerability (V): the degree of loss to a given element or set of elements-at-risk resulting from the occurrence of a natural phenomenon of a given magnitude. Usually expressed on a scale from 0 (no damage) to 1 (total damage).
- Elements at risk (E) means the population, properties, economic activities, including public services, etc. at risk in a given area.

[1] Vide GO (Ms). 343/2015/DMD dated 23rd July 2015, the Government of Kerala has recognized lightning, coastal erosion and 'strong wind less than cyclone or cyclonic storms which causes damages to life and property' as state specific disasters with entitlement for relief assistance from NDRF/SDRF.
[2] The term "windfall" refers both to a tree that has toppled to the ground, and to the disturbance created by its fall (Govt. of Canada).

- Risk (R): is a function of hazard, vulnerability of cumulative loss potential, often expressed in monetary-value/time.

The universally accepted method for conducting HVRA follows the guiding formula:

R = H * V * Amount

where, Amount is the monetary-value of the element(s)-at-risk. Thus for each hazard probability scenario one can estimate a specific vulnerability and a specific risk. This is pictorially illustrated in Figure 2. All this is easily said than done. There are complexities involved in all stages of this calculation, starting from hazard quantification (for example, how to calculate the return probability of epidemics, road accidents, lightning strikes etc.) to assigning a specific monetary-value to social elements at risk (for example, an ancestral temple, a tomb, a pregnant woman, etc.). All the three components of HVRA have spatial and temporal dimensions and the results if to be useful for administrators have to be spatially explicit and thus have to be maps generated in a Geographic Information Systems (GIS) environment that provides integrated spatial analysis capabilities.

The primary objective of undertaking a HVRA is to anticipate the potential hazards and possible mitigation measures to help save lives, protect property, assets, reduce damage and facilitate a speedy recovery. The HVRA helps the policy makers, administrators and the community to make risk based choices to address vulnerabilities, mitigate hazards, and prepare for response to and recovery from hazard events. Further, in areas identified as potential hazard hotspots through HVRA, early warning systems that incorporate instrumented monitoring devices, high-end numerical predictive models and communication devices may be developed and deployed such that sufficient time may be made available to authorities for evacuation and implementing contingency measures in the eve of an impending disaster.

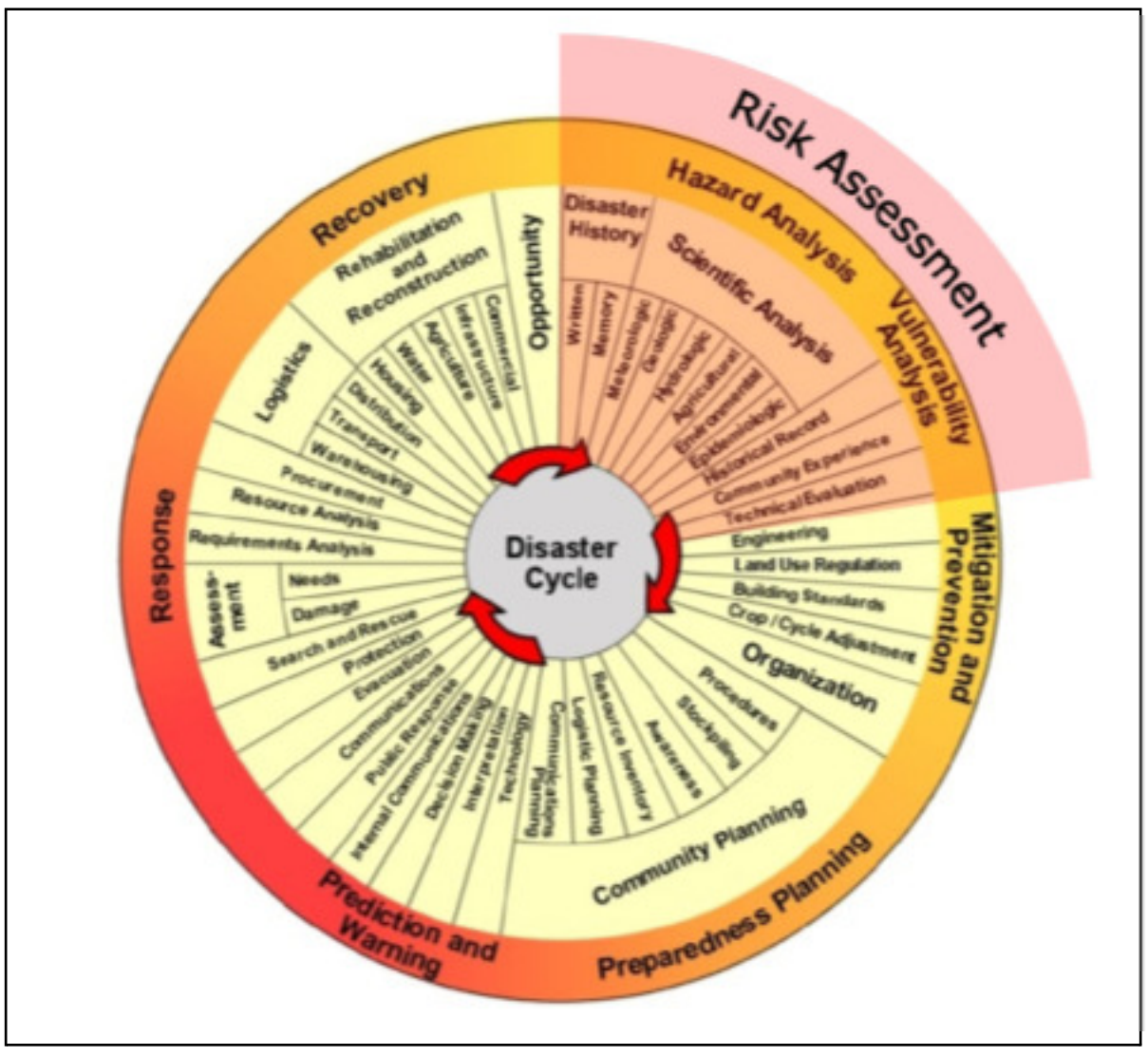
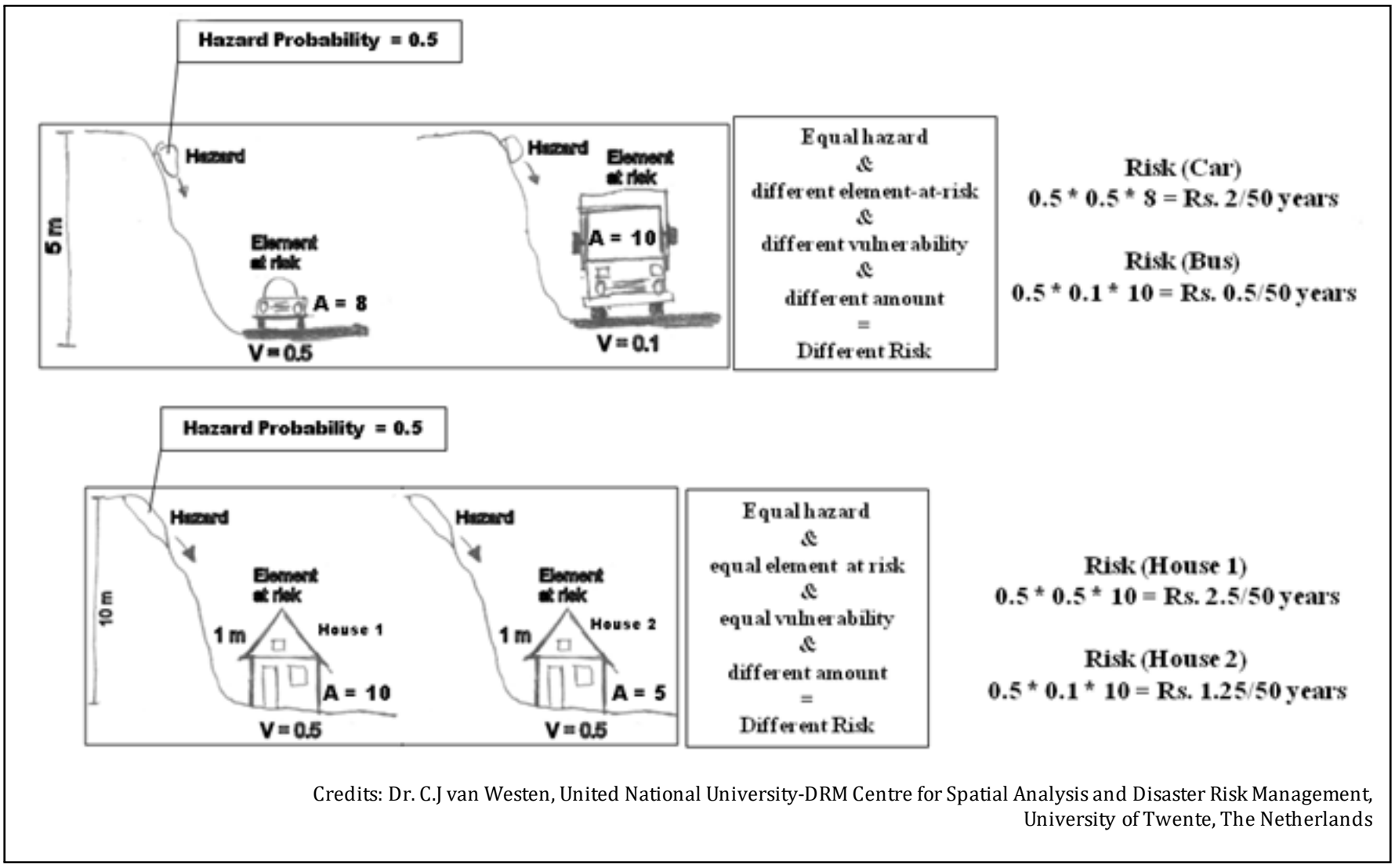


FIGURE 1: TRADITIONAL DISASTER RISK REDUCTION CYCLE AND THE ROLE OF HAZARD, VULNERABILITY AND RISK ASSESSMENT

The scope of the present report is limited to the assessment of hazards and vulnerabilities of Thiruvananthapuram City to apparent disasters in a heuristic manner. Risk quantification is not attempted in its strict definition sense due to non-availability of necessary data.



Credits: Dr. C.J van Westen, United National University-DRM Centre for Spatial Analysis and Disaster Risk Management, University of Twente, The Netherlands

FIGURE 2: PICTORIAL REPRESENTATION OF RISK CALCULATION

2. OVERVIEW & HISTORY OF THIRUVANANTHAPURAM CITY

Thiruvananthapuram, the capital of Kerala, is one of the ancient cities that have references in Greek and Roman literatures. The Ays were the prominent political power in Thiruvananthapuram during the early 10th century with their dynasty extending from Nagercoil in the South to Thiruvalla in the North. However, the city came to vanguard when the Venad Dynasty came into power of Southern regions of India in 14th century. The Venad rulers were known for their expertise in administration and it is during the reign of Maharaja Marthanda Varma the kingdom of Travancore was formed. The kingdom included many small states and various feudal principalities like Attingal, Kollam, Kayamkulam, Kottarakara, Kottayam, Changanassery, Meenachil, Poonjar and Ambalapuzha. The entire city kingdom was dedicated to the deity Lord Padmanabha by the king, making it the land of Lord Vishnu, "Thiru-anantha-puram".

In 1745, the entire administration was moved to Thiruvananthapuram city from the Royal headquarters of Sree Padmanabhapuram Fort in present day Tamil Nadu. Maharaja Marthanda Varma shifted the capital to Thiruananthapuram mainly because of the proximity of Padmanabha Temple and Royal residences. Thiruvananthapuram thus became the capital of Travancore and the city started growing around the temple.

The city continued to flourish in art, education and heritage under the rule of Raja Rama Varma and Maharaja Swati Thirunal. Thiruvananthapuram city, under the royal patronage grew into a major academic and cultural hub of India. The Maharajas always took great efforts to keep the city in forefront in all aspects of development. The power and wealth of Travancore Kingdom reached its peak during early 20th century and as a result Thiruvananthapuram became a major prosperous city. Travancore was one of the richest princely states even during the British reign. Formal English education was opened to civilians in 1834 through an English school at Thiruvananthapuram.

In 1836, an observatory and a charity hospital were established. In 1873, the University College was opened. It was during the reign of Sri Moolam Thirunal (1885-1924) that the Sanskrit College, Ayurveda College, Law College and a second grade College for Women, started at Thiruvananthapuram. In 1949, Thiruvananthapuram was made the capital of Thiru-Kochi (Travancore and Kochi kingdoms combined). With independence of India, the Travancore chose to join the India Union. After formation of Kerala State in 1956, it was decided to sustain Thiruvananthapuram as the capital city. Since its accession as the capital and administrative city of Kerala State, Thiruvananthapuram has become one of the major educational and cultural centres in Kerala, owning a number of firsts to its credit.

Thiruvananthapuram city was one of the first cities to be entirely electrified in South India, to possess a full-fledged sewage draining system for its residents, the first city in South India to implement the concept of drinking water through pipelines, had the only airport down South and had city buses operating in the city even during the princely days. The establishment and growth of Technopark as the largest Information Technology Park in South Asia, made a major stimulus to the progress of city. The evolution of Thiruvananthapuram as the capital city paved way for many employment opportunities and in the process became a populous city. Previous decades witnessed the increase of urban agglomeration and urban outgrowths in and around Thiruvananthapuram city. The growth in urban population owes to the advancements in service sectors and urbanization.

2.1. TOPOGRAPHY

Thiruvananthapuram city is located at 8°30'N and 76°54'E (Figure 3). The City Corporation which spreads over an area of 215.86 km^2 stretches over 35 km of low lying coastal belt. The undulating mid land is sandwiched between the green mountain forests of Western Ghats in the west and Lakshadweep Sea in the east. The elevation of land varies from 0 m to 165 m from sea level. Although the city has a rolling terrain towards the hills and plain

towards the coastal belt, Kovalam-Vizhinjam regions show rolling terrain in the coastal belt and this natural feature of terrain benefits the city of Thiruvananthapuram to be a natural sea port (Figure 4).

2.2. GEOLOGY

Geologically, Thiruvananthapuram City is underlined by Precambrian crystalline acid to ultrabasic intrusive of Archean to Proterozoic age. Followed by Tertiary, Sedimentary rocks and Quaternary Sediments of fluvial and marine origin. Both the crystallines and Tertiary sediments have been extensively laterised (Figure 5).

2.3. SOIL

The city has many types of soil, laterite and alluvial soils being the most commonly occuring. Alluvial soil is seen in low lying areas and valleys whereas laterite soil are found in the summits and slopping area. Sandy soil is found towards the beach (Figure 6).

2.4. NATURAL DRAINAGE NETWORK

2.4.1. BACKWATERS

The extensive backwaters of city provide picturesque public spaces for recreation. The major lakes in the city are Veli, Akkulam and Velayani (fresh water). Another significant water body, the Thiruvananthapuram-Shornur canal, partly an artificial waterway, acts as a connection between Akkulam-Veli and Velayani lakes and passes through Vallakadavu.

2.4.2 RIVERS

Among the three rivers in the district, the Karamana and Killiy Ar flows through the city. Karamana River with two reservoirs at Peppara and Aruvikkara is the main surface water source for Thiruvananthapuram City's fresh water supply scheme. Figure 7 illustrates the natural drainage network of Thiruvananthapuram City Corporation.

2.5 TRANSPORTATION NETWORK

2.5.1 ROAD

Road network is the most crucial transport medium in the city having a density of 4.11/km. NH 66*, which passes through city centre, divides it into two halves. National High Way is bypassed from Kazhakuttom to Kovalam and runs parallel to the coastline of the city. Other arterial roads, namely MC road, TS road, SH 02, MG road and Palayam Chakai road serves as major lifelines of the city. The arterial roads along with the intra city link roads have a carriageway width ranging from 6 to 16 m (Figure 8).

2.5.2 RAILWAYS

The city is connected via rail network to all parts of the state and country. The urban population within and from neighbouring districts depend on railways service for daily transportation. Apart from the central station at Thampanoor, there are stations at Pettah, Veli, Kochu Veli and Kazhakoottam (Figure 8).

2.6 MAJOR LANDMARK BUILDINGS

Sree Padmanabha Swami Temple, Kanakakkunnu Palace, Observatory, Science and Technology Museum, Government Secretariat, Kowdiar Palace, St. Joseph's Cathedral, Tagore Centenary theatre, Museum and Zoo are some of the tourist attractions in the city.

Sree Chitra Art Gallery with its rich collection of exquisite paintings is another attraction. The gallery has a special Ravi Varma section other than one for murals, water and oil painting. The S.M.S.M Institute, Botanic Gardens at Palode and Chitranjali Studios are added attractions.

The Raj Bhavan, Central Library, Kerala University, Residency Bungalow, University College, College of Fine Arts and the Wellington Water Works are a few of the landmarks that adorn the city. There are three big stadiums, namely, the University Stadium, Chandrasekharan Nair Stadium and the Central Stadium in the city. The international Airport at Vallakadavu and the upcoming Vizhinjam port is also within the limits of the City Corporation. Figure 9 shows some important landmarks of Thiruvananthapuram City.

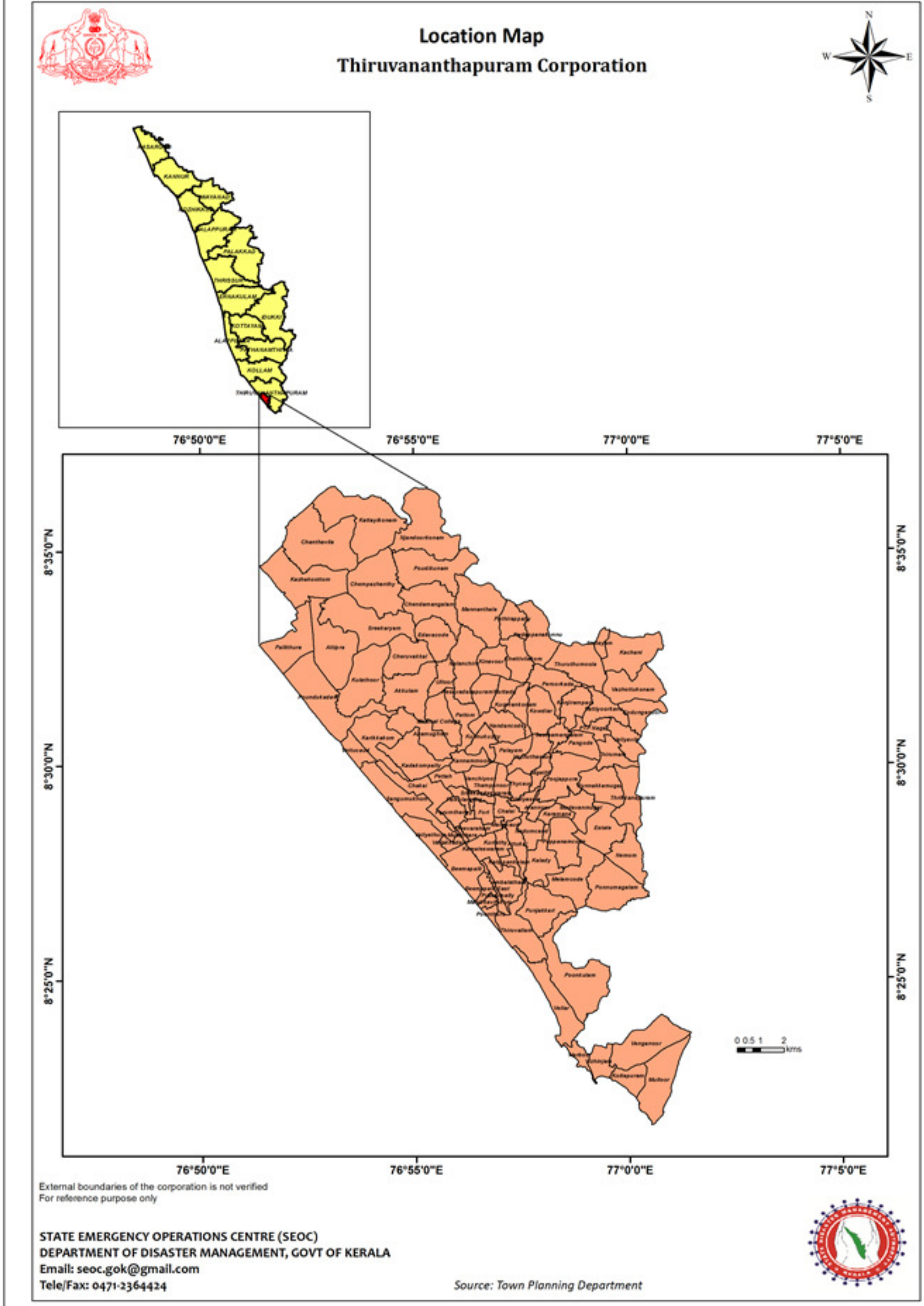


FIGURE 3: LOCATION MAP OF THIRUVANANTHAPURAM CITY

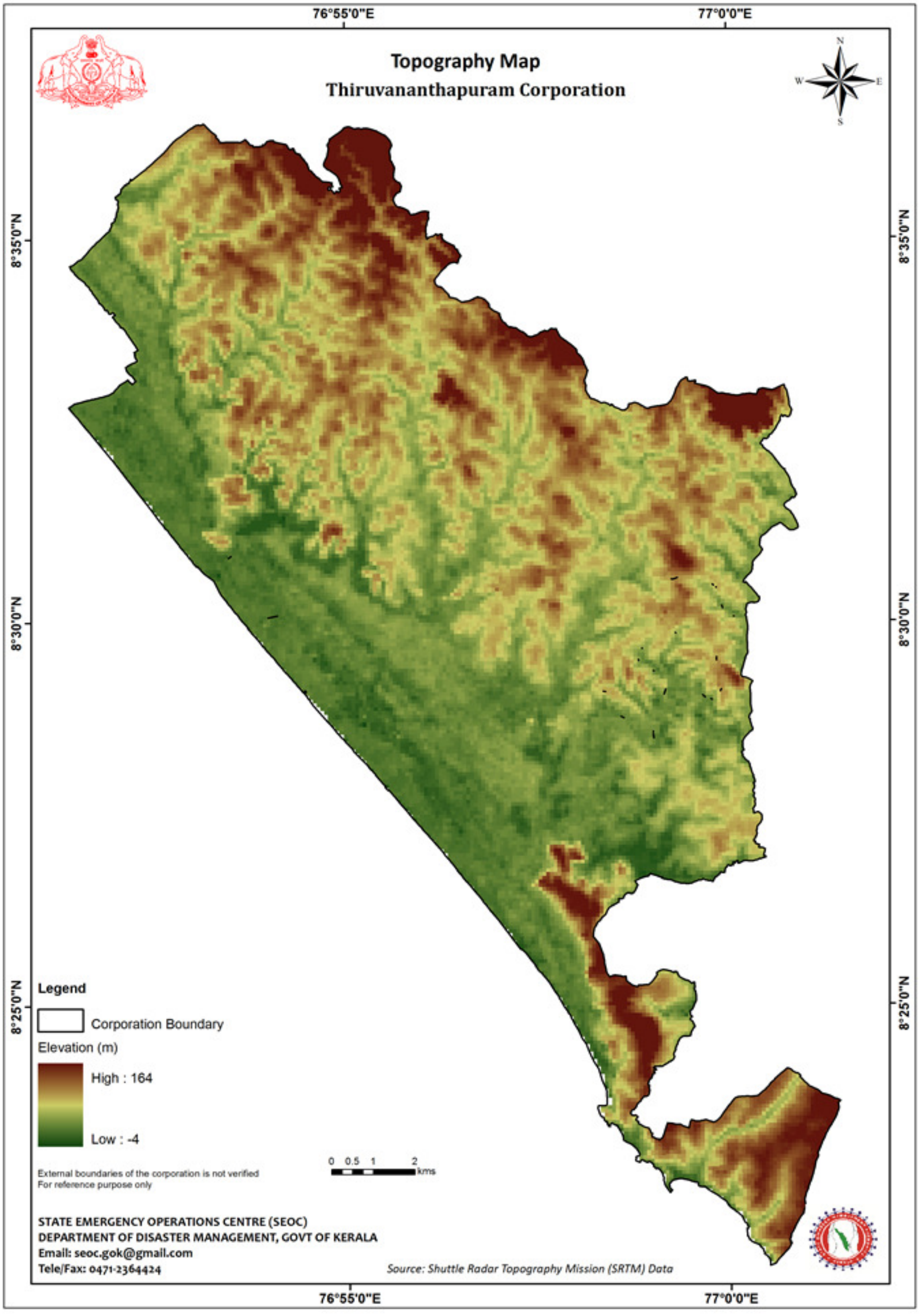


FIGURE 4: TOPOGRAPHY OF THIRUVANANTHAPURAM CITY

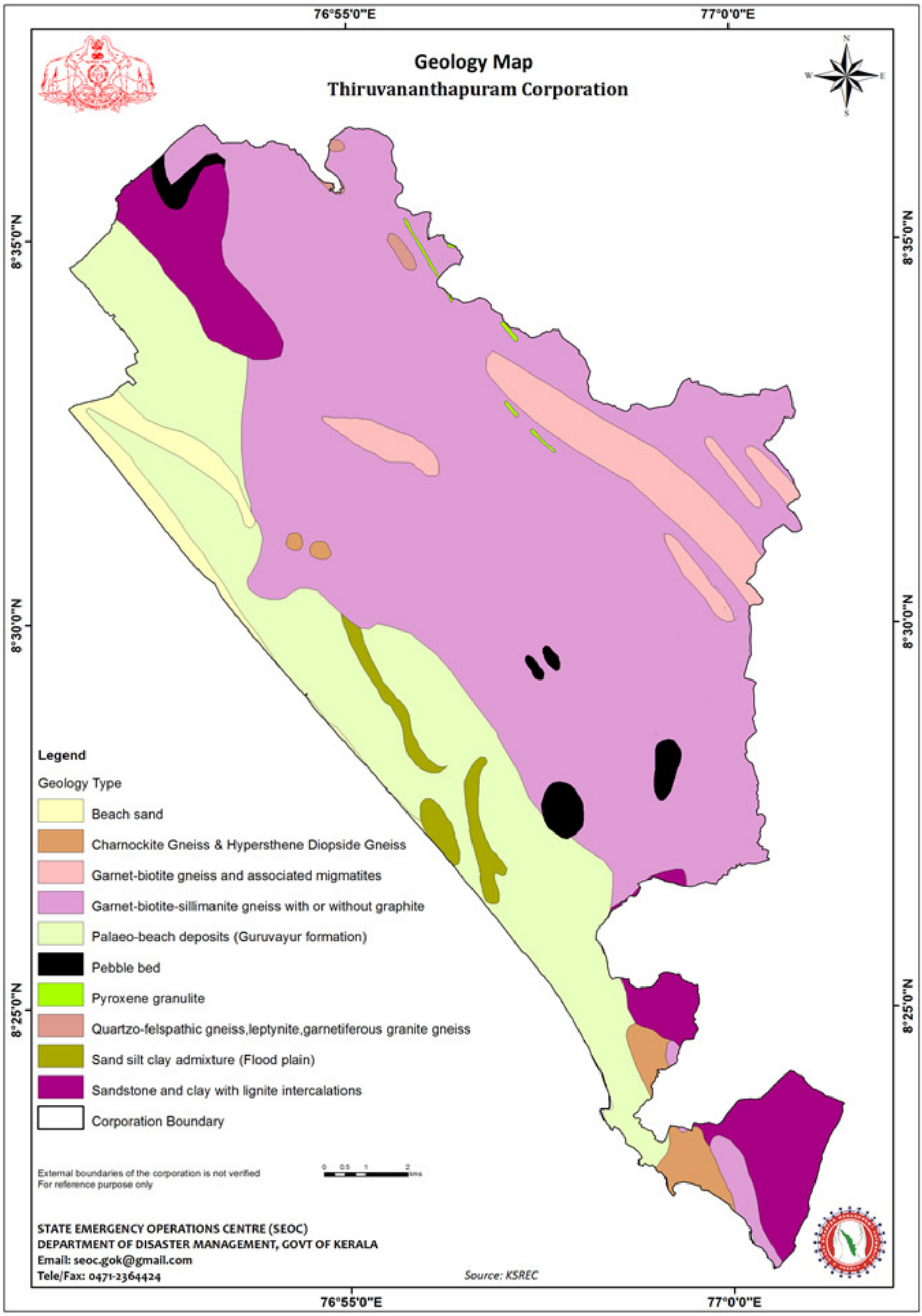


FIGURE 5: GEOLOGY OF THIRUVANANTHAPURAM CITY

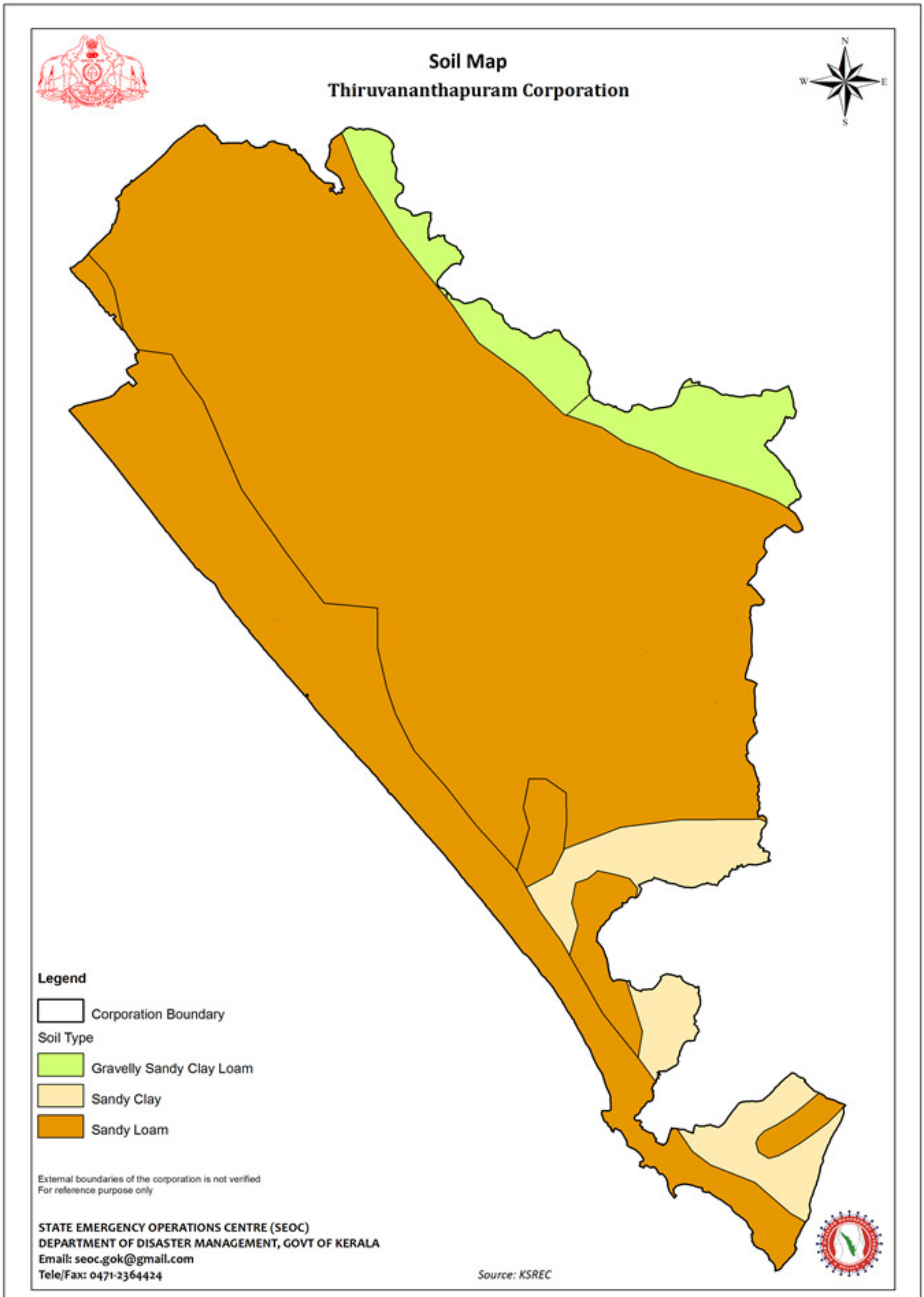


FIGURE 6: MAJOR SOIL TYPES OF THIRUVANANTHAPURAM CITY

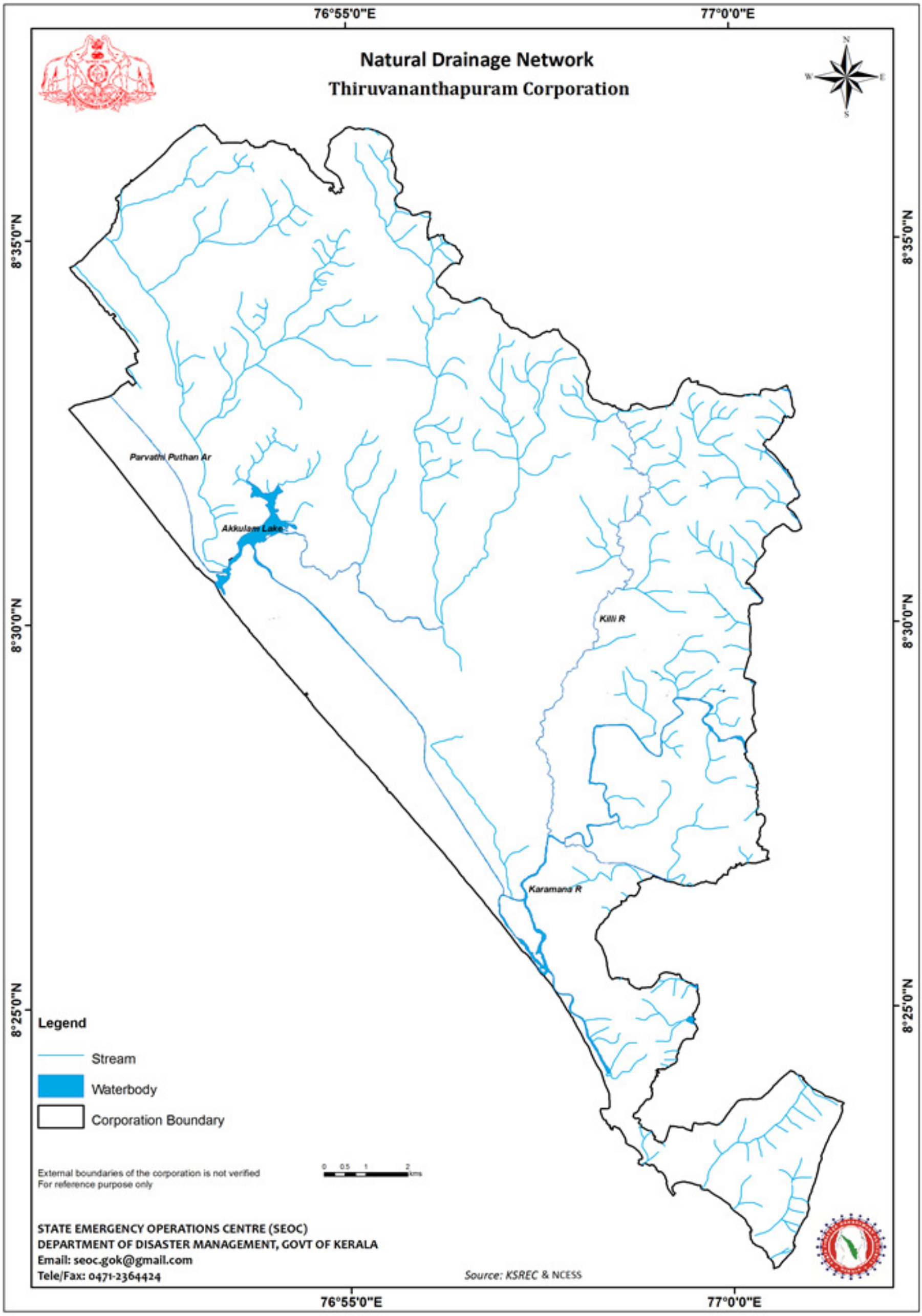


FIGURE 7: NATURAL DRAINAGE NETWORK OF THIRUVANANTHAPURAM CITY

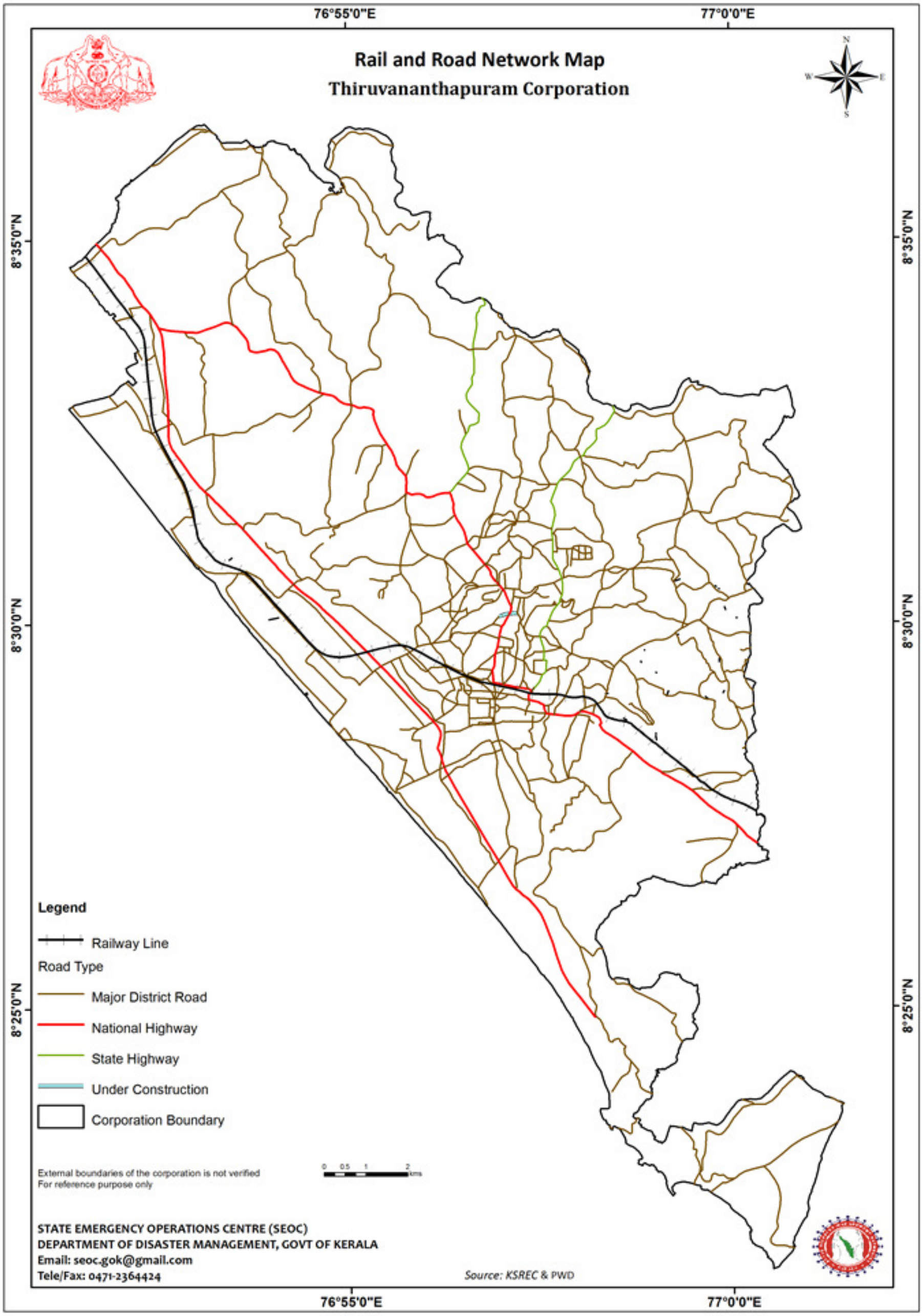


FIGURE 8: ROAD AND RAILWAY NETWORK OF THIRUVANANTHAPURAM CITY

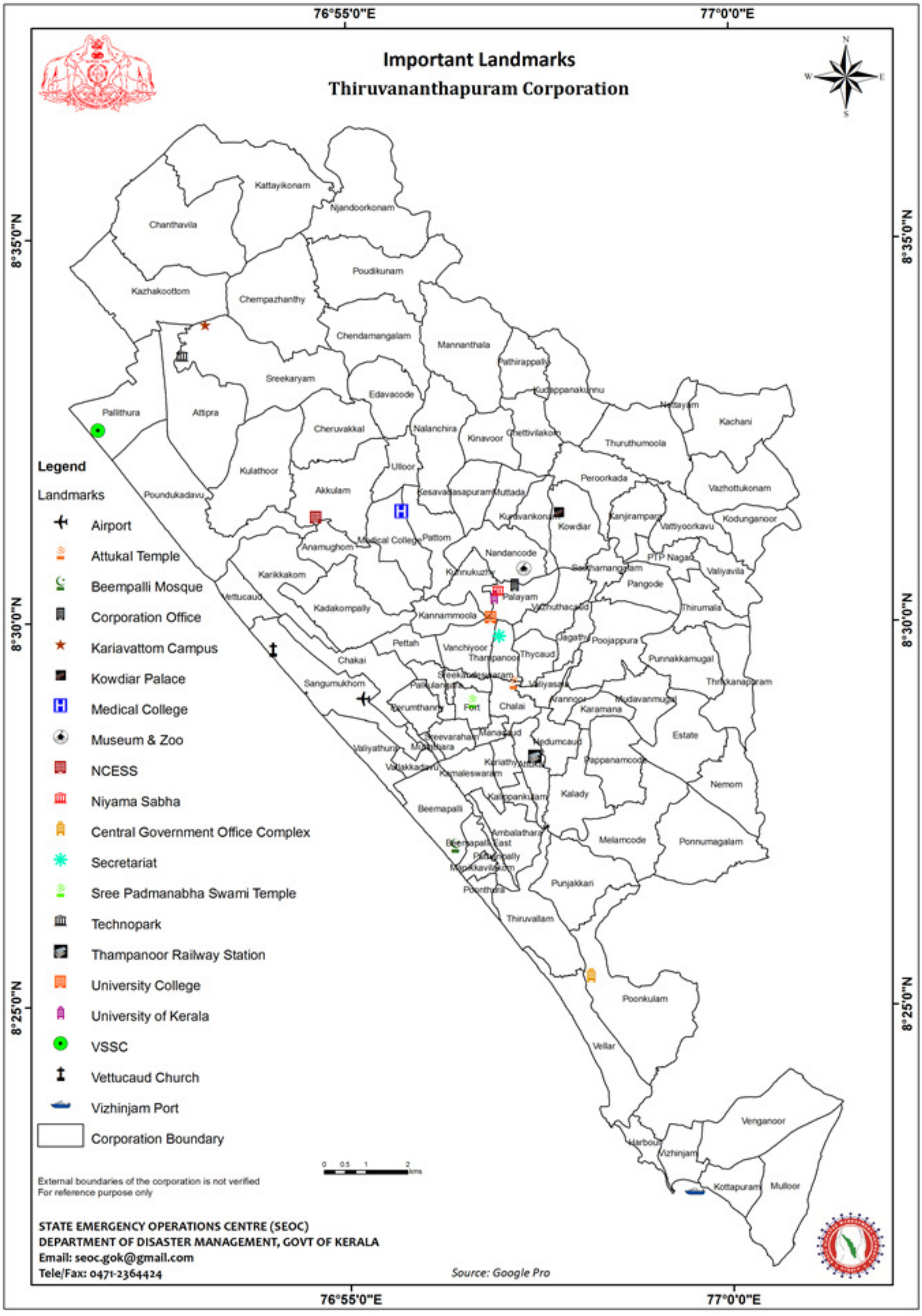


FIGURE 9: MAJOR LANDMARKS IN THIRUVANANTHAPURAM CITY

3. CLIMATE

3.1. RAINFALL

Thiruvananthapuram is the first city along the path of the south-west monsoon and gets its first showers in early June. The city also gets rain from the receding north-east monsoon which hit the city by October.

- 2348.7 mm in 1975 is the highest annual rainfall recorded in the city during the period 1971-2013
- 872 mm in 1991 is the highest monthly rainfall recorded in the city during the period 1971-2013

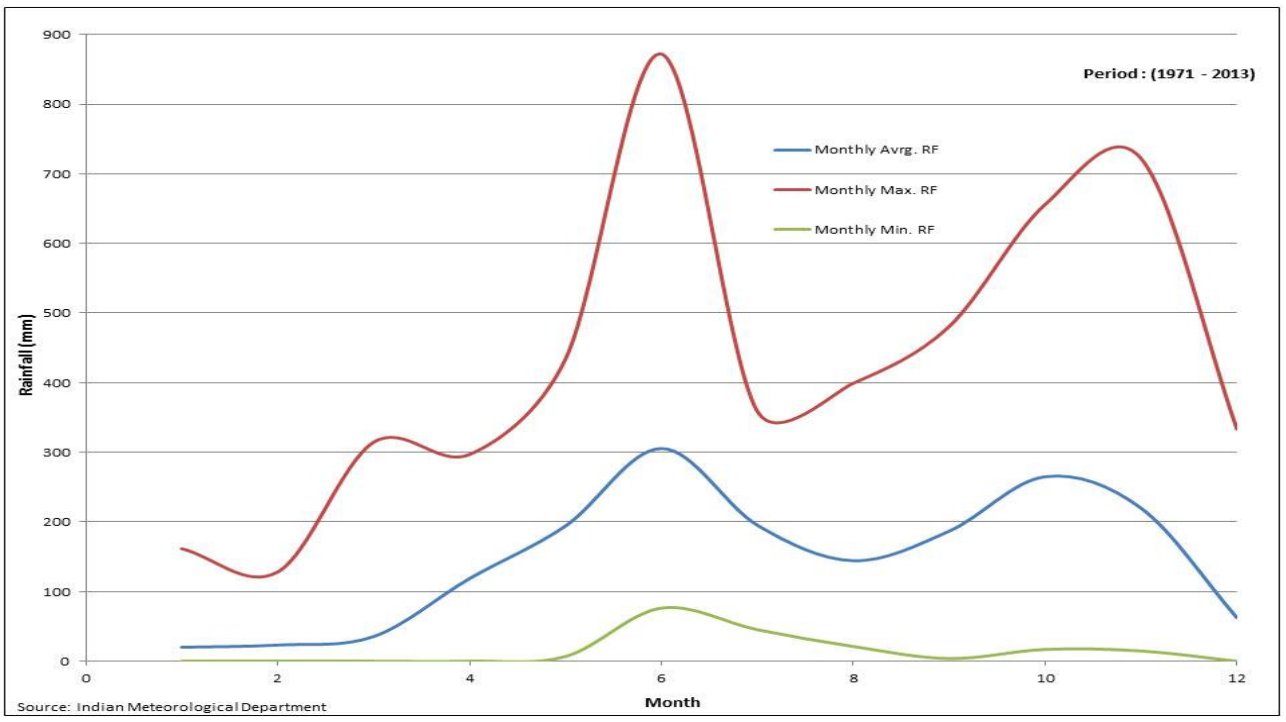


FIGURE 10: MONTHLY RAINFALL EXTREMES RECORDED IN THE CITY (1917-2013)

3.2 TEMPERATURE

The city has a mean maximum temperature of 34°C and the mean minimum temperature is 21°C. The lowest temperature recorded during winter was 15°C, and the highest temperature recorded in summer is 39°C.

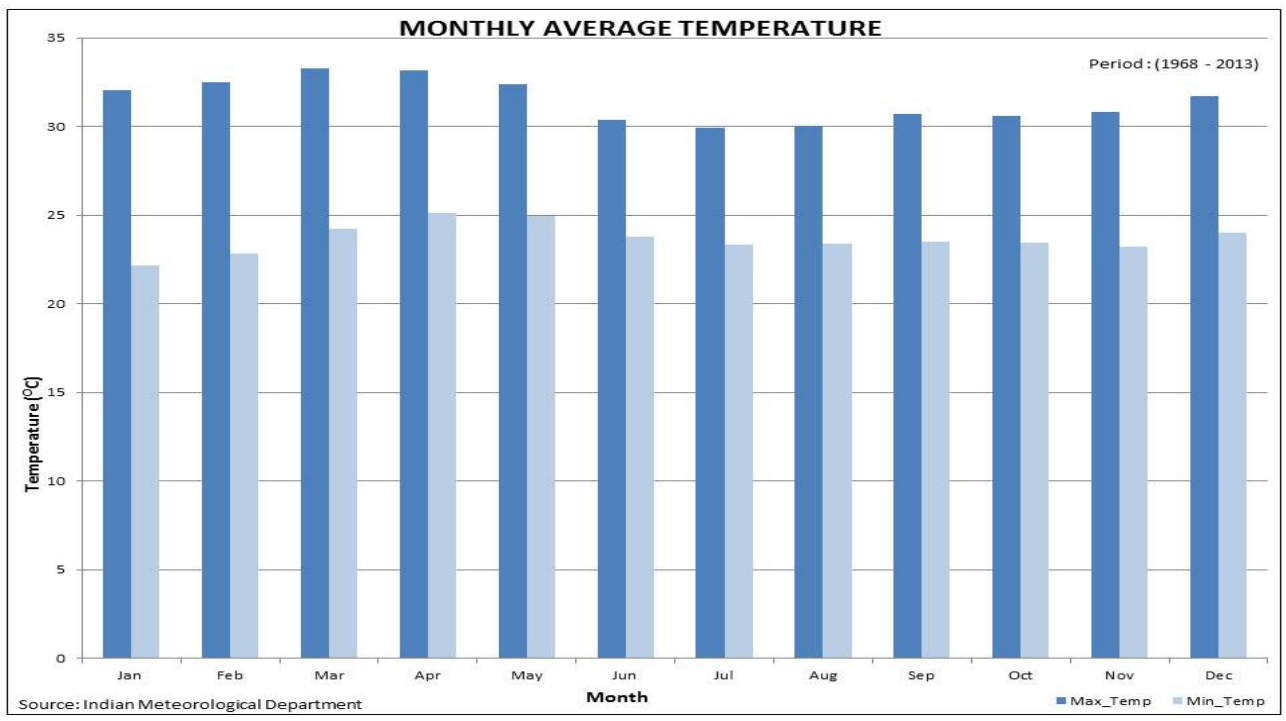


FIGURE 11: MONTHLY AVERAGE TEMPERATURE IN THE CITY (1968-2013)

- The city experiences a moderately hot and dry climate throughout the year
- Highest monthly average Maximum temperature of 34.9 °C was recorded on April 1998
- Lowest monthly average Minimum temperature of 20.4° C was recorded on January 1974

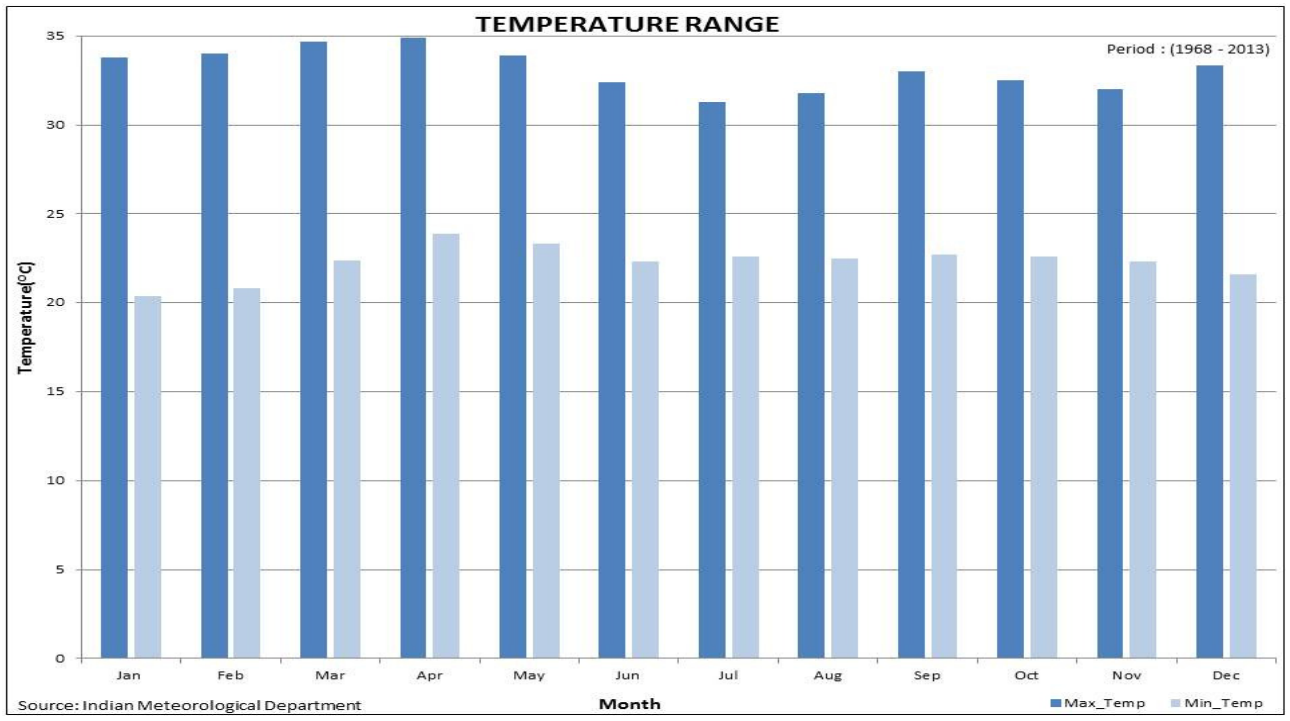


FIGURE 12: MONTHLY TEMPERATURE RANGE IN THE CITY (1968-2013)

- Highest annual Maximum temperature was recorded on 2009 (32.4°C)
- Lowest annual Minimum temperature was recorded on 2003 (22.3°C)

3.3 HUMIDITY

The humidity is high and rises to about 90% during the monsoon season and remains relatively high till December. In summer seasons the humidity is at its minimum, in the City.

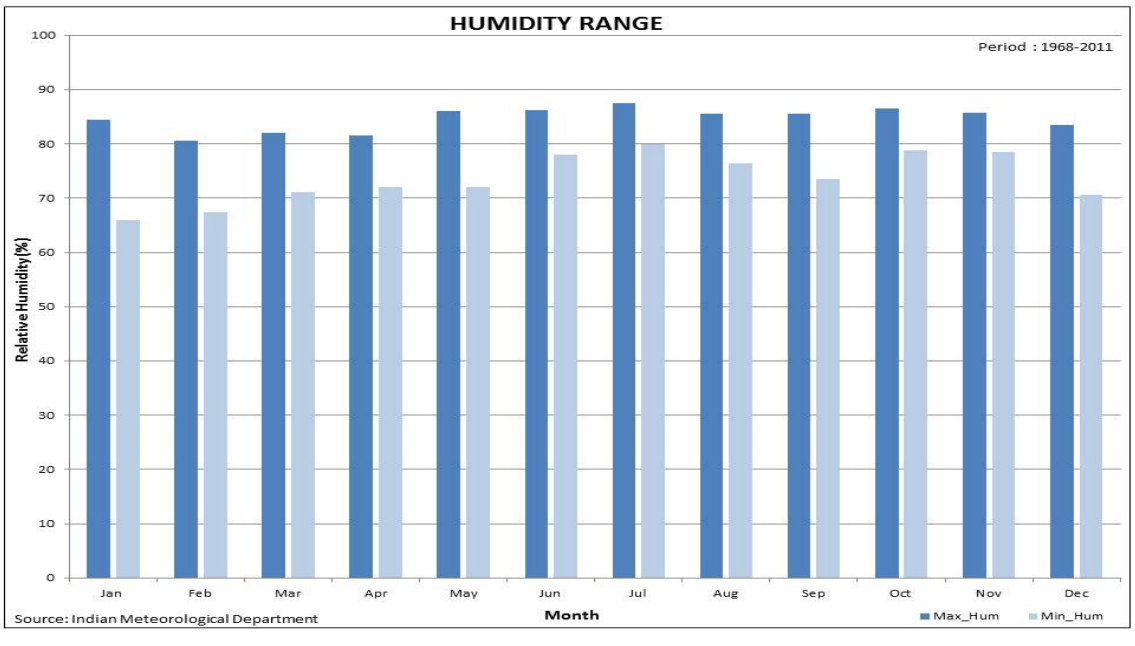


FIGURE 13: MONTHLY HUMIDITY RANGE IN THE CITY (1968-2011)

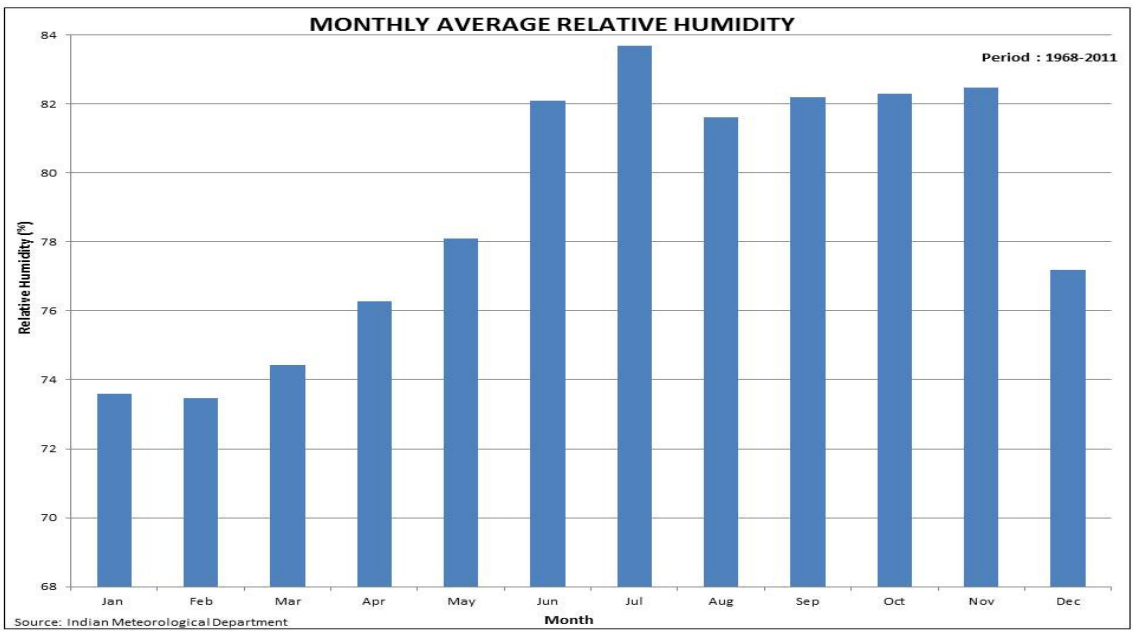
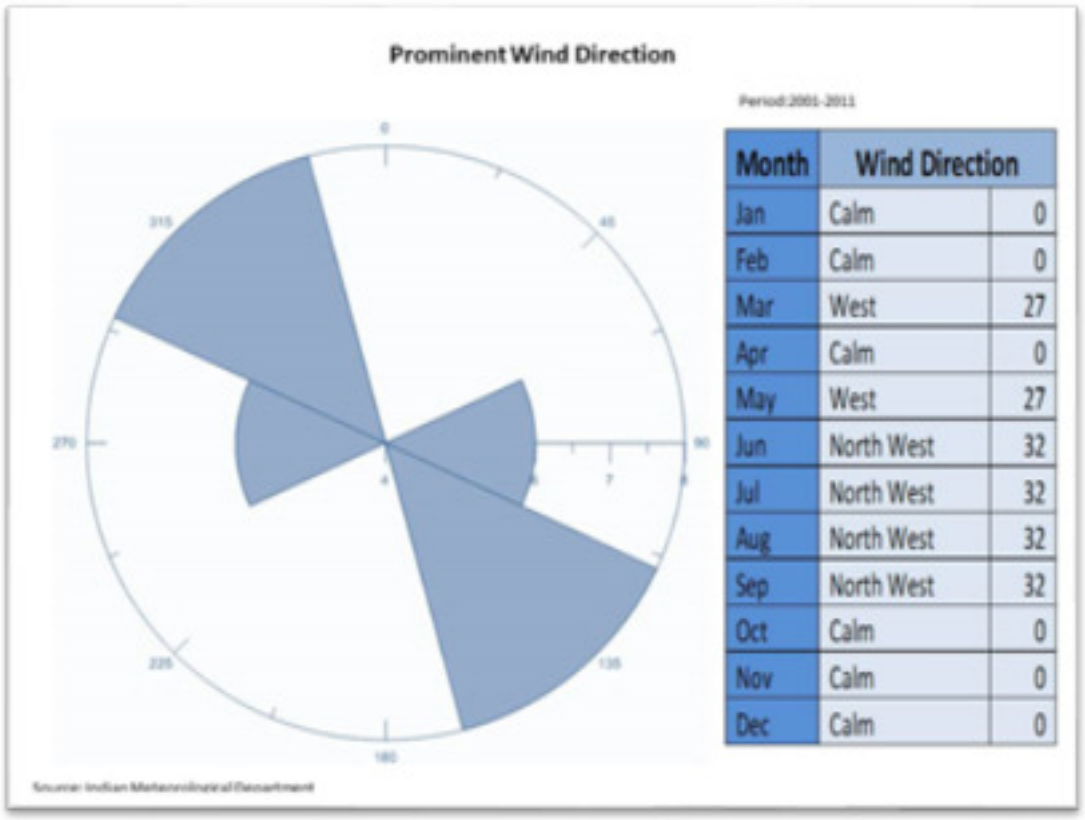


FIGURE 14: MONTHLY AVERAGE RELATIVE HUMIDITY (1968-2011)



Month	Wind Direction	
Jan	Calm	0
Feb	Calm	0
Mar	West	27
Apr	Calm	0
May	West	27
Jun	North West	32
Jul	North West	32
Aug	North West	32
Sep	North West	32
Oct	Calm	0
Nov	Calm	0
Dec	Calm	0

FIGURE 15: PROMINENT WIND DIRECTIONS

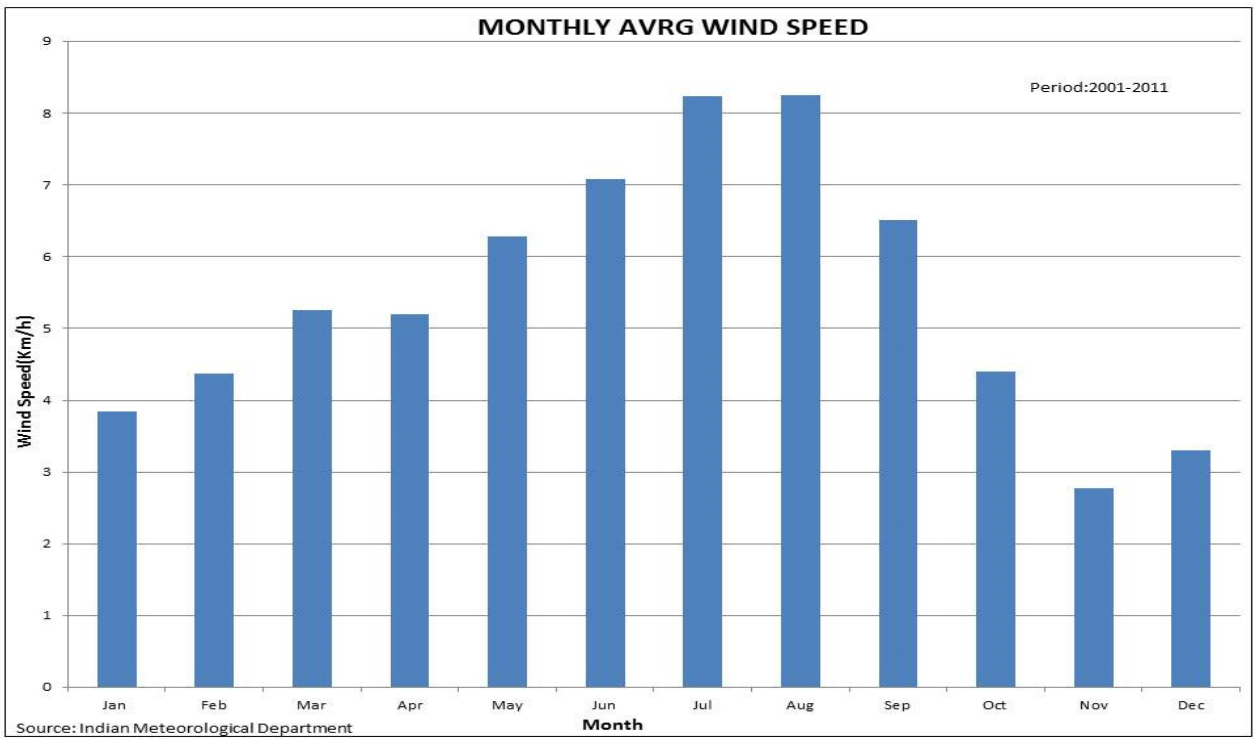


FIGURE 16: MONTHLY AVERAGE WIND SPEED (2001-2011)

The predominant wind direction is in the North West direction as shown in Figure 15. The winds gradually gain speed during the pre-monsoon and is at its highest during the monsoon period.

4. SOCIO-ECONOMIC PROFILE

Thiruvananthapuram Corporation is the largest city corporation in Kerala and holds the highest number of population with average population density of 3808 persons/km^2. As per Census 2011 the total population of Thiruvananthapuram Corporation is 7,88,271, which was 7,44,983 during 2001. To have a comprehensive notion about the demographic dynamics, it is necessary to view the population size and other aspects from a broader perspective. Census 2011 place Kerala's population at 3,33,87,677 persons. Although Kerala accounts for only about one per cent of the total area of India; it contains about 2.76% of the country's population. The population of Thiruvananthapuram district as per Census 2011 is 33,07,284. Though Thiruvananthapuram accounts for only 5.64% of state's area (2192 km^2 against 38863 km^2) it comprises 9.9% of the state population. The population is more concentrated in the coastal wards towards south of airport, and the size is less in wards located towards city core. Among wards within the corporation, total population is highest in ward number 88 (25,736) and least in ward number 83 (3,466).

As natural disasters impact inequitably on vulnerable populations around the world, disaster preparedness, recovery and reconstruction is increasingly being approached through the lens of integrated public policies on development, demographics, and disaster risk reduction. How the cross-cultural context influences disaster risk governance, and how new communities and families arise from the destruction will form the core dialogue of the present study. The following features were assessed for the holistic purpose of analysing the methodology and ways which could be employed to manage the population of Thiruvananthapuram Corporation effectively against an impending disaster.

Socio Economic Indicators	
1	Percentage of Male Female population
2	Percentage of children below age group 0-6
3	Percentage of Depressed Classes Against Total Population
4	Percentage of Literates Vs. illiterates
5	Percentage of Marginal workers, Non Marginal workers and main workers
6	Percentage of ward with maximum population vs. total population

4.1 WARD WITH MAXIMUM POPULATION VS. TOTAL POPULATION

Increased population density and urbanization increase vulnerability to disasters. Nearly 3.16% of the total population in the city corporation resides in Kovalam area which being more vulnerable to coastal hazards. Congestion, limited escape routes, dense infrastructure and availability of meagre financial resources adds to the vulnerability. In these relatively rural communities, basic services, disaster warning and response mechanisms are limited. Their limited capacity to plan for and respond to coastal hazards makes them increasingly vulnerable to disasters of various kinds.

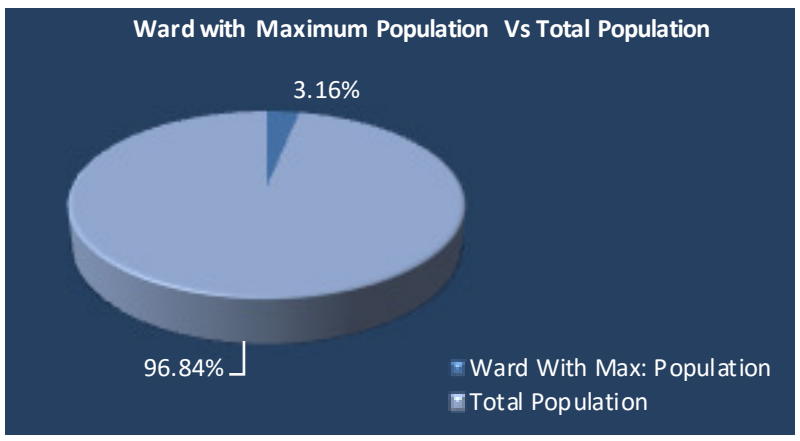


FIGURE 17: WARD WITH MAXIMUM POPULATION VS. TOTAL POPULATION OF THE CITY (CENSUS 2011)

4.2 MALE-FEMALE RATIO

It is known from past experience world over that female population is often more vulnerable to diasters. Thiruvananthapuram Corporation having a high female population requires a greater emphasis on information dissemination through self-help groups which can drastically reduce the risk factors during a disaster. Kerala being the state with high sex ratio and high literacy rate, the methodologies of using mass communication media will be highly effective in this context.

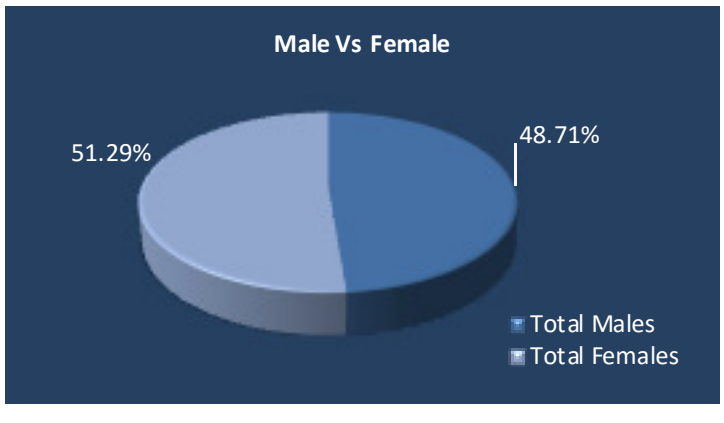


FIGURE 18: MALE VS. FEMALE PERCENTAGE (CENSUS 2011)

4.3 CHILDREN UNDER AGE GROUP 0-6

The population which is fully exposed to hazards could be bracketed in age group 0-6. These comprise 8.12% of the total population and the reduction of vulnerability of hazards on this age group could be done through managing the adult female population who in normal case bear the responsibility. Proper information services and training to educational institutions associated with this age group would also imbibe the culture of risk avert into this young aged people who will act as national assets in the future

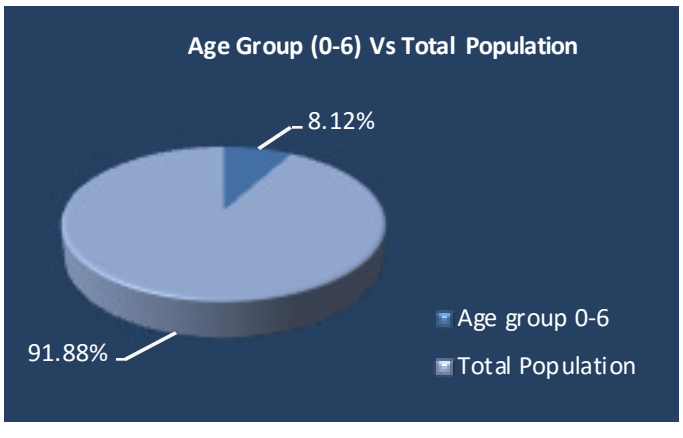


FIGURE 19: AGE GROUP OF -6 YEARS AGAINST TOTAL POPULATION (CENSUS 2011)

4.4 DEPRESSED CLASSES VS. TOTAL POPULATION

With empowerment of state functionaries and improved citizen consciousness the barrier of depressed class versus general has become very thin but still a focused approach is highly advised since the residents and type of job employed by the depressed class shows an agglomeration which put them into higher vulnerability.

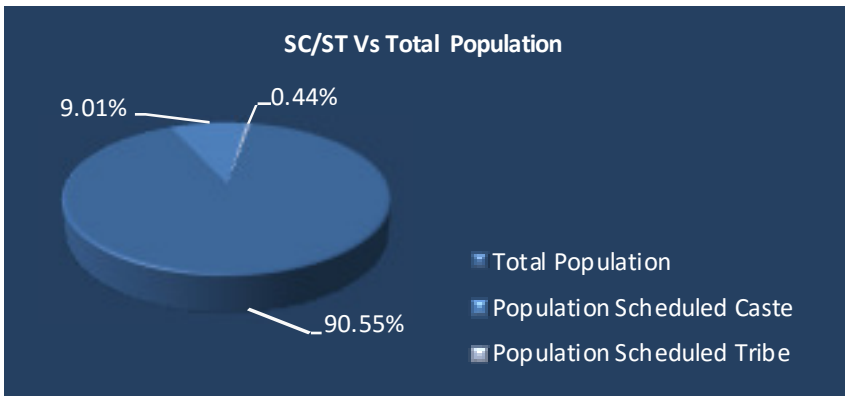


FIGURE 20: SC/ST AGAINST TOTAL POPULATION (CENSUS 2011)

4.5 LITERATES VS. ILLITERATES

As per the Census 2011, Kerala has been the most literate state in India. The present literacy rate of 93.91% as against the rate for India at 74.04% national average is a feather on the cap for the state. Thiruvananthapuram district is far below other districts; however the city corporation is above the state average by 96.84%. With this large population being literate, it is quite easy for the government in reducing their vulnerability through effective disaster risk reduction measures using information, communication and technology measures.

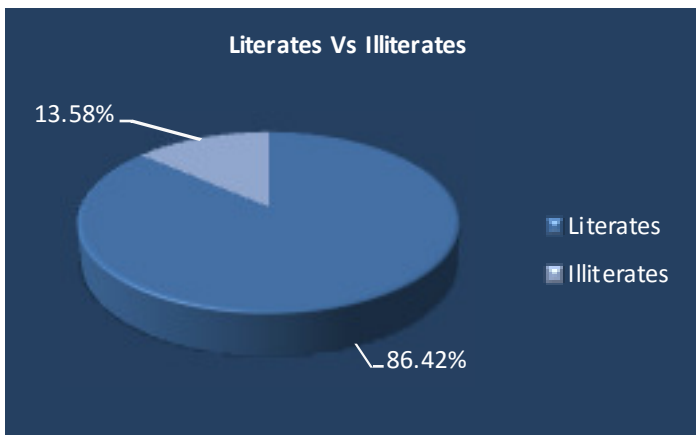


FIGURE 21: LITERATES AGAINST ILLITERATES (CENSUS 2011)

4.6 MAIN, MARGINAL AND NON WORKERS

Marginal workers and non-workers are heavily dependent population with less resilience to disasters. They constitute nearly 3.20% and 77.4% respectively of the total population in the City. While analysing the Census data (2011), its found that higher number of marginal workers and non-workers are living in the most vulnerable, densely populated area of the city, Kovalam. Thus Kovalam, the ward with maximum number of population is also the area with large number of dependent population which gets exposed to frequent number of hazards every year, adding economic burden to the people.

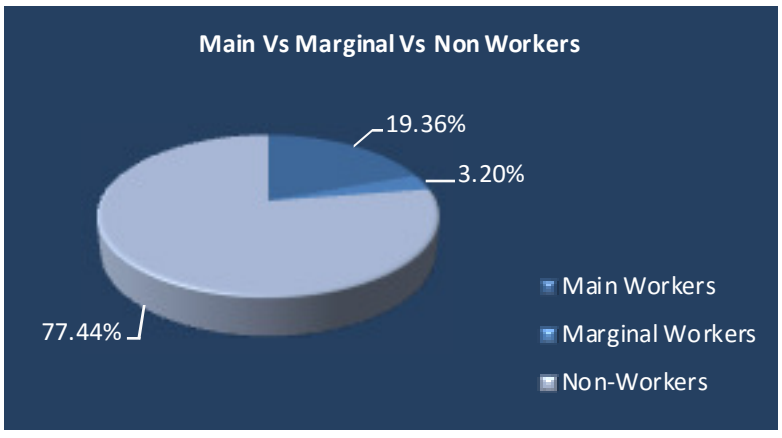


FIGURE 22: MAIN VS. MARGINAL VS. NON-WORKERS (CENSUS 2011)

5 HAZARD FOOT PRINTS

5.1 FLOODS

One of the earliest accessible Governmental records regarding the flood proneness of the present day Thiruvanathapuram city is the Royal Proceedings dated 21st December 1920 issued by Mr. N. Rajaram Row, Chief Secretary to Government. This proceedings talk about flooding in Karamana River due to which a Government farm located in present day Karamana had to be shifted from that location to other parts surrounding the city.

Table 2 shows the years that 5, 50 and 100 year return interval one day rainfall was exceeded in the City based on available rainfall records from 1986 to 2013 for 3 rain gauges surrounding the City. Continuous daily rainfall data pertaining to the City is not available and hence data from adjoining rain gauges are used. It is evident that occurrence of extreme rainfall events were few in number, however, urban flooding in the city is an annual event. This indicates that urban flooding in the City is primarily owing to inadequate maintenance and management of sewerage systems and storm water drains. Natural streams in the city flows through constrained channels due to encroachments on the banks of the streams, siltation, crisscrossing of communication cables and utility pipelines and dumping of solid waste, particularly plastic waste. Improper construction of pavements, buildings, roads, other impervious structures, choking of drainage etc. are factors that aggravate the magnitude of urban floods.

TABLE 1: FIVE, FIFTY AND HUNDRED YEAR RETURN INTERVAL DAILY RAINFALL AND YEARS OF EXCEEDANCE

Sl. No	**Nedumangadu**			**Neyyattinkara**			**Varkala**		
RI	5	50	100	5	50	100	5	50	100
Rainfall (mm)	127.5	159	168.1	108.3	131.6	138.4	131.9	155.9	162.9
Years exceeded	1993, 2003, 2004	2005, 2010, 2011	1992, 1996	1994, 2001, 2004, 2005, 2010	0	1993, 1995, 1998, 2003	1998, 2007	1989	1987, 2004, 2006, 2011

Thiruvananthapuram city has been experiencing recurrent floods, particularly in Thampanoor area where in the central railway station and main bus station are located. The areas adjoining Thampanoor also get frequently flooded during pre-monsoon (summer rain) and monsoon showers.

Pazhavangadi Thodu (drain) is one of the important storm water drains, which runs through the heart of the Thiruvananthapuram city. Pazhavangadi Thodu starts from Kerala Water Authority (KWA) at Vellayambalam and emerges into Aamayizhanjan Thodu near Kannamoola and has a length of about 5.75 km. It is the main discharge channel of Thiruvananthapuram City and traverses through key places of the city like Thampanoor, Pazhavangadi, Thakaraparambu, Vanchiyur, Pattoor etc. The water collected during a down-pour in the area adjacent to the railway station and bus stand is not drained quickly into the Thodu as the carrying capacity of the leading drains are significantly low in some places and not sufficient elsewhere. The most severe and frequent flooding in the city occurs at Thampanoor and East Fort, Pazhavangadi areas, followed by Uppilamoodu and Kannamoola areas.

Despite repeated attempts involving various types of engineering interventions the area still faces flooding during rains and this obstructs the business continuity of the area causing significant loss to public and private property. Mixing of potable and sewerage water occurs during such flood and this has increased the occurrence of epidemics in the city limits. Frequent disruption of rail and bus transport due to floods result in great inconvenience to passengers who at times get stranded for days together. Several instances of electrocution have been reported on

account of floods damaging electrical lines. The sewerage accumulates and leads to wide spread epidemic and other hardships to the people of the area. The cumulative effect of this recurrent phenomenon is the continued burdening of the State Exchequer for engineering interventions, relief assistance/compensation, emergency health care, and loss of revenue due to obstruction of business activities. During every instance of flooding in the city area, the district administration had to press emergency services into action and ensure that normalcy is attained. As this became a routine matter, the Chairman DDMA invoked emergency powers vested upon the DDMA vide Kerala State Disaster Management Rules, 2007 under Chapter VI of the Disaster Management Act 2005 to ensure an immediate solution to this threatening disaster situation. Accordingly vide proceedings number H1-33275/15(2) dated 2-05-2015 the DDMA initiated several steps to ensure that the city is free of storm water flooding. Government vide GO (Ms) No. 178/15/DMD dated 12-05-2015 named the programme as 'Operation Anantha' and appointed a Cabinet Sub-Committee vide GO (Rt) No. 2893/2015/DMD dated 5-06-2015 to monitor the implementation of 'Operation Anantha' and designated Kerala Road Fund Board as the nodal agency for implementation of the activities. Figure 24 shows flood prone area overlaid on ward wise population density.

5.2 DROUGHT

Kerala, the southern strip of Indian mainland is blessed with 44 rivers and two seasons of rainfall per year. Despite this, Kerala experience seasonal drought condition every year during the summer months. The uneven and erratic nature of monsoon leads to lots of problem in the recent decades.

Based on available research it is noted that the frequency of dry days was increasing[2], the onset date of monsoon is being delayed in Kerala[3] and the rainfall in monthly, seasonal and annual time scales are showing decreasing trend over the last 100 years period[4]. The annual average rainfall of Thiruvananthapuram City is 1746 mm based on rainfall data from 1986 to 2013. During the period, the annual rainfall of the city was less than long period average in the years 1986, 1988, 1989, 1990, 1995, 1996, 2000, 2002, 2003, 2009, 2011, 2012 and 2013 (13 times). Thus the general trend and the observations indicate that the City is increasingly prone to drought like conditions due to reduction in rainfall from long period average.

The situation is aggravated by the fact that about 41% of the City has deficiency in availability of potable centrally supplied pipe water. Present capacity of potable drinking water production in the City is 273 Million Litres per Day (MLD) and there exist a gap of 137 MLD between production and demand; transmission loss is approximately 35.5%. The presence of sock pits, sewerage pipelines and open sewerage cannals restricts the possibility of digging open wells for potable drinking water, particularly in the City limits as ground water may be contaminated with the presence of coliform and fecal coliform. Monitoring results in Akkulam-Veli lakes and Parvathy Puthanar shows high values of total coliform and fecal coliform[5]. This situation aggravates the natural drought proneness of the City.

In 2012-13, the state experienced the 'worst' drought situation in its history with mercury soaring to 41°C in some parts and numerous cases of sunstroke were reported. On the basis of meteorological, hydrological and economic factors all fourteen districts were declared meteorologically drought affected. A drought prone area assessment was carried out using rainfall data, Normalized Difference Vegetation Index derived from MODIS satellite and Ground Water departure data. The assessment showed that the entire City falls under moderately drought prone category as shown in Figure 25.

5.3 COASTAL HAZARDS

Coastal erosion becomes a hazard where human activity is threatened by the erosion of sea-coast shoreline. As much as 63 per cent of the sea-coastline of Kerala is facing sea erosion. The district-wise statistics indicate that erosion is dominant in all coastal districts with minimum erosion in Thrissur (1.5%) and maximum in Thiruvananthapuram district (23%).Thiruvananthapuram coast has its share of seasonal erosion and deposition. Accelerated coastal erosion occurs during monsoons due changes in the sediment flow pattern. Sea surge and high waves hastens the rate of erosion in the coastal stretch besides causing massive damage to nearby settlements and public infrastructure.

Figure 26 shows the coastal erosion/accretion prone areas and the worst case scenario storm surge inundation limits (Tsunami 2004 inundation limits). Based on systematic field survey conducted by National Centre for Earth Science Studies, 6.5 km of the 27.4 km of Thiruvananthapuram City's coastline is prone to high rates of coastal erosion. In the worst case scenario, sea level may rise by 15 to 38 cm by mid-21st century[6]. Considering the tsunami inundation level this anticipated increase is negligible and thus, tsunami inundation level is also considered as the worst case scenario inundation level in the event of major storm surges.

5.4 LIGHTNING

Kerala is a place of high lightning incidence. Higher population density and vegetation density result in more fatalities, injuries and property damage. Lack of awareness also aggravates the situation. Accidents caused by ground conduction from trees, which is a special feature of Kerala, add to the casualties and loss of property. The records show that the months of April, May, October and November have the highest lightning rates. The most probable time of lightning hit in the day is from 15:00 to 19:00. Nearly 20 cases of lightning have been reported during the years between 1988 and 2003.

Thiruvananthapuram City experiences frequent incidence of lighting. Lighting being a random phenomenon, spatial probability of occurrence cannot be mapped as an aerial extent. The undulating terrain and the density of electrification may be considered as factors that contribute to lighting fatality and damages in the city. Figure 27 shows the lightning incidents in the city and the frequency of lighting per ward based on long term data of fatal and major damage causing lighting events reported.

5.5 INDUSTRIAL HAZARDS

Since 1946, Travancore Titanium Products Ltd. (TTP) in the City has been producing titanium dioxide and has become the leading manufacturer of anatase grade titanium dioxide in recent years. It has been operating close to the most tourist frequented beach of Thiruvananthapuram, the Shanghumugham, for several years without an effluent treatment plant. The factory has its own sulfuric acid plants and generates around 120 tons of concentrated sulfuric acid everyday which is dumped into the Arabian Sea directly without any prior treatment. Figure 28 shows the locations where probable anthropogenic hazards can occur. Karikkakom and Vettucad wards of the city are encompassed directly in the 500 m buffer zone of Indian Oil Corporation, Kochuveli. Eight (8) petrol pumps are located within the city premises.

The City has one major accident hazard unit namely the Indian Oil Corporation Tank Farm at Kochuveli. Two other petroleum tank farms, they being Bharat Petroleum bottling plant at Kazhakuttom and BPCL Plant near Kochuveli, although are just outside the Corporation limits possess threat to the corporation area. Figure 28 shows the major petroleum storage hazard susceptibility map of Thiruvananthapuram City. The map was prepared in

ALOHA considering maximum permissible storage of the most inflammable petroleum product stored in these locations and the long term wind direction and wind speed of the region.

5.6 LANDSLIDE

The City although is in an undulating terrain, the possibility of landslide is limited to one ward, namely Thirumala ward (Thirumala Village). This is owing to the presence of loose rock boulders atop Parakovil hill, a small hill housing a temple. All sides of the hill are densely populated and thus, extraction of the loose rock boulders is not an easy task. Figure 30 shows the map of the area prone to rock fall from Parakovil hill in Thirumala ward.

5.7 EARTHQUAKES

The city falls in seismic zone III and is thus vulnerable to earthquakes. Tremors of minor magnitudes have occurred in and around the city in 2012. The spectral acceleration in Thiruvananthapuram district ranged above 0.4 g over 10% study area. The spectral acceleration of 50% of study area is in the range of 0.2 to 0.3 g and 40% of the area has spectral acceleration less than 0.2 g. The spectral period coincides with natural frequencies of 2 to 7 storey buildings and hence immense care is to be taken in the design of such buildings [7]. In the City limits, the spectral acceleration values ranged from 0.025 to 0.295g. The United Nations Development Programme furnished a report to Ministry of Home Affairs in 2006 in which Thiruvananthapuram is listed as city with potential for significant damages in the event of major earthquakes.

5.8 MASS GATHERING EVENTS

Thiruvananthapuram City experiences the following major mass gatherings, they being a) Attukal Pongala, b) BeemapallyUrus, c) Madre De Deus Church, Vettucaud Pilgrimage and d) Onam Celebrations organized by the State Government. Amongst these, Attukal Pongala which registers about 37 lakh women pilgrims congregating throughout the city is the most important. Devotees cook a mixture of rice, jaggery and coconut in earthen pots in the street that is offered to the goddess seeking divine blessings. The Chief Priest of the temple lights the main hearth from the fire inside the sanctum sanctorum of Attukal Temple. This fire is exchanged from one oven to another. Being a traditional festival the devotees are self-disciplined and accidents involving fire have been minimal. However, the potential of stamped and fire outbreak cannot be ruled out. In order to assess the area occupied by the devotees and to evaluate the availability of resources, a team mapped the maximum areal extent of Attukal Pongala on 2014. Figure 31 shows the map of the areal extent of Attukal Pongala in 2014 and other known locations of mass gatherings.

5.9 COMMUNICABLE DISEASES

With the approach of South West Monsoon, the incidences of various water borne communicable diseases such as dengue, cholera, malaria and leptospirosis reaches alarming levels. Epidemics such as AES and H1N1 claim several lives every year. The outbreak of communicable diseases usually starts during June-July during monsoon and major causes of these water borne diseases are the non-hygienic situation and the lack of proper awareness. Figure 23 below shows fatality due to communicable diseases in the last 8 years (2006-2013). However, an outbreak of dengue (135 incidences) was reported during the drought declared year 2012. This may have occurred due to storage of drinking water in unhygienic containers. Table 2 shows number of incidences of communicable diseases.

Communicable disease	Number of incidences
Malaria	*2*
Dengue	*15*
Leptospirosis	*23*
Hepatitis A	*3*
Hepatitis B	*12*
ADD	*1*
H1N1	*29*
Cholera	*1*
AES	*3*

TABLE 2: NUMBER OF INCIDENCES OF COMMUNICABLE DISEASES, 2006-2013

Increase/decrease in epidemics is a direct consequence of climate change. The major epidemics reported from the City are cholera, leptospirosis, typhoid, hepatitis (A, B and C), dengue fever, chicken pox, acute diarrhoeal disease, malaria, chikungunya and indigenous malaria. Based on disease reports from January to November 2014, maps showing the incidence of dengue, malaria, chikungunya, leptospirosis, scrub typhus, hepatitis A, B & C and typhoid were prepared and are given from Figure 32 to Figure 40. Long term ward wise data was not made available by the concerned and hence a long term assessment and a meaningful projection of population exposure could not be done.

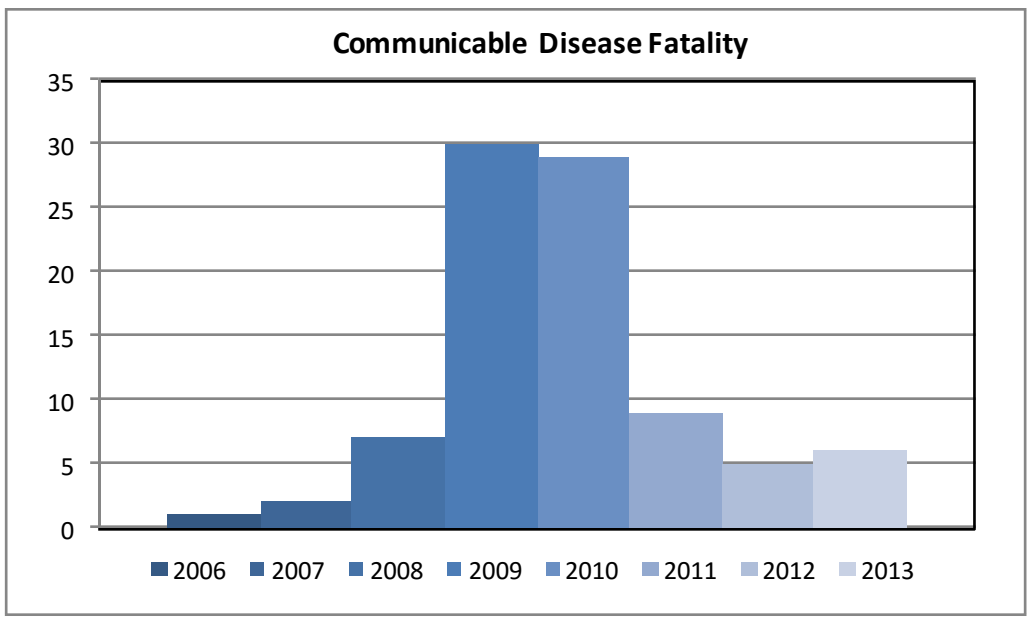


FIGURE 23: COMMUNICABLE DISEASE FATALITY (2006-2013)

5.10 BIOLOGICAL HAZARDS

Hazards from hospital wastes (tissues and body parts that are removed during surgery or autopsy) can lead to the transmission of the following diseases like, AIDS, Hepatitis B, most common bacterial infections including cholera, dysentery and typhoid, plague, tuberculosis and many parasitic infections. Pest attack like giant African snail in many places in the city has been reported. The presence of hazardous chemical fertilizers was detected in 15 kinds of vegetables used in our day-to-day chores like curry leaves and small onions.

5.11 HUMAN CONFLICTS

Till date no terror attack has been reported in the City. The communal riots near the coastal region of Bheempally-Cheriyathura region is the only serious clash that has been reported. In 2009 May, 5 people were killed in police firing during the clash between the representatives of two regions and more than 30 people were injured.

5.12 RADIOLOGICAL INSTRUMENTS

Radiation is used for medical purposes such as Teletherapy, Brachytherapy, Cath Lab, Computed Tomography, Radiography and Fluroscopy in the city. Thiruvananthapuram Medical College, in addition to the CT

and MRI scans, will be soon equipped with the Pet (Positron Emission Tomographic Scan) scan facility. The Regional Cancer Centre (RCC) at Thiruvananthapuram is a cancer care hospital and research centre that uses radioactive materials for cancer treatments. Instruments used for research purposes in CTCRI and botanical research institute are also potential sources of radiation.

Radiological exposure incidents have not been reported from Thiruvananthapuram City in the last 50 years. However, the March 2010 accident at Mayapuri Scrap Market, New Delhi was an eye opener to agencies involved in radioactive safety regulations in the country. An AECL Gamma cell 220 research irradiator owned by Delhi University since 1968, but unused since 1985, was sold at auction to a scrap metal dealer in Mayapuri on February 26, 2010. The orphan source arrived at a scrap yard in Mayapuri during March, where it was dismantled by workers unaware of the hazardous nature of the device. The Cobalt-60 source was cut into eleven pieces. The smallest of the fragments was taken by the scrap metal dealer who kept it in his wallet and two fragments were moved to a nearby shop, while the remaining eight remained in the scrap yard. Eight people were hospitalised as a result of radiation exposure, where one later died.

This incident points to the hazard potential of otherwise non-hazardous radiation sources such as X ray units, CT scanners, PET scanner, Gamma Chambers, Auto Radiography, Gas Chromatograph Units, Atomic Absorption Spectrophotometer, Microwave digestion system, CHNS Analyzer and Cyclotrones. A map of institutions utilizing such radiological equipment is given as Figure 41.

5.13 FIRE

Fires are perhaps the most frequent disaster in urban areas. Urban issues like high population, overcrowding, unregulated commercial activities are frequently responsible for urban fires. Fire has emerged as critical issue in Urban Planning due to rising frequency of Fire accidents, leading to huge losses of life & property. Fires can occur with the same ferocity in residential buildings, slums and squatter settlements, public places like auditoria, cinema halls, shopping malls, LPG godowns/petrol pumps, industries, chemical handling units, etc. Figure 42 shows the fire prone areas of the City.

Fire incidents expose major lacunae in the responding capability of the City administration and the general public. As recently as on 14th November 2015, fire gutted 10 shop in the Chalai Market. Specialised fire engine of the International Airport had to be employed to subside the inferno. Operating forces experienced significant difficulty in ensuring prompt and efficient response primarily due to the congregation of on-looking public.

In Thiruvananthapuram fire risk can arise from the following sources:

- Large number of closely built old timber framed buildings
- High-rise buildings with inadequate fire-fighting facilities and slums
- Commercial activities in Chala, Palayam, Eastfort, MG road areas
- Small, medium and hazardous industries in suburban areas

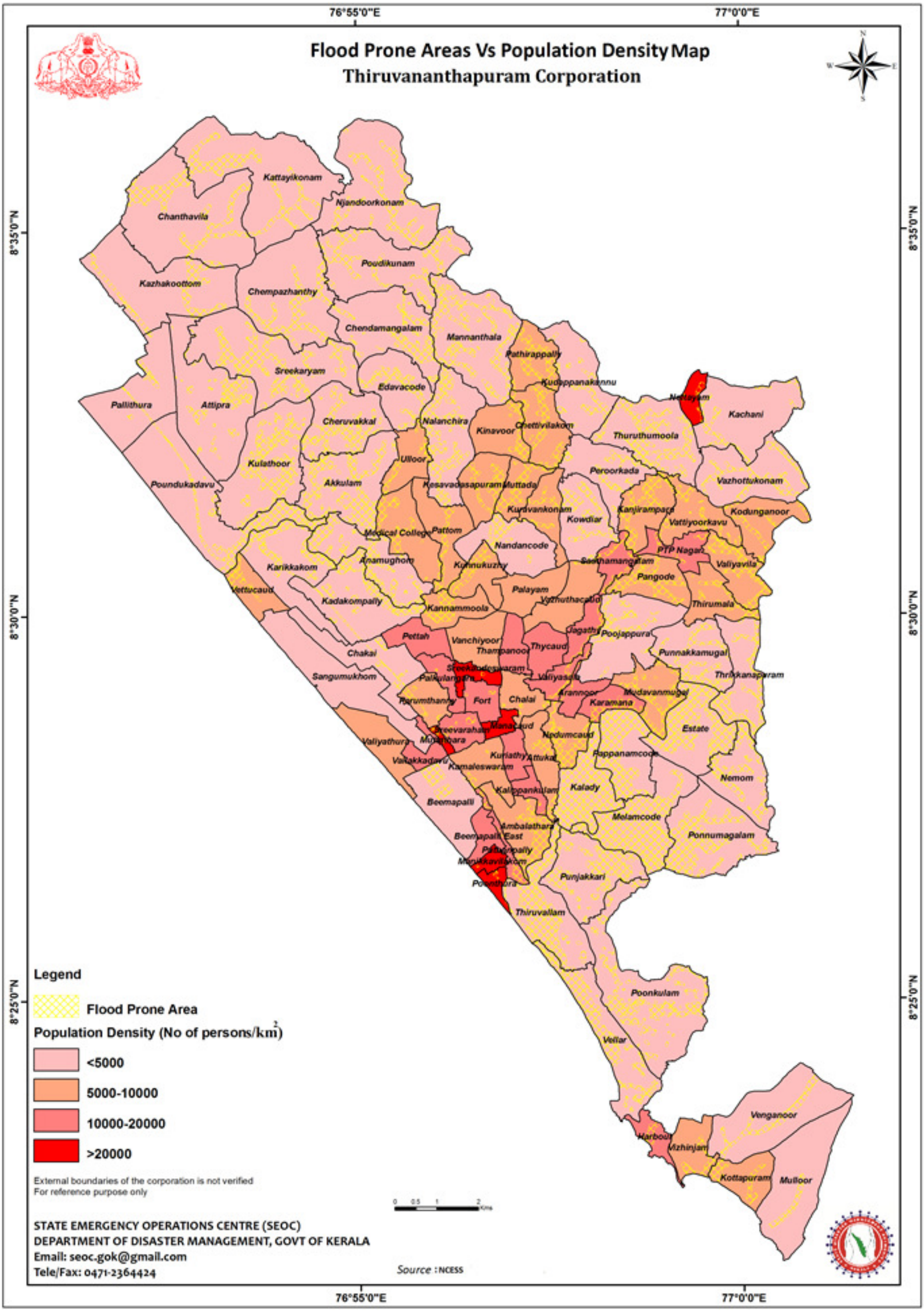


FIGURE 24: FLOOD PRONE AREAS OVERLAID ON POPULATION DENSITY

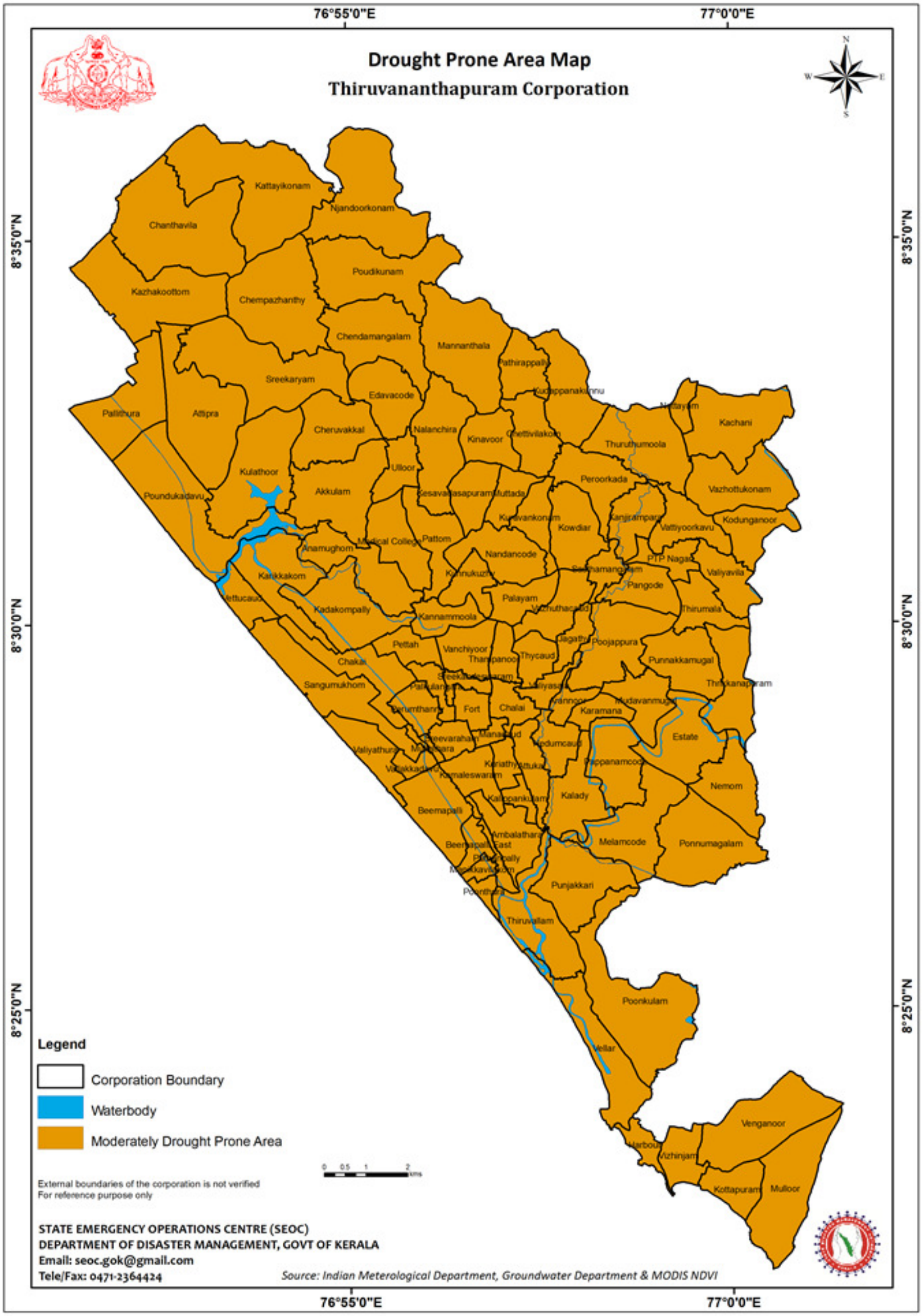


FIGURE 25: DROUGHT PRONE AREAS MAP OF THIRUVANANTHAPURAM

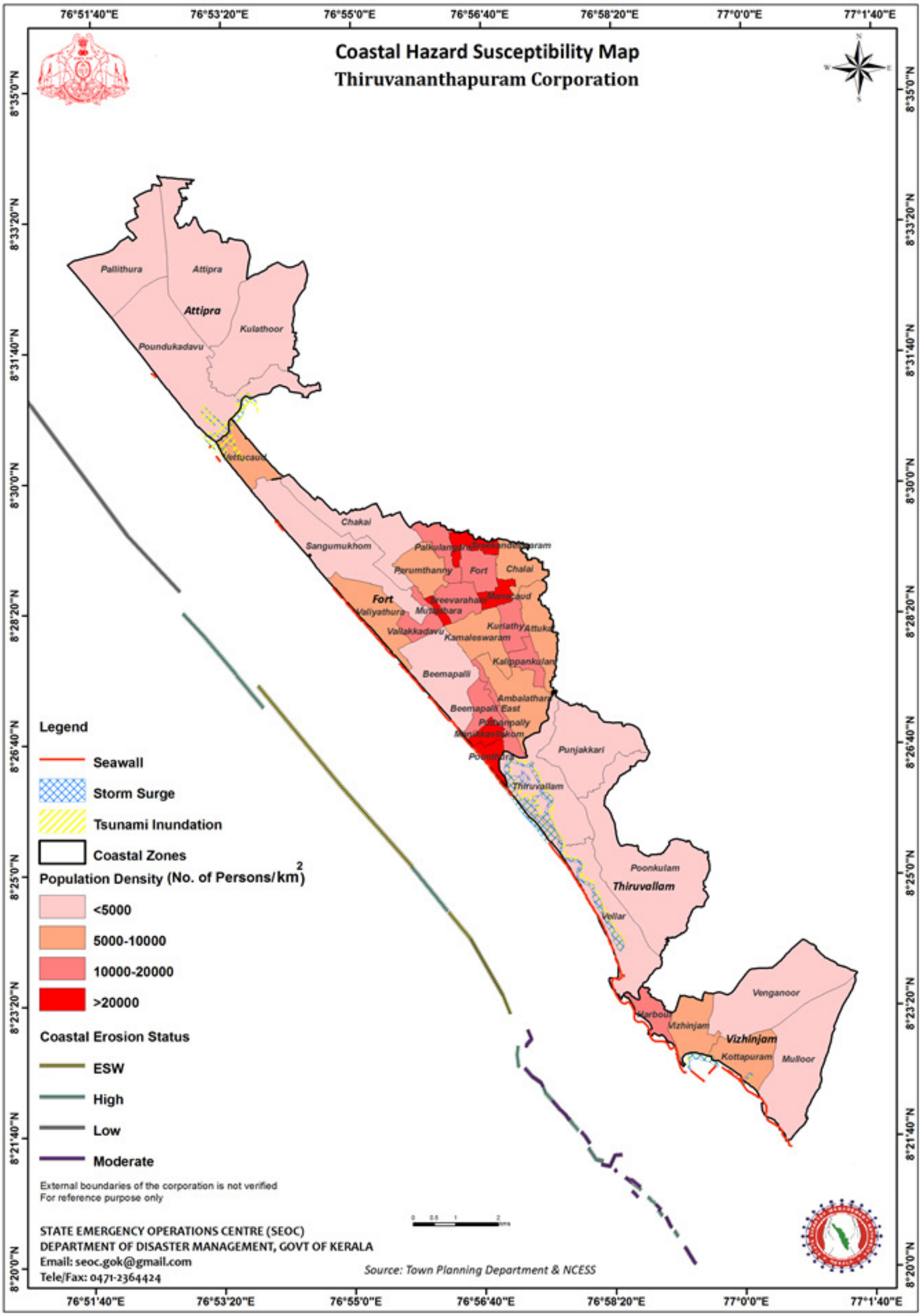


FIGURE 26: COASTAL HAZARD SUSCEPTIBILITY OF THIRUVANANTHAPURAM

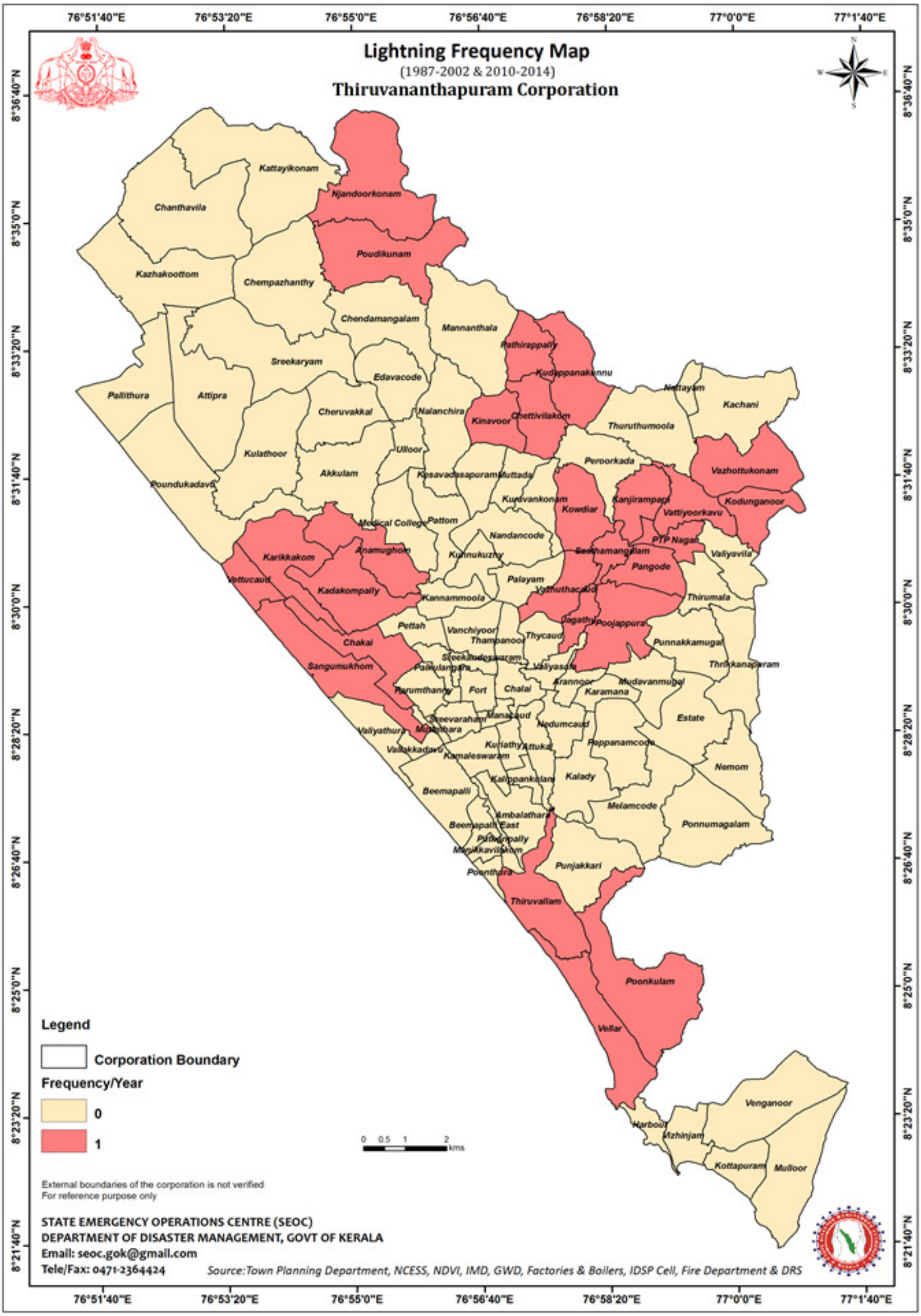


FIGURE 27: LIGHTNING FREQUENCY OF THIRUVANANTHAPURAM

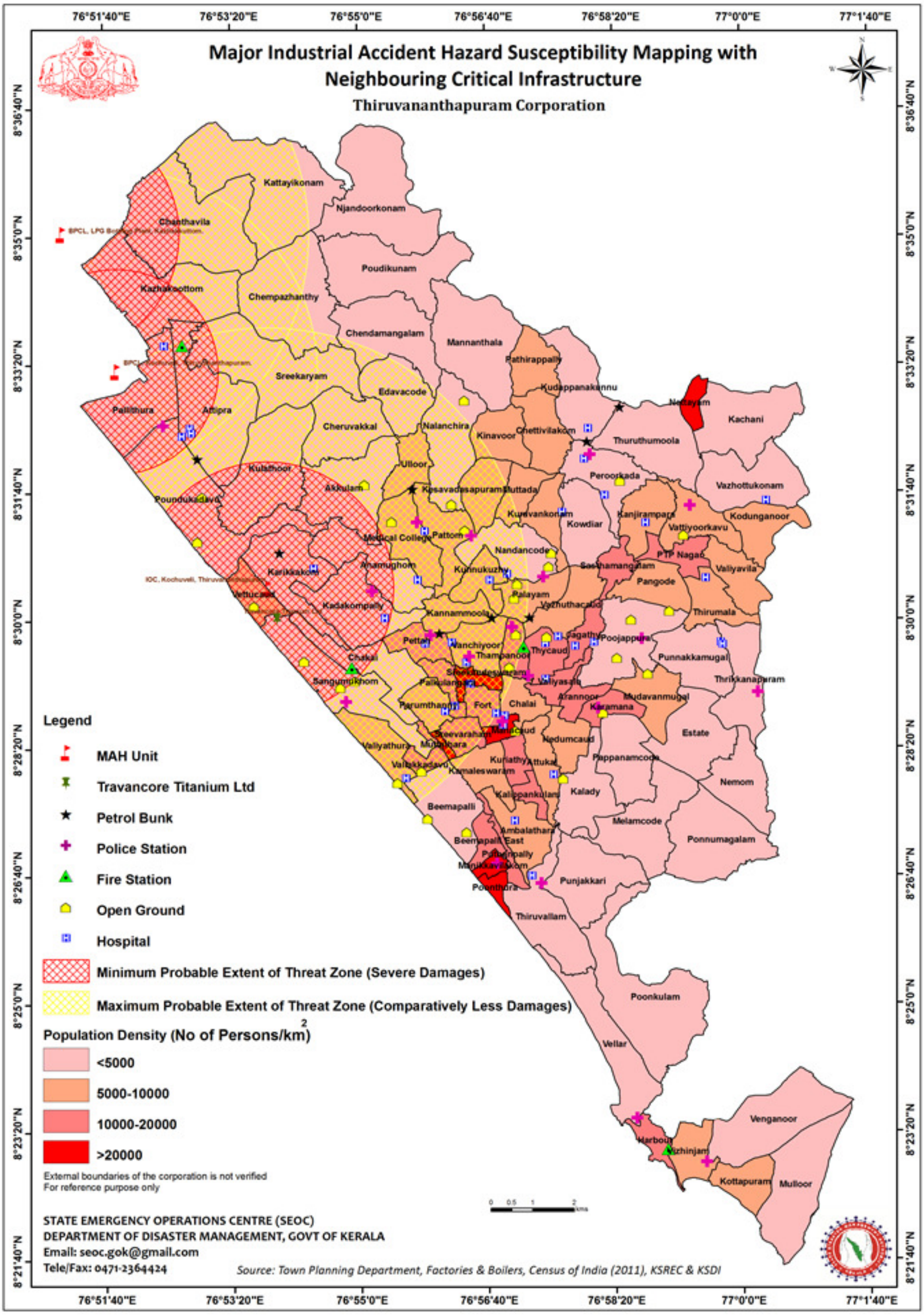


FIGURE 28: MAJOR INDUSTRIAL ACCIDENT HAZARD SUSCEPTIBLE AREA WITH NEIGHBOURING CRITICAL INFRASTRUCTURE OF THIRUVANANTHAPURAM

5.14 MASS ROAD TRANSIT ACCIDENTS

Traffic accidents are a major cause of death and injuries in Thiruvananthapuram City. More than half of the road accident victims fall in the age group of 20 to 55, the key wage earning and child raising group. State Crime Records Bureau, Thiruvananthapuram is maintaining a database on Road Accident cases in Kerala State and the graph below shows the details for road accidents for the last five years in Thiruvananthapuram District. City specific data was not available at the time of preparing this report.

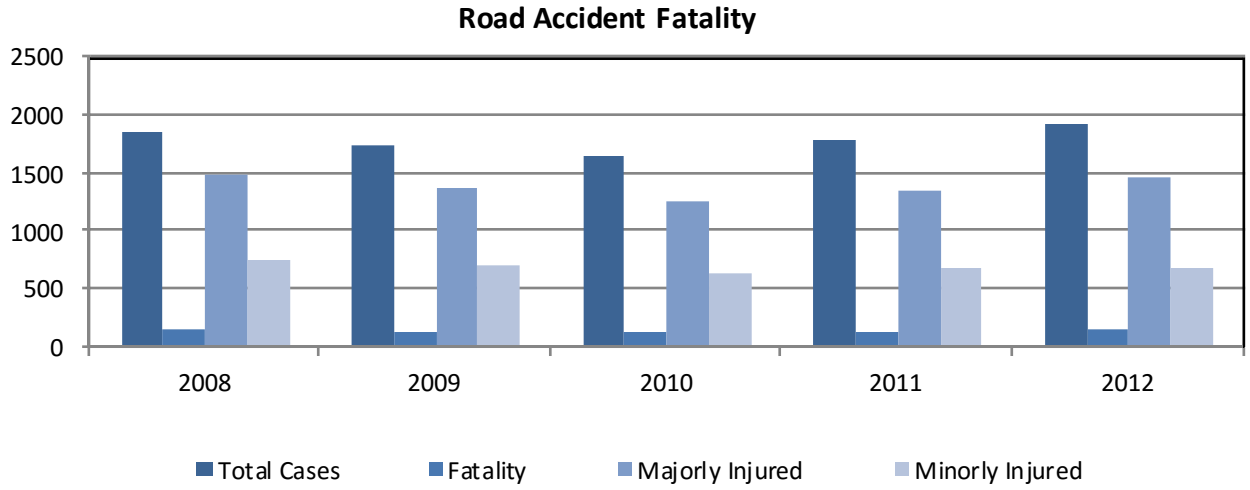


FIGURE 29: FATALITY DUE TO ROAD ACCIDENTS IN THIRUVANANTHAPURAM DISTRICT (2008-2012)

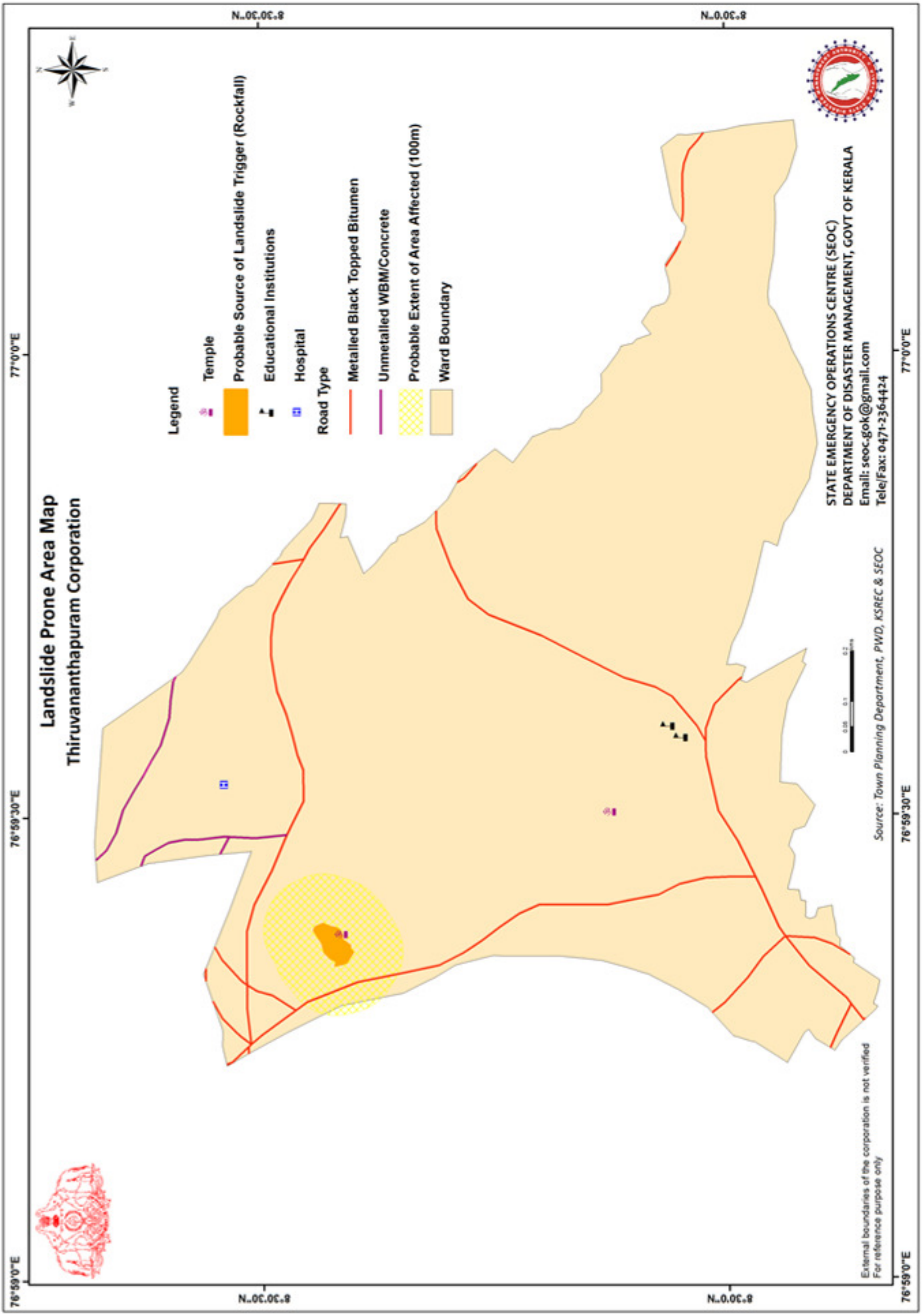


FIGURE 30: LANDSLIDE PRONE ARE

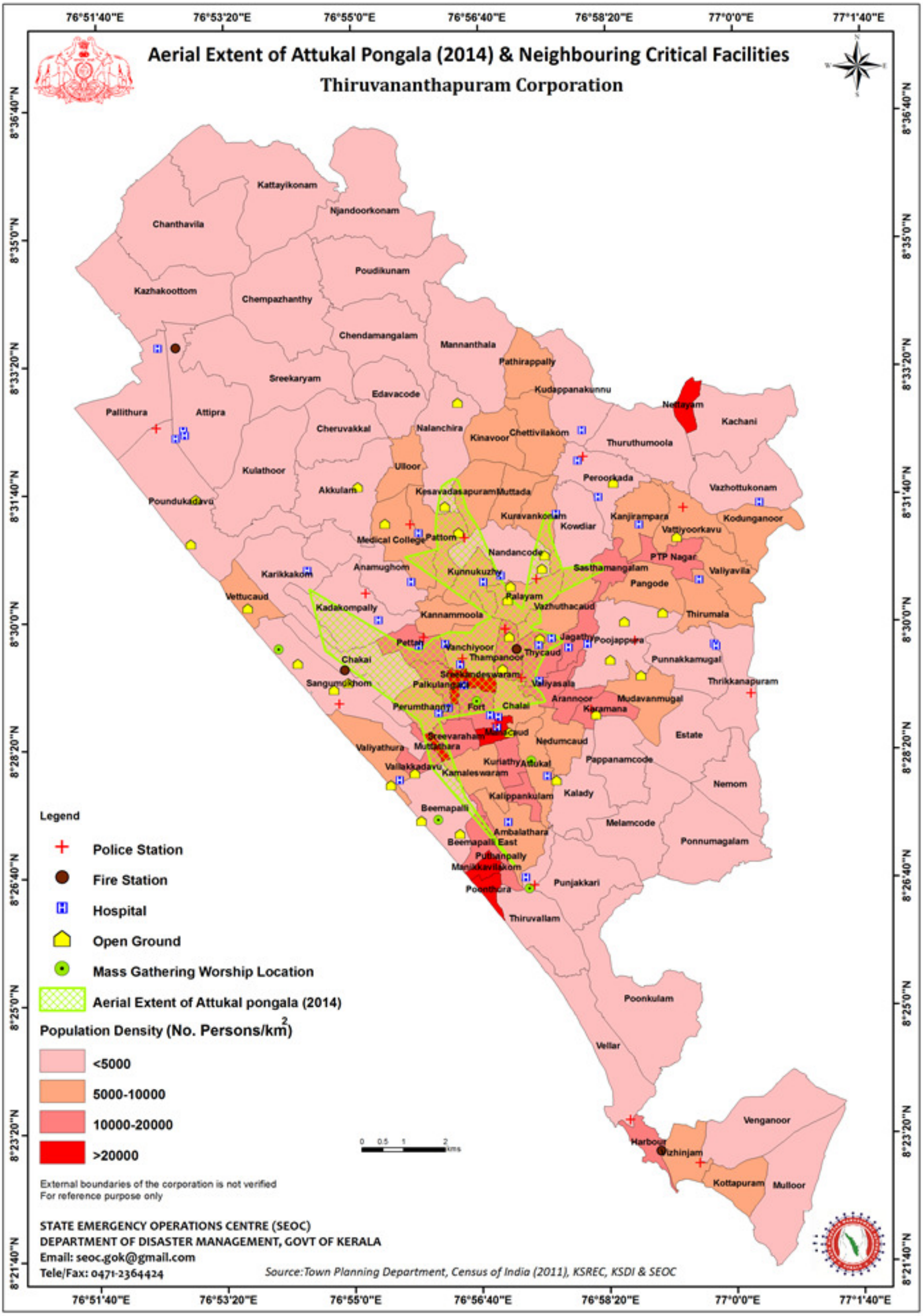


FIGURE 31: AERIAL EXTENT OF ATTUKAL PONGALA (2014) AND CRITICAL FACILITIES

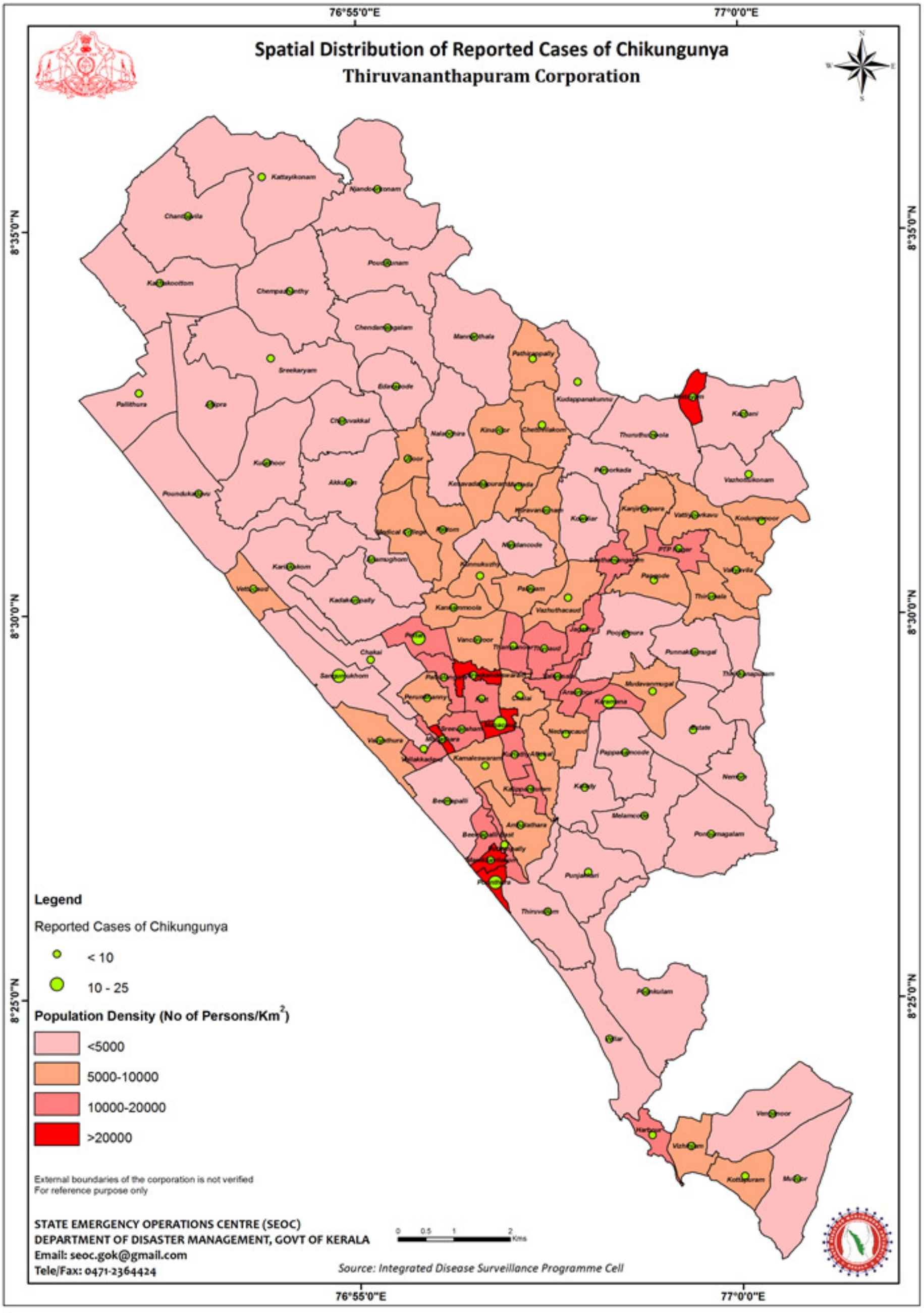


FIGURE 32: DISTRIBUTION OF REPORTED CASES OF CHIKUNGUNYA (JANUARY 2014 – JUNE 2015)

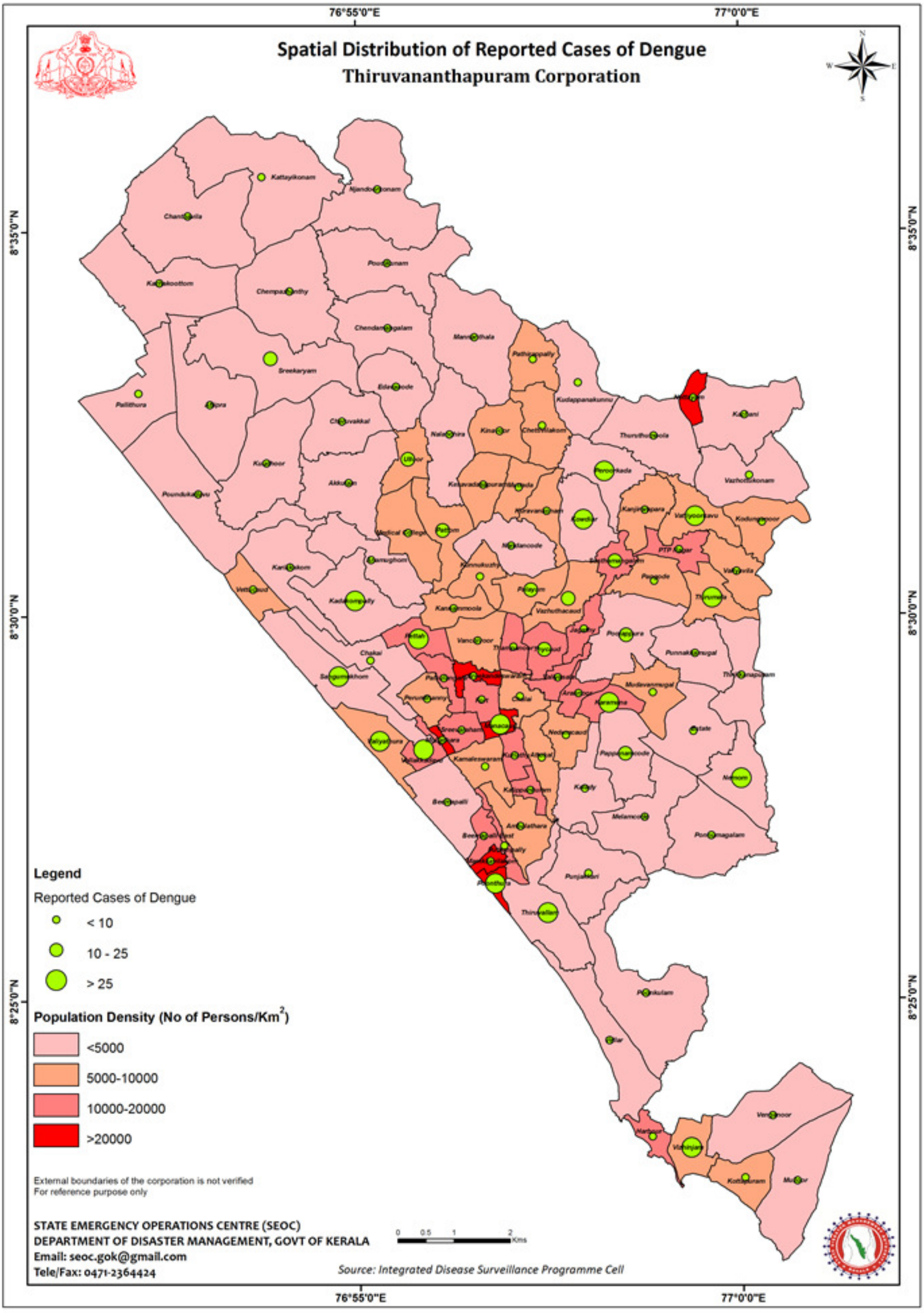


FIGURE 33: DISTRIBUTION OF REPORTED CASES OF DENGUE (JANUARY 2014 – JUNE 2015)

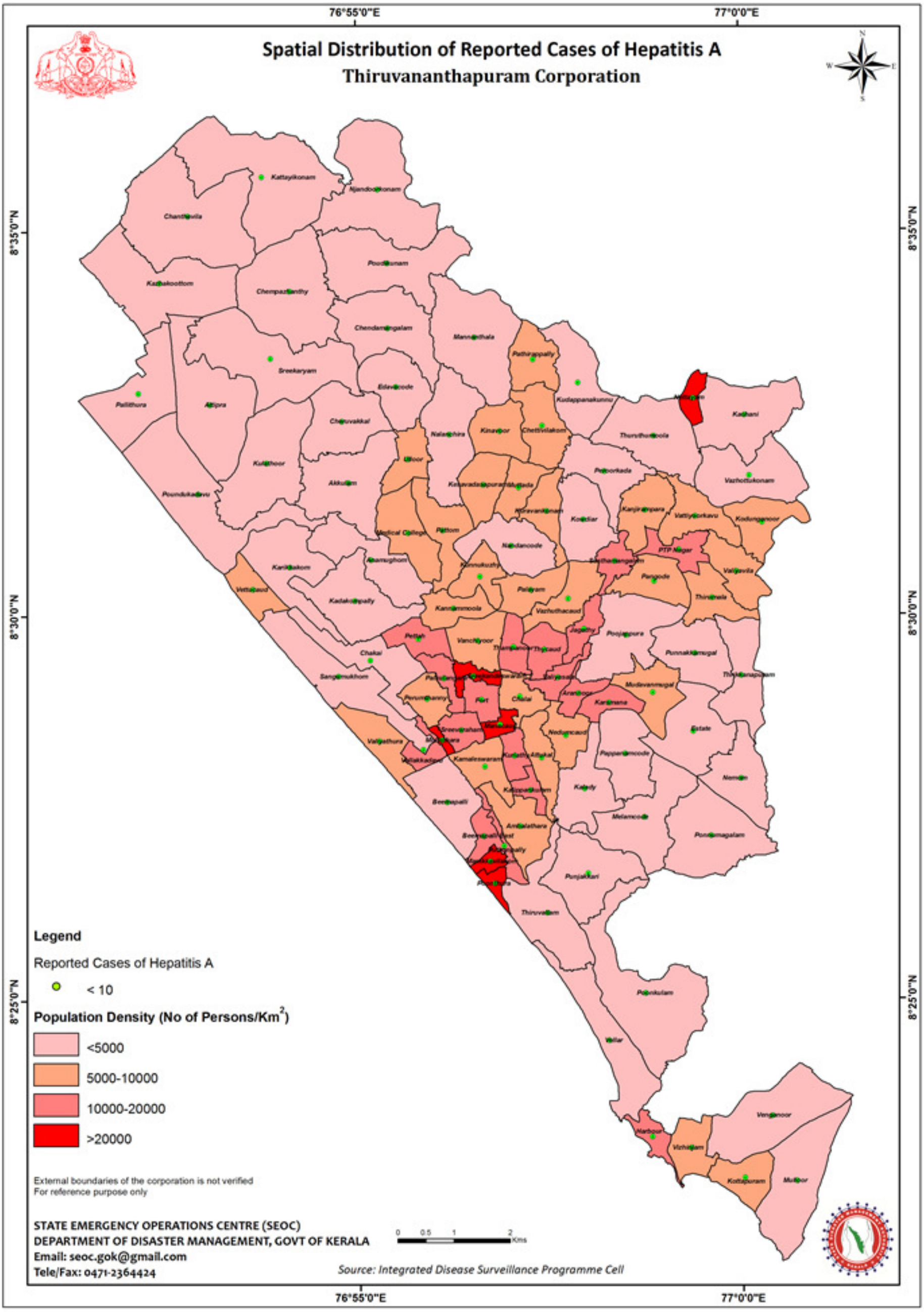


FIGURE 34: DISTRIBUTION OF REPORTED CASES OF HEPATITIS A (JANUARY 2014 – JUNE 2015)

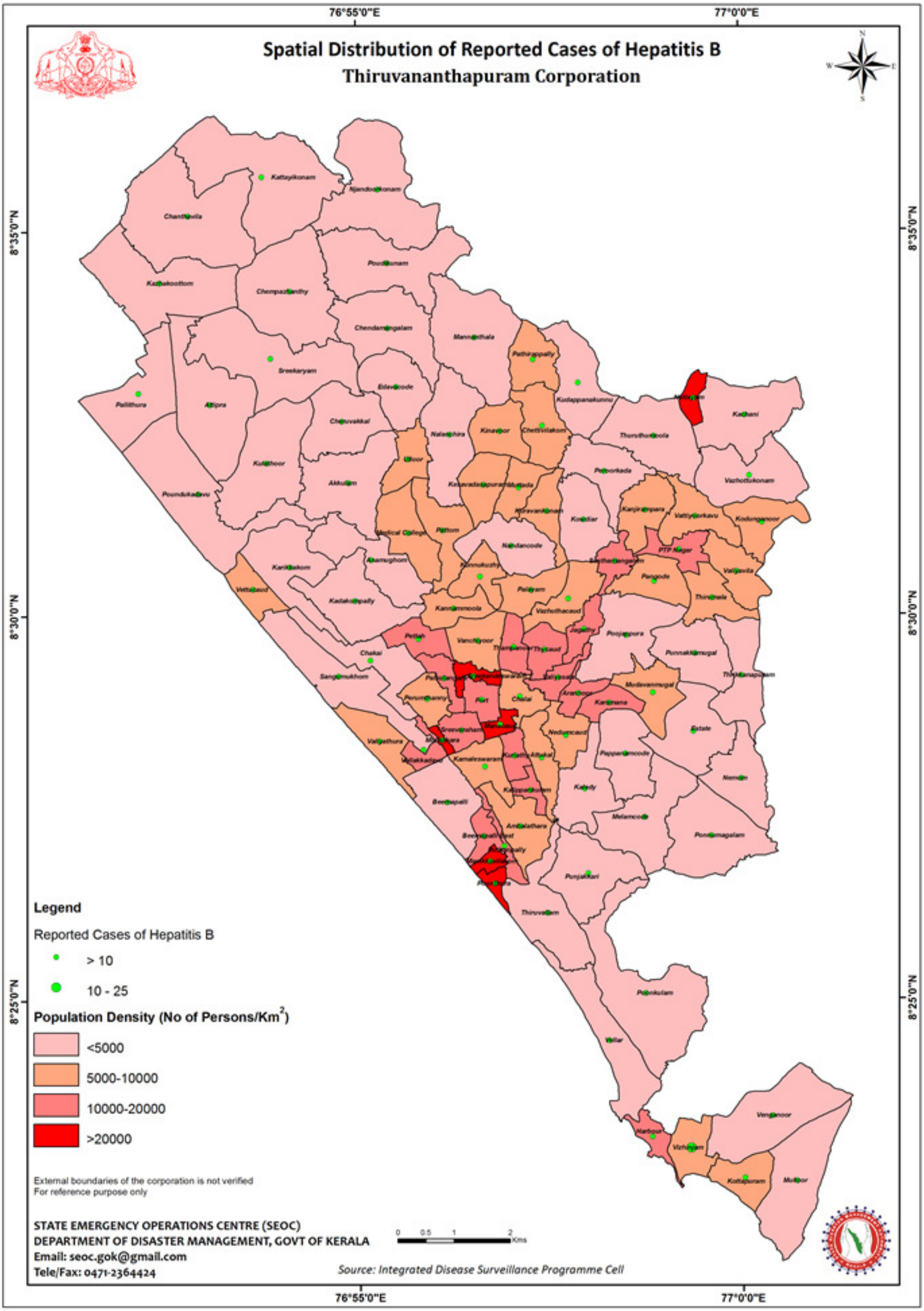


FIGURE 35: DISTRIBUTION OF REPORTED CASES OF HEPATITIS B (JANUARY 2014 – JUNE 2015)

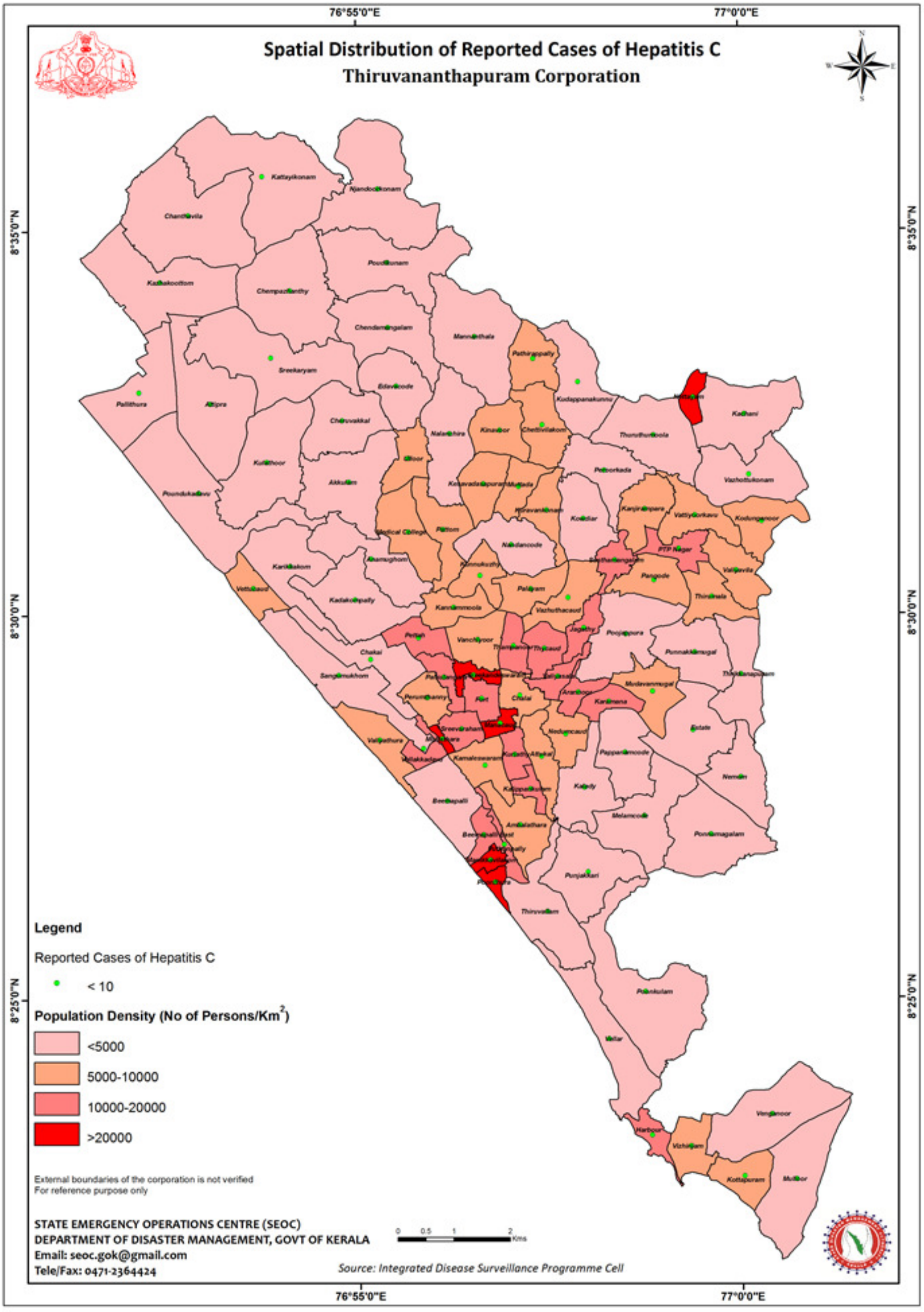


FIGURE 36: DISTRIBUTION OF REPORTED CASES OF HEPATITIS C (JANUARY 2014 - JUNE 2015)

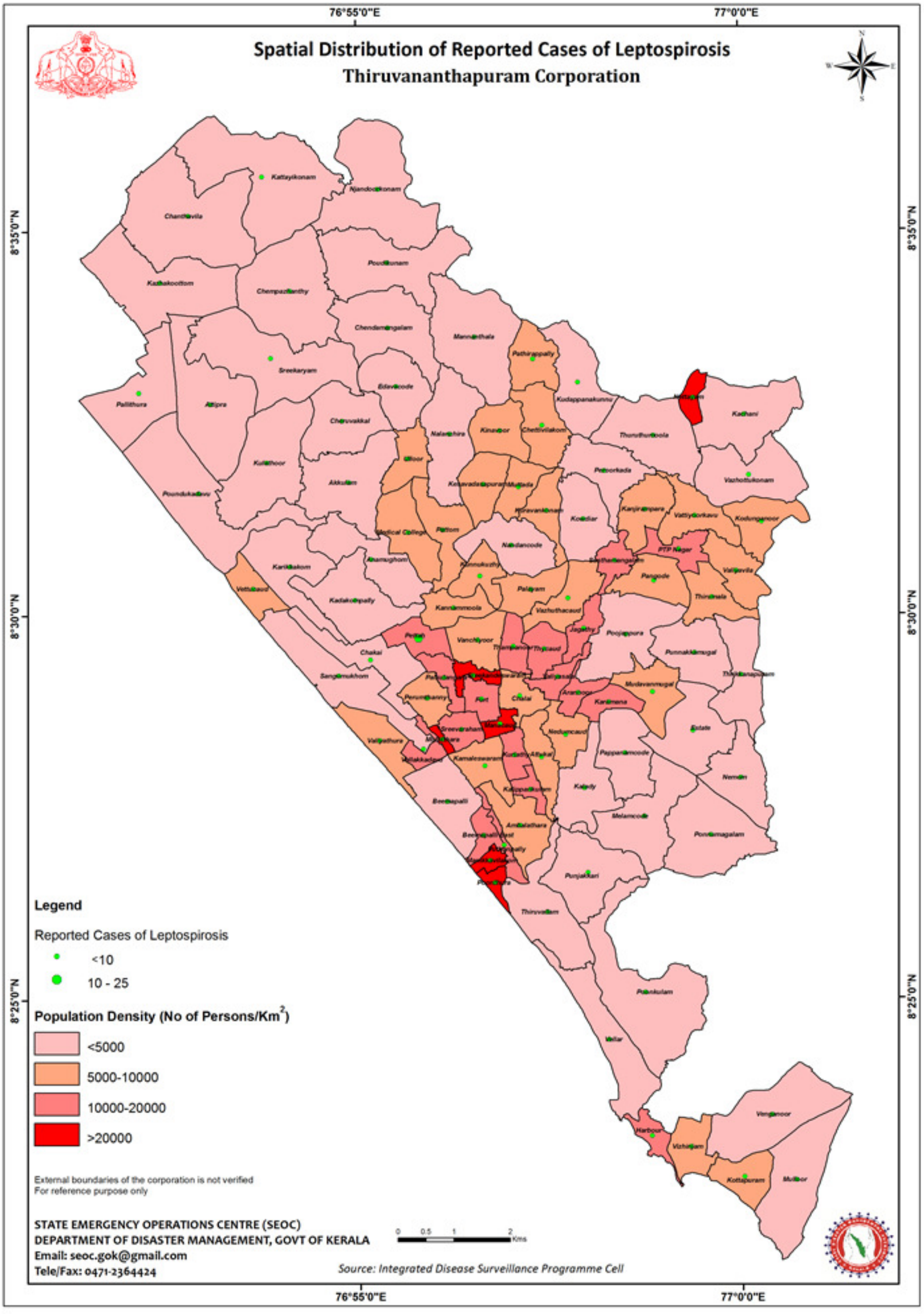


FIGURE 37: DISTRIBUTION OF REPORTED CASES OF LEPTOSPIROSIS (JANUARY 2014 - JUNE 2015)

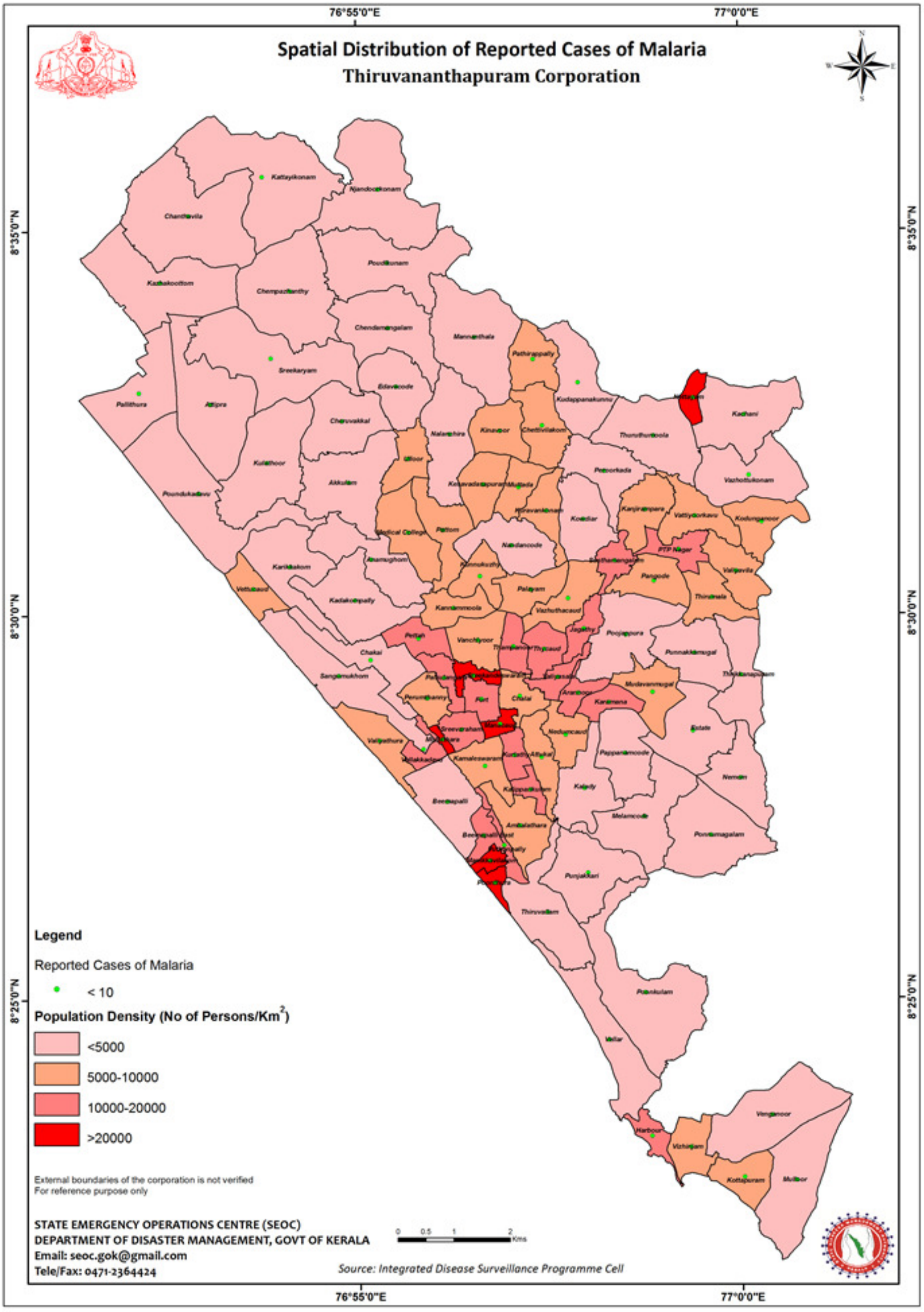


FIGURE 38: DISTRIBUTION OF REPORTED CASES OF MALARIA (JANUARY 2014 - JUNE 2015)

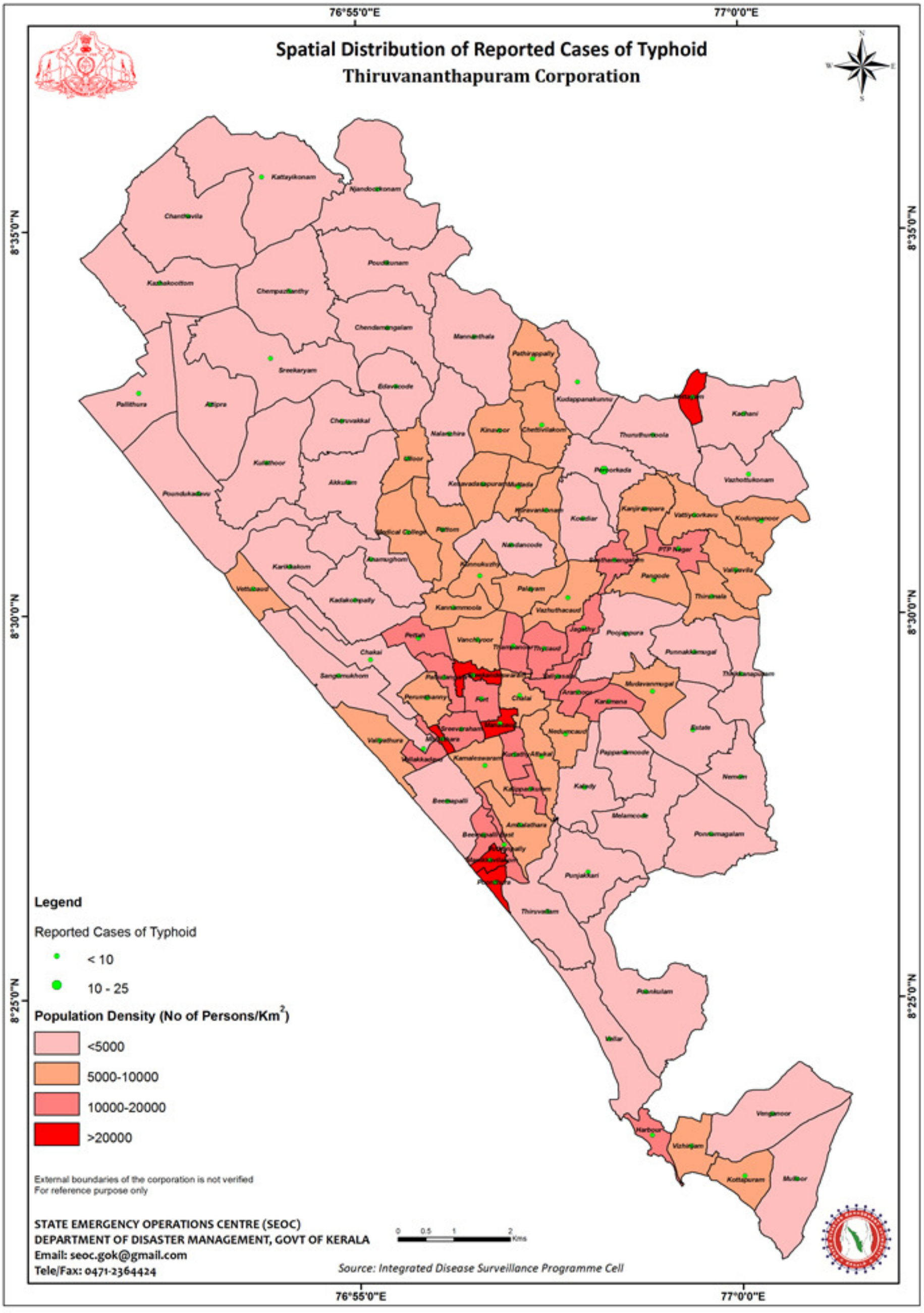


FIGURE 39: DISTRIBUTION OF REPORTED CASES OF TYPHOID (JANUARY 2014 - JUNE 2015)

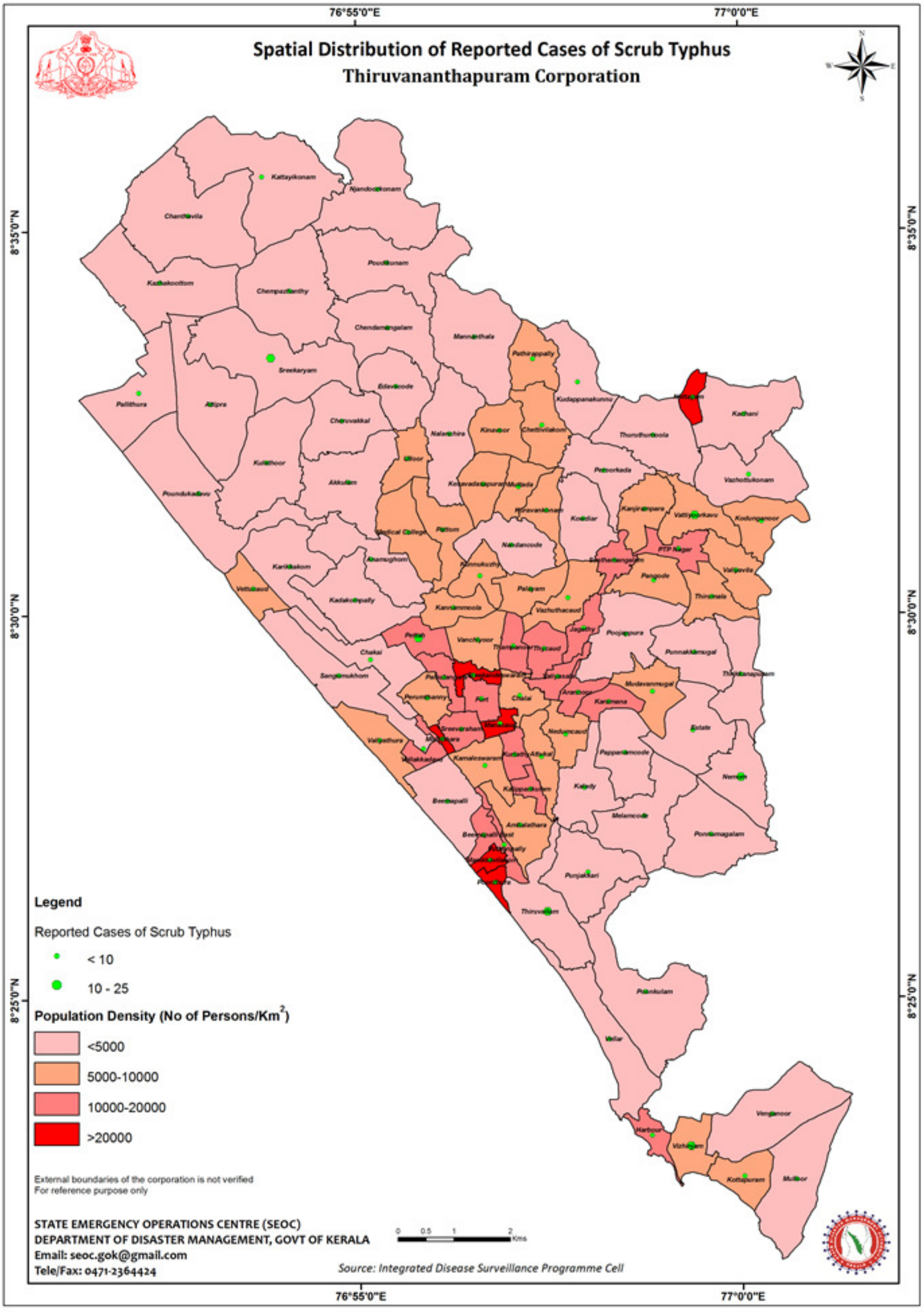


FIGURE 40: DISTRIBUTION OF REPORTED CASES OF SCRUB TYPHUS (JANUARY 2014 - JUNE 2015)

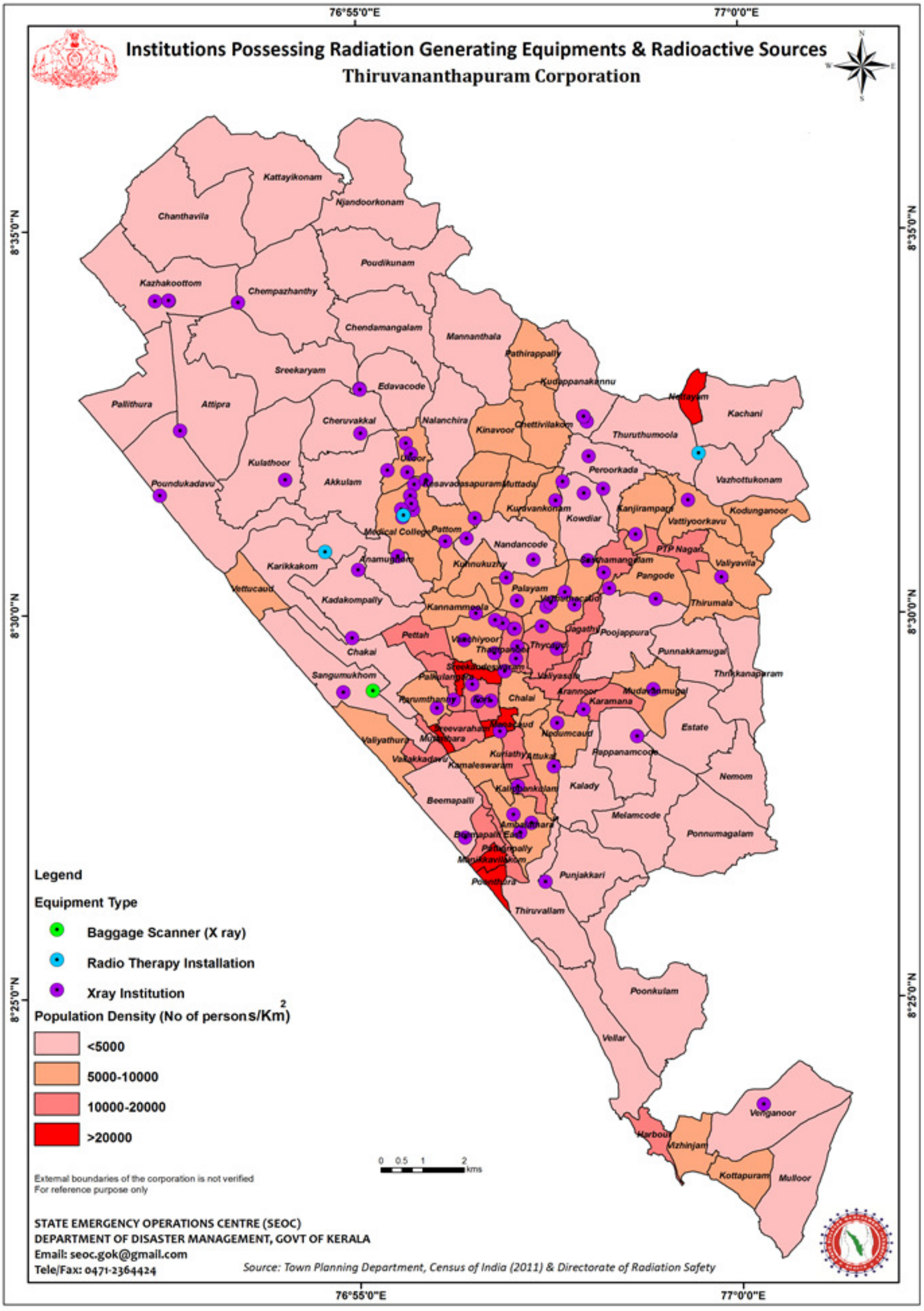
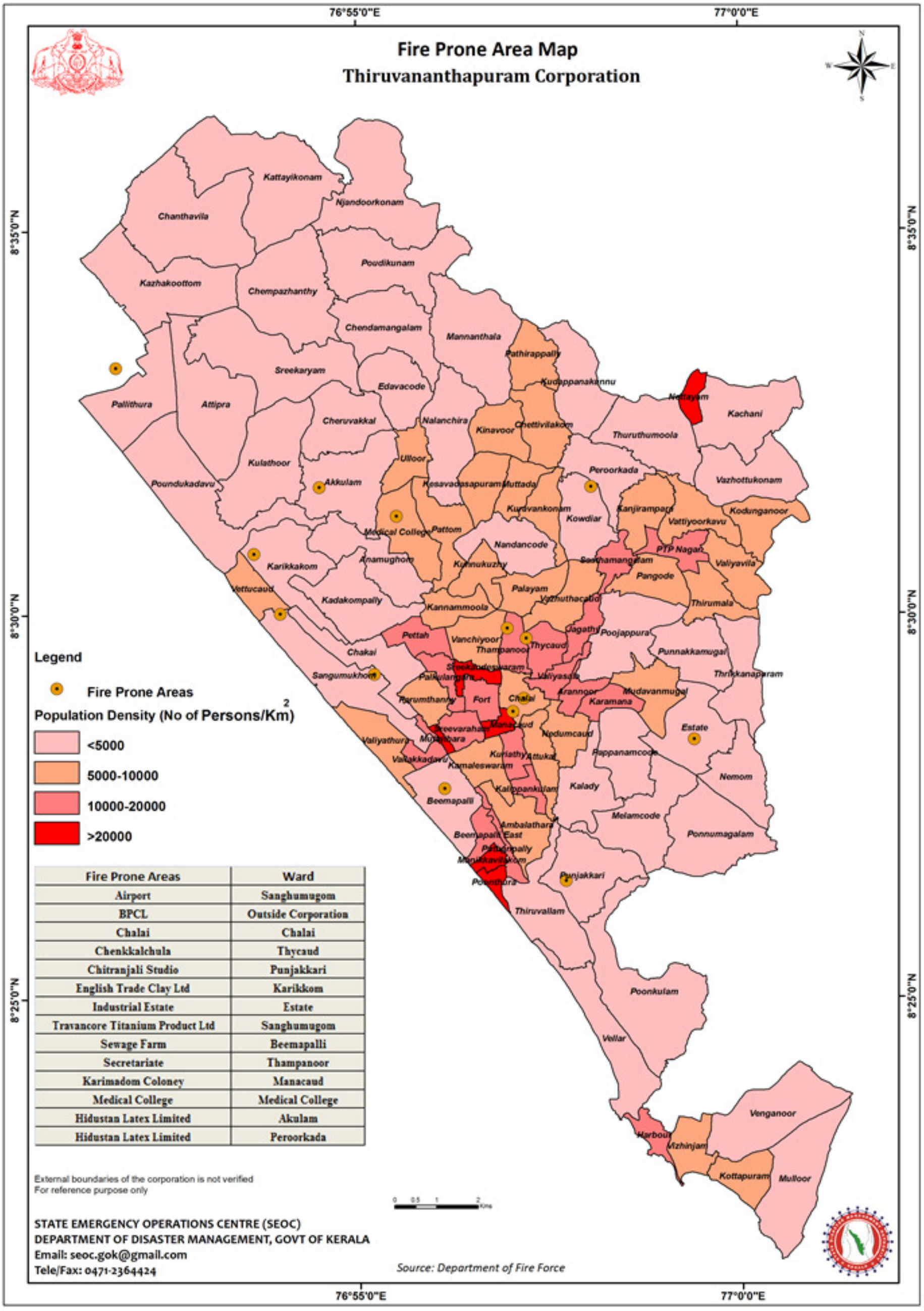


FIGURE 41: INSTITUTIONS POSSESSING RADIATION GENERATING EQUIPMENT & RADIOACTIVE SOURCES



Fire Prone Areas	Ward
Airport	Sanghumugom
BPCL	Outside Corporation
Chalai	Chalai
Chenkkalchula	Thycaud
Chitranjali Studio	Punjakkari
English Trade Clay Ltd	Karikkom
Industrial Estate	Estate
Travancore Titanium Product Ltd	Sanghumugom
Sewage Farm	Beemapalli
Secretariate	Thampanoor
Karimadom Coloney	Manacaud
Medical College	Medical College
Hidustan Latex Limited	Akulam
Hidustan Latex Limited	Peroorkada

FIGURE 42: FIRE PRONE AREAS OF THIRUVANANTHAPURAM

5.15 MULTI-HAZARD SUSCEPTIBILITY OF WARDS

Based on the hazard susceptibility detailed above, a multi-hazard ward map of Thiruvananthapuram City was prepared using a heuristic rating and weighting approach. The heuristic criteria used for preparing the multi-hazard susceptibility ward map (Figure 43) are shown in Table 3 and Table 4.

TABLE 3: HEURISTIC CRITERIA USED FOR PREPARING THE MULTI-HAZARD SUSCEPTIBILITY WARD MAP

Hazard type	Ward category	Ward weighting
Flood	>50% of ward area	12
	25 to 50% of ward area	8
	5 to 10% of ward area	4
	>0 to 5% of ward area	1
	0	0
Drought (Moderate)	>50% of ward area	6
	25 to 50% of ward area	4
	5 to 10% of ward area	2
	>0 to 5% of ward area	1
	0	0
Coastal hazards	>50% of ward area	8
	25 to 50% of ward area	4
	5 to 10% of ward area	1
	>0 to 5% of ward area	0
	0	0
Lighting	>1 event	3
	No event	1
Epidemics	>10 events	10
	5 to 10 events	5
	>0 to 5 events	2
	0	0
Industrial hazards	>50% of ward area	8
	25 to 50% of ward area	4
	5 to 10% of ward area	2
	>0 to 5% of ward area	1
	0	0
Mass gathering	>50% of ward area	6
	25 to 50% of ward area	4
	5 to 10% of ward area	2
	>0 to 5% of ward area	1
	0	0
Landslide	>50% of ward area	4
	25 to 50% of ward area	3
	5 to 10% of ward area	2
	>0 to 5% of ward area	1
	0	0
Radiological entities	>3 entities	4
	1 to 3 entities	2
	0 entities	0
Fire Prone Areas	More Frequent	3
	Least Frequent	1

TABLE 4: RELATIVE RATING OF HAZARD SUSCEPTIBILITY OF WARDS BASED ON THE HEURISTIC CRITERIA

Multi-hazard rate	Multi-hazard susceptibility
0	No hazard
1 to 15	Low
15 to 30	Moderate
30 to 45	High
>45	Very High

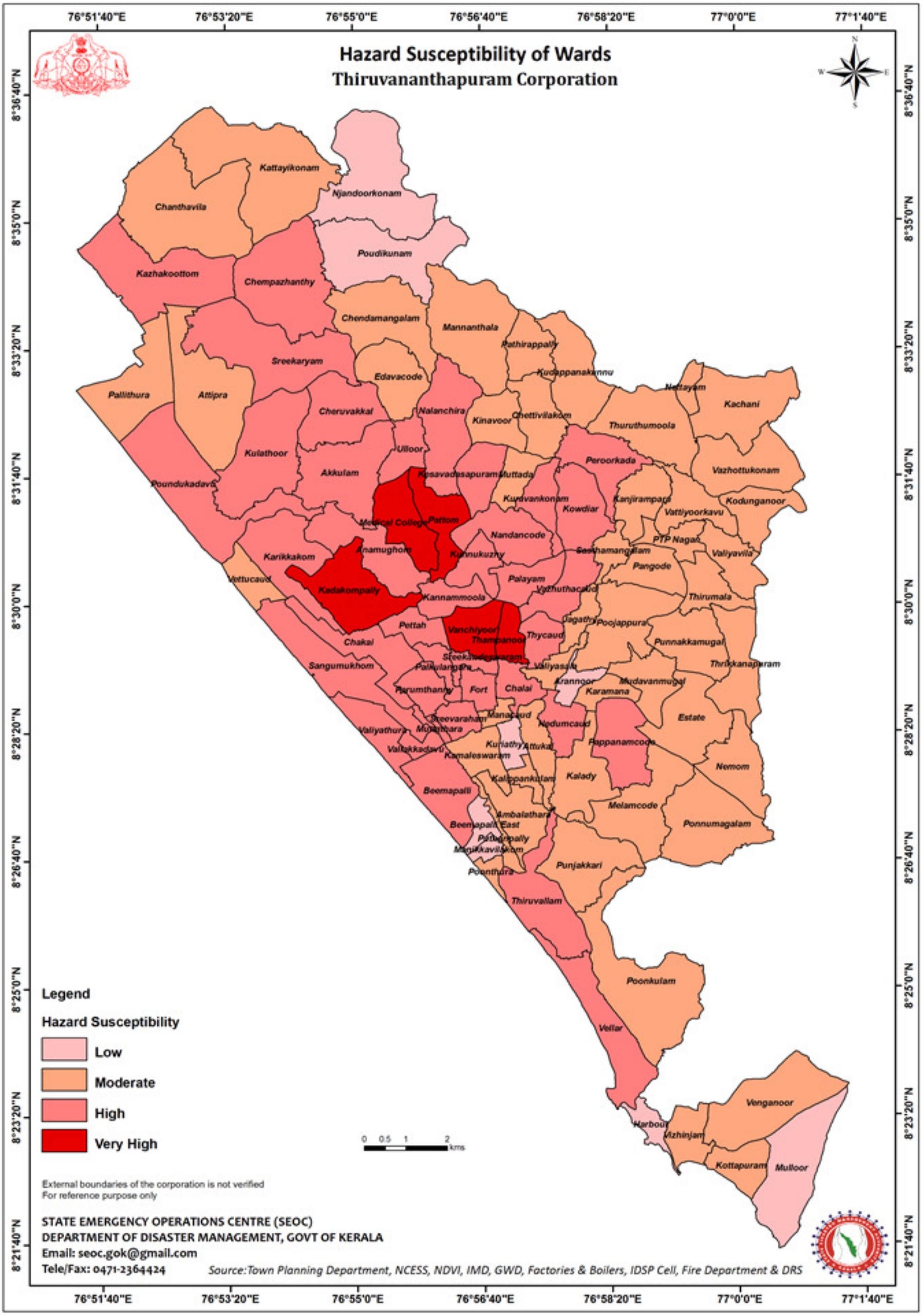


FIGURE 43: MULTI-HAZARD SUSCEPTIBILITY MAP OF THIRUVANANTHAPURAM

6 VULNERABILITY

Vulnerability is the degree of loss to a given element or set of elements-at-risk resulting from the occurrence of a natural phenomenon of a given magnitude. Usually expressed on a scale from 0 (no damage) to 1 (total damage). Vulnerability has a wide range of interpretations and multiple definitions. Vulnerability refers to the conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility of a community to the impact of hazards. It is the susceptibility to damage and/or the intrinsic fragility of exposed elements, systems or communities that facilitate loss when affected by hazard events. It also covers the lack of resilience that influences the capacity to anticipate, cope with, resist, respond to, and recover from the impact of a hazardous event (www.move-fp7.eu/).

The vulnerability of communities and households can be analysed in a holistic qualitative manner using a large number of criteria that characterize physical, social, economic and environmental vulnerability. The importance of each of these indicators is evaluated by assigning individual weights to them and combining them using spatial multi-criteria evaluation. Physical vulnerability is evaluated as the interaction between the intensity of the hazard and the type of element-at-risk, making use of heuristic or quantitative criteria. Vulnerability is, therefore, multi-dimensional (physical, social, economic, environmental, institutional, and human factors define vulnerability), dynamic (it changes over time), scale-dependent (it can be expressed on different scales from individuals to countries), and site-specific (each location might need its own approach) (http://drm.cenn.org). In this project, semi-quantitative heuristic solutions are used for the analysis of vulnerability.

6.12 POPULATION VULNERABILITY TO HAZARDS

Based on population density and worst-case-scenario hazard prone area, population exposed per ward to different hazards were calculated as shown in Table 5.

TABLE 5: POPULATION EXPOSURE TO HAZARDS

Hazard type	Hazard prone area (km^2)	Population exposed	Ward wise details
Floods	39.9	1,58,477	Annexure 1
Drought	Entire city is moderately drought prone		
Coastal Hazards	2.1	8,209	Annexure 2
Lightning*	44.2	1,81,640	Annexure 3
Landslide	0.05	393	Annexure 4
Industrial hazards	90	3,53,191	Annexure 5
Mass gathering**	15.93	1,36,568	Annexure 6

*Entire ward was classified as lightning prone, if at least one event has been reported from the ward
**Areal extent of Attukal Pongala alone was mapped as public congregation during other events were limited to less than 1 km from the respective religious centre

6.13 PHYSICAL VULNERABILITY OF PUBLIC BUILDINGS

Physical vulnerability is essentially the potential for physical impact of hazards on the built environment and population. It is defined as the degree of potential loss, to a given element-at-risk or set of elements-at-risk, resulting from the occurrence of a natural phenomenon of a given magnitude; it is expressed on a scale from 0 (no damage) to 1 (total damage). Physical vulnerability is related to the characteristics of the elements-at-risk and the hazard

intensity. Physical vulnerability, as such, is not a spatial component, but is determined by the spatial overlay of exposed elements-at-risk and hazard footprints (http://drm.cenn.org).

Thiruvananthapuram City has an assemblage of public buildings ranging from schools, hospitals, public offices and museums. In the event of calamities, functioning of local relief and rescue management will be significantly affected if these buildings are affected. Specific structural assessment of all these buildings are not feasible and is not required from a disaster risk reduction perspective. However, through a rapid visual screening, the general vulnerability of these buildings to accidents and hazards may be assessed. Hence a rapid visual screening (RVS) of 378 public buildings was conducted. These public buildings were chosen based on the inputs provided by local people's representatives. Table 6 shows the categories of public buildings that were subjected to RVS.

TABLE 6: CATEGORY OF BUILDINGS SUBJECTED TO RAPID VISUAL SCREENING

Sl. No	Category	No. of buildings
1	Higher Educational Institutions	45
2	Government Institutions	130
3	Hospitals	42
4	Public Buildings	44
5	Schools	117
	Total	**378**

Traditionally, RVS is conducted with several technical parameters which can only be handled by technically qualified personnel. This impedes the replicability of such techniques as a routine time bound procedure, particularly in situations of financial constrain. Hence, as part of this project, a simple, pragmatic and replicable RVS method has been adopted which contains ten parameters only. The parameters were chosen so as to represent the lumped vulnerability of individual buildings to hazard events after consultation with civil and electrical engineers, fire & rescue officers and town and country planning officials. Table 7 shows the criteria used.

TABLE 7: CRITERIA USED FOR VULNERABILITY ASSESSMENT OF SELECTED PUBLIC BUILDINGS

Sl. No	Criteria	Highly vulnerable	Moderately vulnerable	Least vulnerable
1	Safety equipment	Not equipped	Equipped but not well maintained	Highly equipped & well maintained
2	Accessibility for water tenders around the building	No space for movement of water tenders around the building	<9 m space around the building & restricted movement of water tenders possible	9 m or more space all around the building for movement of water tenders
3	Evacuation routes	No evacuation routes marked	Evacuation routes are present, but not clearly marked	Well marked evacuation routes
4	Early warning systems	No alarms, smoke detectors or fire detectors present	Alarms, smoke detectors or fire detectors are present, but not well maintained	Well maintained alarms, smoke detectors or fire detectors are present
5	Occupancy	>1000 persons	500 to 100 occupants	<100 occupants
6	Accessibility of emergency services to the building	>1 km from main PWD roads	Within 1 km from main PWD roads	Within 200 m of PWD roads
7	Damageability of buildings	Very old, damaged and not properly maintained	Old, physical damages visible but maintained	No physical damages visible and well maintained
8	Electrical insulation	Electrical wires visibly hanging	Sealed and insulated, but not affixed properly to walls	Well insulated, sealed and affixed to the walls
9	Storage of fuel	Storage of petroleum products within the building	Storage of petroleum products immediately outside the building	Storage of petroleum products in separate fire resistant rooms; no storage of

				petroleum products
10	Accessibility to medical facilities	Distance to medical facility >1 km	Distance to medical facility within 1 km	Distance to medical facility within 200 m

With this simple RVS method 378 public buildings spread across Thiruvananthapuram City could be screened within 20 days with the involvement of 7 graduates in science hired on daily wages. Annexure 7 gives the list of buildings evaluated per ward and the vulnerability category that each building falls in, based on the RVS. Based on the absolute number of public buildings evaluated using RVS per ward, the wards were categorized into high, moderate and low vulnerability. Figure 44 shows the ward wise physical vulnerability map of Thiruvananthapuram City.

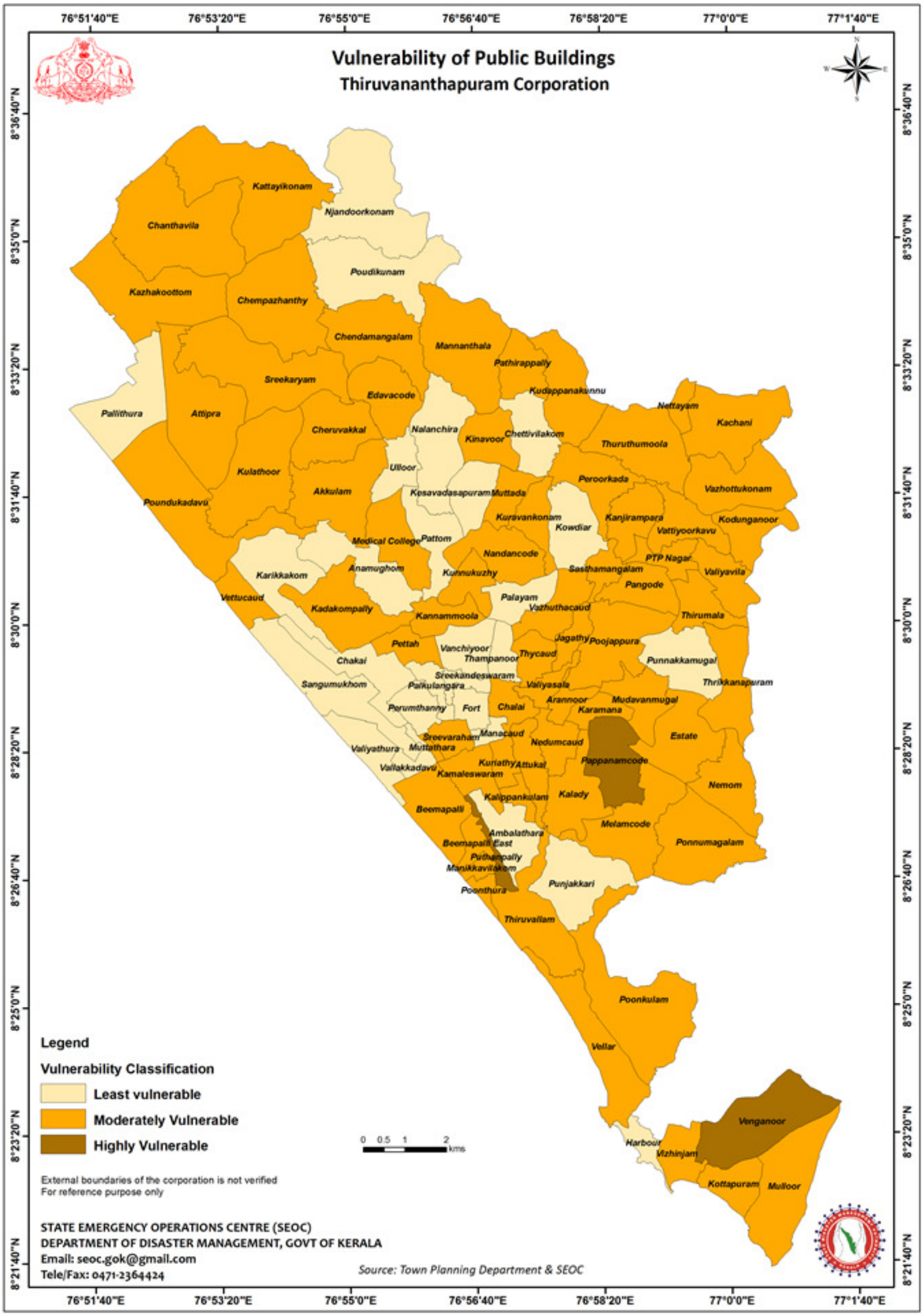


FIGURE 44: PHYSICAL VULNERABILITY OF THE WARDS OF THIRUVANANTHAPURAM CITY

6.14 LOSS-POTENTIAL ASSESSMENT

Based on the vulnerability assessment using the RVS, a loss-potential assessment was also conducted for using in the risk assessment. The criteria used for quantifying the loss were also kept simple and replicable. It may be noted that in Thiruvananthapuram City, building damage data pertaining to coastal erosion and windfall alone are available. Hence the scale has been based on field based expert judgement with data pertaining to coastal erosion. No specific vulnerability curves were utilized for the purpose as such curves are non-existent for the types of buildings in the City. Table 8 shows the criteria used for classifying the loss potential of buildings based on expert opinion of engineers.

TABLE 8: CRITERIA USED FOR VULNERABILITY ASSESSMENT OF SELECTED PUBLIC BUILDINGS

Hazard susceptibility	Building vulnerability class	Loss potential
No hazard	Highly vulnerable	0.2
	Moderately vulnerable	0.1
	Least vulnerable	0.1
Low	Highly vulnerable	0.6
	Moderately vulnerable	0.4
	Least vulnerable	0.2
Moderate	Highly vulnerable	0.8
	Moderately vulnerable	0.5
	Least vulnerable	0.3
High	Highly vulnerable	0.9
	Moderately vulnerable	0.6
	Least vulnerable	0.4
Very High	Highly vulnerable	1
	Moderately vulnerable	0.7
	Least vulnerable	0.5

6.15 SOCIO-ECONOMIC VULNERABILITY

Socio-economic vulnerability is the potential impact of events on vulnerable groups within a society. It considers public awareness of risk, ability of groups to self-cope with catastrophes, and the status of institutional structures designed to help them cope. In this project, the parameters used were literacy rate, total population, working population, sex ratio and number of households in a given ward. By incorporating working population into the social vulnerability assessment, the attempt was also to capture the economic vulnerability. Common data in terms of authenticated ward boundaries and Census 2011 data were available only for 78 wards. Hence, social vulnerability of only 78 wards could be assessed. Individual parameters were classified and weights were assigned to each class, heuristically. Wards were assigned specific vulnerability scores by aggregating the weights. As and when Census Department releases complete data regarding the 100 wards of the City, further additions will be made to this assessment.

6.15.1 LIVELIHOOD

According to Census 2011, 84% of the city population are categorised under main other workers population and 14% are employed as marginal workers. Only 1% of population are involved in agricultural and household industrial activities and less than 1% is involved in cultivation activities. Thus the city's economic resilience in terms of livelihoods is significantly high in general and hence this criteria is not separately added to the socio-economic vulnerability assessment. However, special attention is needed for the marginal worker population who may be economically highly vulnerable to disasters. Annexure 8 shows the ward wise pattern of livelihood pattern of population. Figure 45 shows the livelihood pattern of Thiruvananthapuram City’s population.

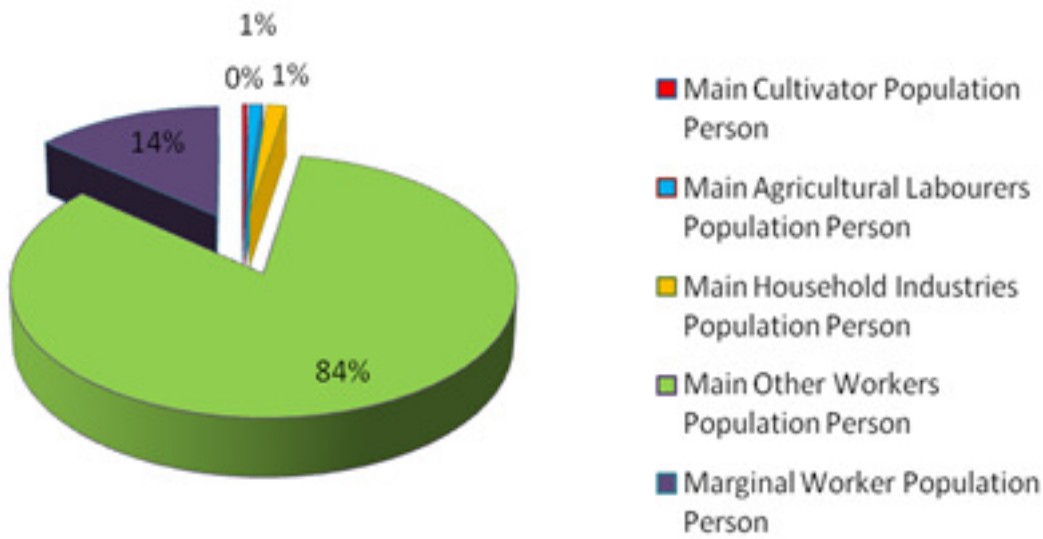


FIGURE 45: LIVELIHOOD PATTERN OF THIRUVANANTHAPURAM CITY

6.15.2 MARKETS, COMMERCIAL CLUSTERS AND SLUMS

Thiruvananthapuram city has a number of commercial clusters; places that have contiguous development of commercial establishment. There is 1 main market, 4 submarkets, 7 main zonal markets, 46 local markets and 4 road side markets. Only 3 markets (Kazhakuttom, Sreekariyam and Kanjirampara) have waste management facility. Unhygienic conditions prevail in most of the markets, particularly due to the absence of solid waste management facility. Figure 46 shows the commercial clusters and markets in the City. Annexure 9 shows the list of commercial clusters and markets in the Thiruvananthapuram city and Annexure 10 shows the consolidated data of slums in Thiruvananthapuram city. Figure 47 shows the distribution of slums in Thiruvananthapuram City.

6.15.3 PARAMETER WEIGHTS AND AGGREGATE SCORES FOR SOCIO-ECONOMIC VULNERABILITY ASSESSMENT

Table 9 shows the parameters, classes and weights used for social vulnerability assessment and aggregate scores and vulnerability class used for this project. Figure 48 shows the socio-economic vulnerability of the wards of Thiruvananthapuram City in varying classes based on the criteria laid in Table 9 and Table 10.

TABLE 9: PARAMETERS, CLASSES AND WEIGHTS USED FOR SOCIAL VULNERABILITY ASSESSMENT

Sl. No	Parameter	Class	Weight
1	Literacy rate: Representation of coping capacity; higher the literacy rate, higher is the coping capacity and hence vulnerability is low	>90%	1
2	Total population: Higher the population, higher is the vulnerability	<7000	2
		7000 -10000	4
		>10000	6
3	Total working population: Higher the total working population, higher is the coping capacity and hence less vulnerability	>3000	1
		<3000	3
4	Sex ratio: Higher the sex ratio, higher is the exposure of women to hazards and hence higher is the vulnerability	<1000	1
		>1000	4
5	0-6 age group population: Higher the number of children, higher is the vulnerability to hazards as children below 6 are generally incapable of appropriate response to hazards	<500	2
		500 -1000	4
		>1000	6
6	Households: Higher the number of households, higher is the vulnerability as higher will be the number of buildings affected	<1000	2
		1000 -3000	4
		>3000	6

7	Households without electricity connection (% of the total households in the ward)	>1%	2
8	Households with no drainage & open drainage (% of the total households in the ward)	<25%	1
		25-50%	2
		>50%	4
9	Unhygienic drinking water source - untreated tap water/river/pond water (% of the total households in the ward)	<25%	1
		25-50%	2
		>50%	3
10	House roof - grass/thatch/bamboo/mud/plastic sheet/unburnt wood (% of the total households in the ward)	<10%	1
		10-15%	2
		>15%	4
11	House wall - grass/thatch/bamboo/mud/plastic sheet/unburnt wood (% of the total households in the ward)	<10%	1
		10-15%	2
		>15%	4
12	No. of Slums per ward – Higher the number of slums higher will be vulnerability	<5	1
		>5	4

TABLE 10: AGGREGATE WEIGHTS AND VULNERABILITY CLASS

Sl. No	Aggregate weight	Vulnerability
1	<25	Least
2	25-30	Moderate
3	>30	High

6.16 ENVIRONMENTAL VULNERABILITY

In assessing the cost of damage to natural resources, economists generally assign value to "services" provided by natural resources. Examples of environmental services include hydrological features, atmospheric gas regulation and habitats. Services provided to humans by natural resources include commercial uses such as waterways, water provision, agriculture irrigation, timber harvest, recreation and health. Such an assessment requires bench marks for quantification of the costs of environmental services which is not available for the country. Hence, instead of attempting to quantify the losses, known issues are flagged herein.

Thiruvananthapuram City has few selected environmental expanses. The most important of them are:

a. The Zoo and Museum Campus
b. The Kanakakunnu Palace Grounds
c. The Kawodiar Palace Grounds
d. The Golf Club Grounds

In addition to these locations, the city also has green expanses in the campus of many of the educational institutions and central agencies. Water front recreation facilities are available at multiple beaches along the city and at Velli and Akkulam lakes. Numerous ponds associated to temples are also present in the city. These entities increase the relative resilience of the city. Presence of green cover increases resilience to industrial & traffic related pollution and industrial accidents that may release toxic plumes. Back waters offer a buffer to storm surges. Presence of fresh water ponds increase the surface water storage and thereby act as a buffer against severe drought conditions by offering ground water recharging. However, presence of trees that have exceeded their critical growing age and those that have suffered damages to the roots due to structural developments and road cuts pose significant threat to life and property in the City. In 2013, as many as 300 windfall of trees were reported from the City which caused several fatalities and damage to property. Despite the presence of such green cover, the air quality

of the City is assessed to be moderately polluted with the principal component of pollution in the City being suspended particulate matter. The health effects of exposure to PM10 (particulate matter less than 10 micrometre in diameter) using dose-response coefficients show that the effect is severe in terms of mortality and morbidity parameters [8].

Proximity of various industrial units with chemical storages to water sources poses a minor threat to the water quality and the environmental services offered by such water sources. The threat is categorised as minor given the steep terrain and the presence of several minor streams that drains through the back waters into the sea. Any release of toxic materials into the unconfined water sources such as lakes and back waters will be washed off into the sea, swiftly particularly during the monsoon seasons. Intensity of the event will be higher if it is during the lean, summer season during which water outflow through the streams are minimal. However, as a last resort contingency measure, water stored in Peppara, Neyyar and Aruvikkara dams can be released into streams to wash off any toxic chemicals, although this may reduce the availability of drinking water during the off season. In the event of chemical leakage, ground water contamination is inevitable.

The surface water quality of Thiruvananthapuram City is comparatively poor for potable use as per accepted standards in the country [9]. Water quality assessment in the year 2012-13 of Aruvikkara Reservoir that caters to the City's potable water need indicated that the water is non-polluted and is within the standards laid by WHO. However, the reservoir area was seen to be inhabited by aquatic weeds and noxious phytoplankton that may lead to Eutrophication. Encroachment, agriculture in the bed during the lean season and siltation are also posing threats to the reservoir [10]. Hence, strict measures have to be adopted to protect the reservoir and its catchment area to ensure long term drought resilience. The groundwater quality of Thiruvananthapuram City is poor, particularly around the sewerage farm in Muttathara-Valiyathura area with total coliforms and faecal coliforms present beyond the permissible limits for drinking water quality [11]. In a study report released by Kerala State Council for Science, Technology and Environment in 2010, analysis of water samples collected from 20 locations along the river showed contamination from different sources resulting in poor water quality, especially in the downstream areas of Karamana River, a principal stream that flows through the City. Thrikkannapuram, the Pachalloor estuarine area where tourism projects are centred, and Thiruvallam were found to be the most contaminated reaches. Seventy-five per cent of the river water samples were acidic in nature. Most of the physico-chemical water quality parameters exceeded the desirable limit prescribed by the Bureau of Indian Standards. Ninety per cent of the groundwater samples collected from the river basin was acidic and 53 per cent bacteriologically contaminated. Biological analysis of surface water samples indicated heavy organic pollution at Thiruvallam and Pachallur. The report observes that the Parvathy Puthanar canal is a major source of pollution of the river waters. Bacteriological analysis of the river water clearly indicated microbial contamination. Almost all the stations showed higher index for total coliforms and faecal coliform. E.coli was present in the samples collected during different seasons. The garbage treatment plant at Vilappilsala was polluting the Meenampally Thodu, a stream joining the river in the upstream area. Analysis of sediment samples collected from the Pappanamcode industrial area revealed high concentration of heavy metals like iron, manganese, copper, cadmium and nickel [11]. Another major environmental disaster that the beaches and coastline of the City are prone to is oil spill pollution. The City is close to the international shipping line between Asia and Europe and thereby several ships, including large oil tankers transit the area. The along shore currents of the coast may lead to a condition of oil spreading all across the coast and also may enter into the backwaters and estuaries. Increase in marine shipping activity due to the upcoming Vizhinjam International Port may increase the probability of oil spill pollution.

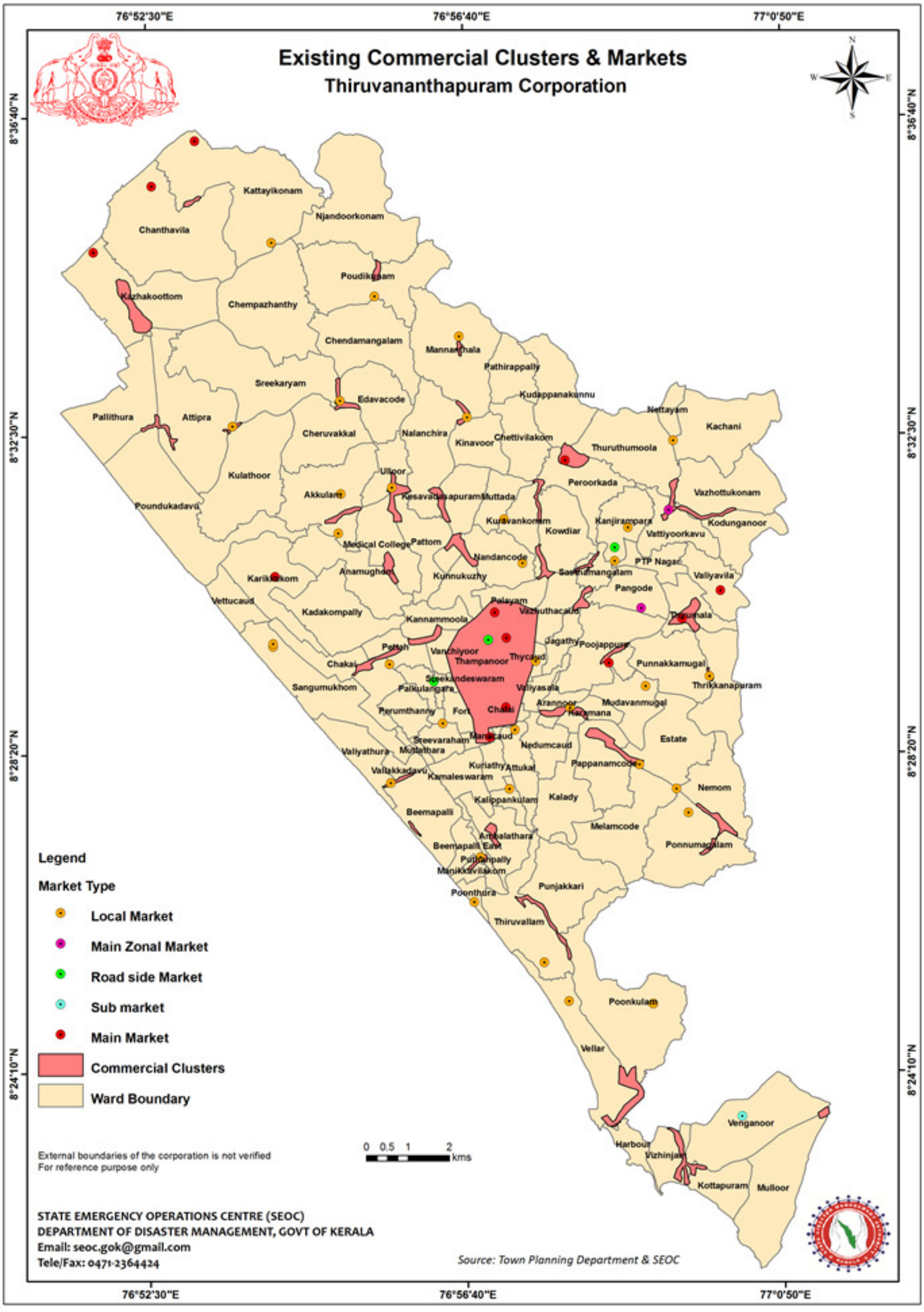


FIGURE 46: COMMERCIAL CLUSTERS AND MARKETS

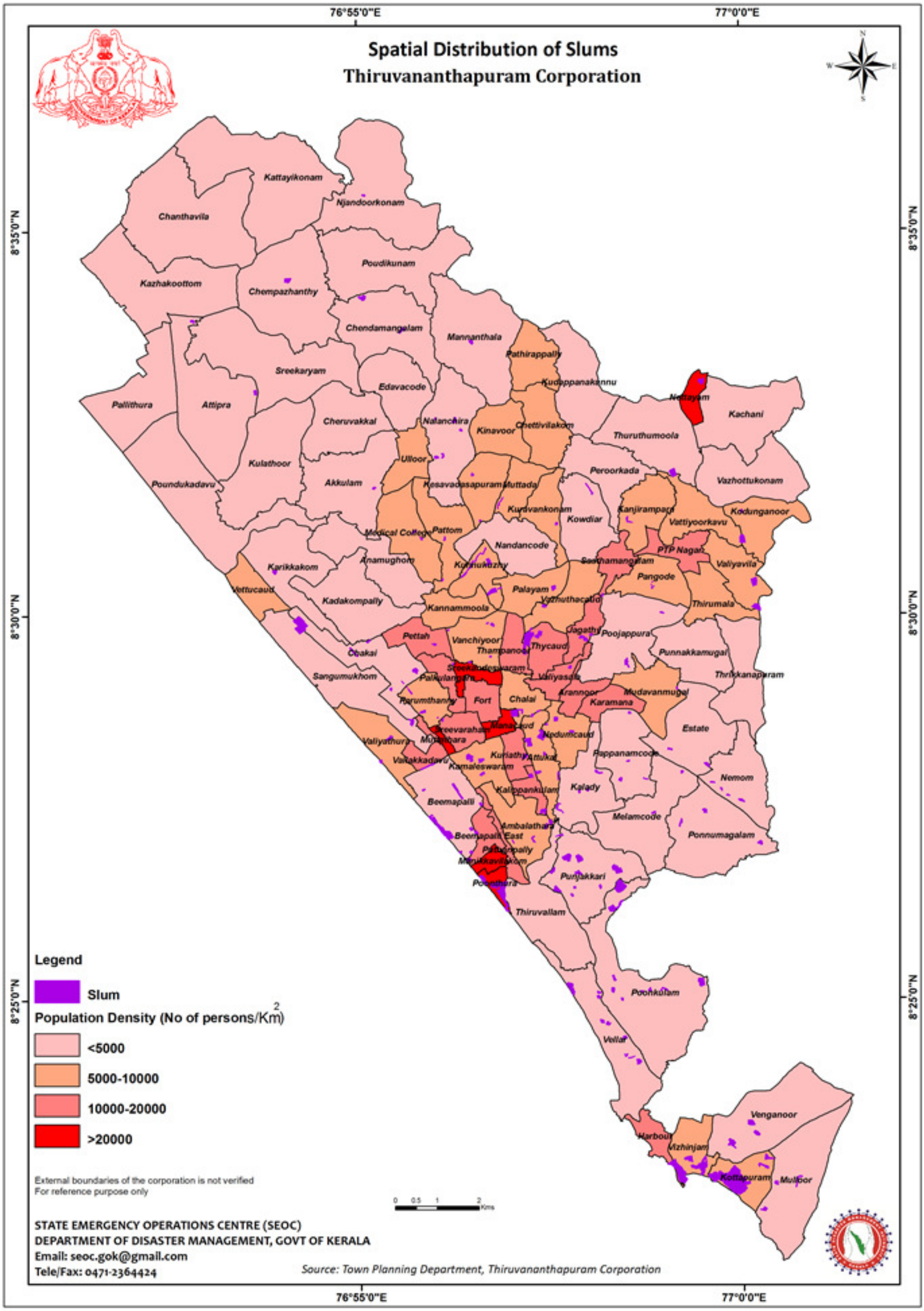


FIGURE 47: SLUMS OF THIRUVANANTHAPURAM CITY

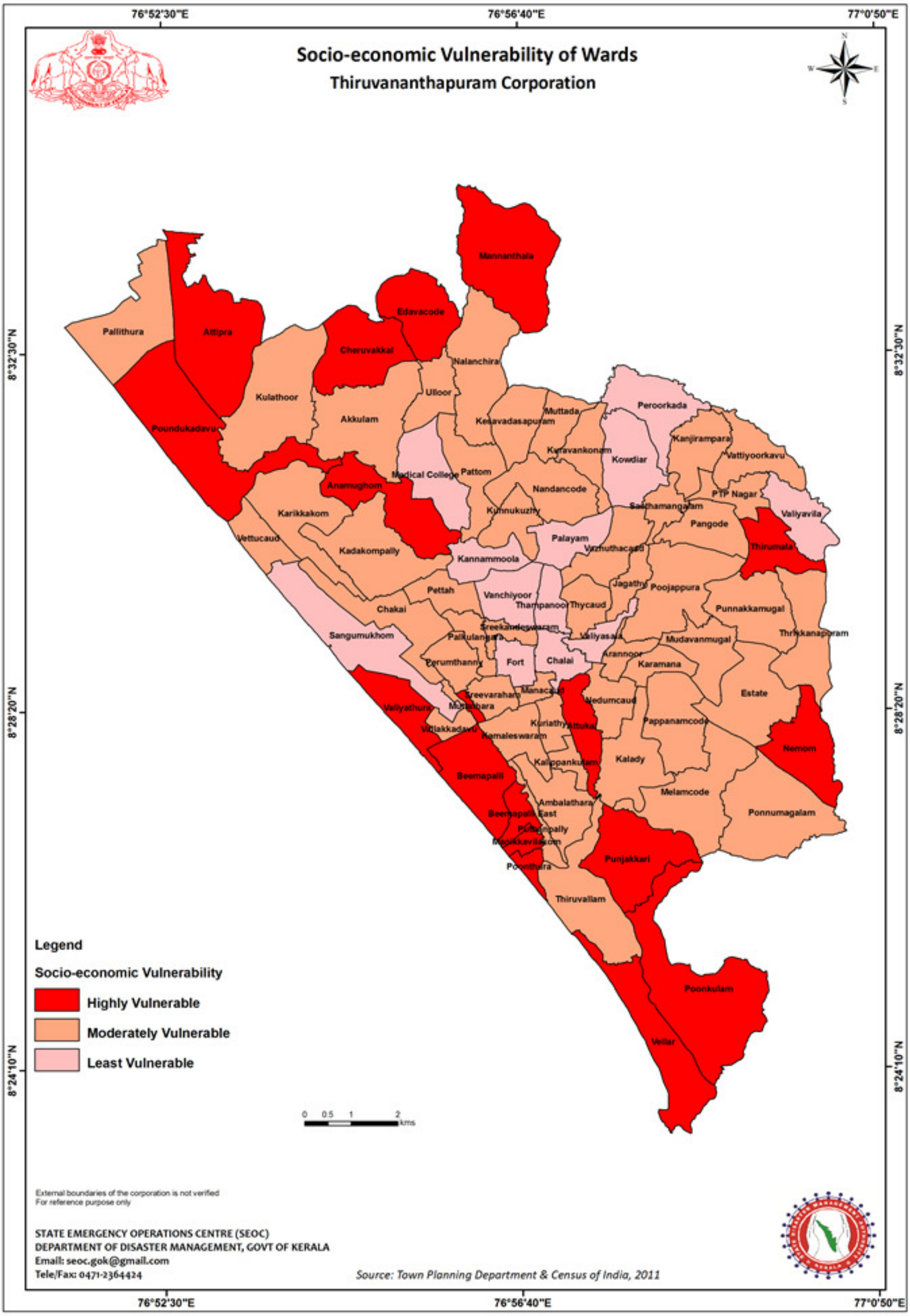


FIGURE 48: SOCIO-ECONOMIC VULNERABILITY OF THE WARDS OF THIRUVANANTHAPURAM CITY

7. EXPENDITURE FROM STATE DISASTER RESPONSE FUND IN THE CITY (2008-2012)

Risk is often expressed in terms of the anticipated amount of monetary loss/time. If quantified for varying hazard scenarios and cumulated for varying return intervals, the cumulated risk may be of such unprecedented values which are non-cognizable. Hence, adopting a pragmatic approach, it was decided to quantify the burden on the state exchequer through the State Disaster Response Fund as relief assistance for a period from 2008 to 2012 and translate it to per-capita burden in the village level. The choice of the time period was arbitrary based on ease of possible availability of recorded data. The data was collected and grouped in a village level and not ward level as the relief assistance payments are dealt through the village administration. The limitations of SDRF/NDRF norms approved for the period is inadvertently the limitation of this data and restricts itself to Coastal erosion, Landslide, Flood, Lightning, Drought, Earthquake, Wind and Heavy rainfall.

For this study, spending details of Calamity Relief fund/State Disaster Relief fund on various natural hazards for the time period 2008–2012 in Thiruvananthapuram City (boarder as on 2010) were obtained from the respective Taluk. The data collected from respective districts were carefully analysed and regions/houses affected by natural calamities were identified, located using a Global Positioning System Survey and geotagged to a Geographic Information System database. A total of 4600 individual relief assistance payments were made in the city limits during the period. Of this 1820 individual houses could be located, while 2780 could not be located with the data available in the Taluk records. A total of ₹1,46,89,350 was expended in the city during the period as relief assistance. Table 11 shows the calamity wise total expenditure and the number of calamity events during the period 2008-12.

TABLE 11: CALAMITY TYPE, TOTAL AMOUNT EXPENDED AND THE NUMBER OF REGISTERED CLAIMS FROM 2008-12

Coastal Flood	₹ 20,05,080	1928
Riverine Flood	₹ 1,08,00,750	2672

Claims for relief assistance in the city were mostly due to riverine flood damages, followed by coastal floods, both during the monsoon seasons. Table 12 shows the village wise SDRF/NDRF allocation statistics for individual claims and the per-capita SDRF/NDRF expenditure. To estimate the losses due to the natural disasters, per-capita SDRF/NDRF expended was calculated using the following equation:

Per-capita SDRF/NDRF = SDRF/NDRF expended in 2008-12 period/population affected*

[Population affected was assuming that each claimant has a family of 4 members]

TABLE 12: VILLAGE WISE SDRF/NDRF EXPENDITURE FOR INDIVIDUAL RELIEF ASSISTANCE (2008-2012)

VILLAGE	NUMBER OF EVENTS	POPULATION AFFECTED	SDRF/NDRF EXPENDED (₹)	PER CAPITA SDRF/NDRF (₹)
Cheruvikkal	35	140	₹ 1,08,600	₹ 776
Kadakompally	47	188	₹ 45,900	₹ 244
Kowdiar	23	92	₹ 14,300	₹ 155
Kudapanakunnu	19	76	₹ 11,000	₹ 145
Manacaud	885	3540	₹ 85,22,750	₹ 2,408
Muttathara	1928	7712	₹ 34,56,000	₹ 448
Pattom	287	1148	₹ 2,82,400	₹ 246
Perrorakada	27	108	₹ 57,500	₹ 532
Pettah	36	144	₹ 1,15,500	₹ 802
Sasthmangalam	315	1260	₹ 5,46,850	₹ 434
Thirumala	39	156	₹ 1,13,700	₹ 729
Thiruvallom	242	968	₹ 4,45,750	₹ 460
Thycaud	210	840	₹ 3,40,700	₹ 406
Ulloor	227	908	₹ 83,700	₹ 92

Vanchiyoor	61	244	₹ 1,02,300	₹ 419
Vattiyoorkavu	86	344	₹ 2,47,900	₹ 721
Nemom	31	124	₹ 67,500	₹ 544
Attipra	27	108	₹ 54,000	₹ 500
Unknown	*75*		*₹ 73,000*	
Total	**4600**	**18100**	**₹ 1,46,89,350**	**Average ₹599**

Figure 50 shows the spatial pattern of per-capita SDRF/NDRF, which clearly indicates that Manacadu and Thirumala villages experience the highest number of claims from SDRF/NDRF.

Average per-capita SDRF/NDRF expenditure of Thiruvananthapuram over a period of 4 years: **₹599**

Village with highest per-capita SDRF/NDRF expenditure: **Manacaud (₹2408)**

Village with highest per-capita SDRF/NDRF expenditure: **Ulloor (₹92)**

Although per-capita SDRF/NDRF expenditure is not a direct indicator of the vulnerability of the population, it may be used as an indicator to assess the quality of mitigation actions taken-up by various agencies in the city.

Per-capita SDRF/NDRF expended shows declining trend in villages, where a smaller number of events of natural disasters were reported. Muttathara Village shows a different inclination. Muttathara village had felt greater impacts of disasters in the given periods, but the monetary losses estimated in terms of per-capita are far less. Instead of per capita SDRF/NDRF allotment being higher in regions that suffered greater impacts of natural disasters, the observed pattern is quite the opposite. Such a trend may be due to influences of standard of living, density of population, social and other biases in the release of funds. Annexure 11 shows the ward-wise per-captia SDRF/NDRF expenditure.

SDRF/NDRF expenditure for repair of roads were analysed for the period from 2010-2012. A total amount of ₹3,32,27,811 was expended for repair of roads during the period. Table 13 shows the statistics of expenditure.

TABLE 13: VILLAGE WISE SDRF/NDRF EXPENDITURE FOR ROAD REPAIR (2008-2012)

YEAR	SDRF/NDRF expended
2010-2011	₹ 67,30,000
2011-2012	₹ 2,64,97,811

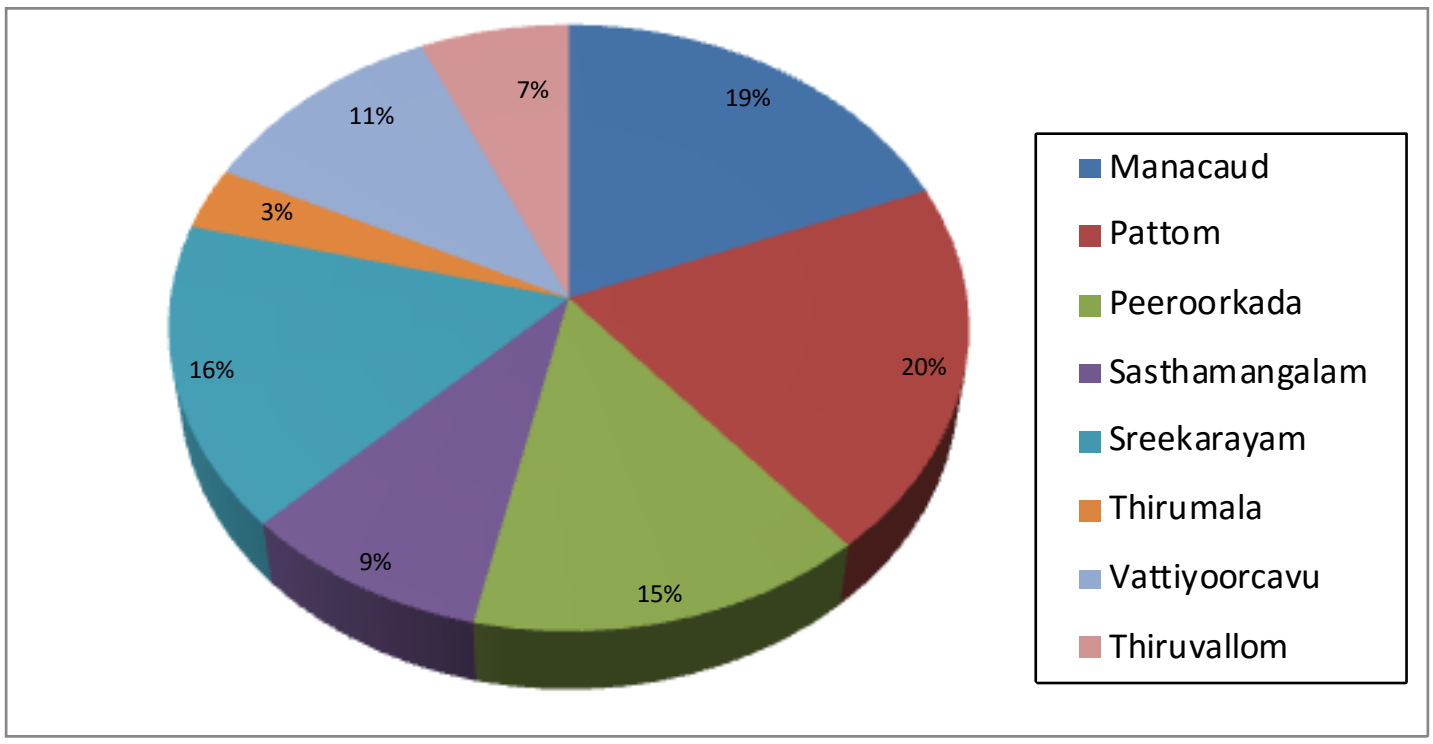


FIGURE 49: VILLAGE WISE EXPENDITURE OF SDRF/NDRF IN THIRUVANANTHAPURAM CITY (2010-12) FOR ROAD REPAIR

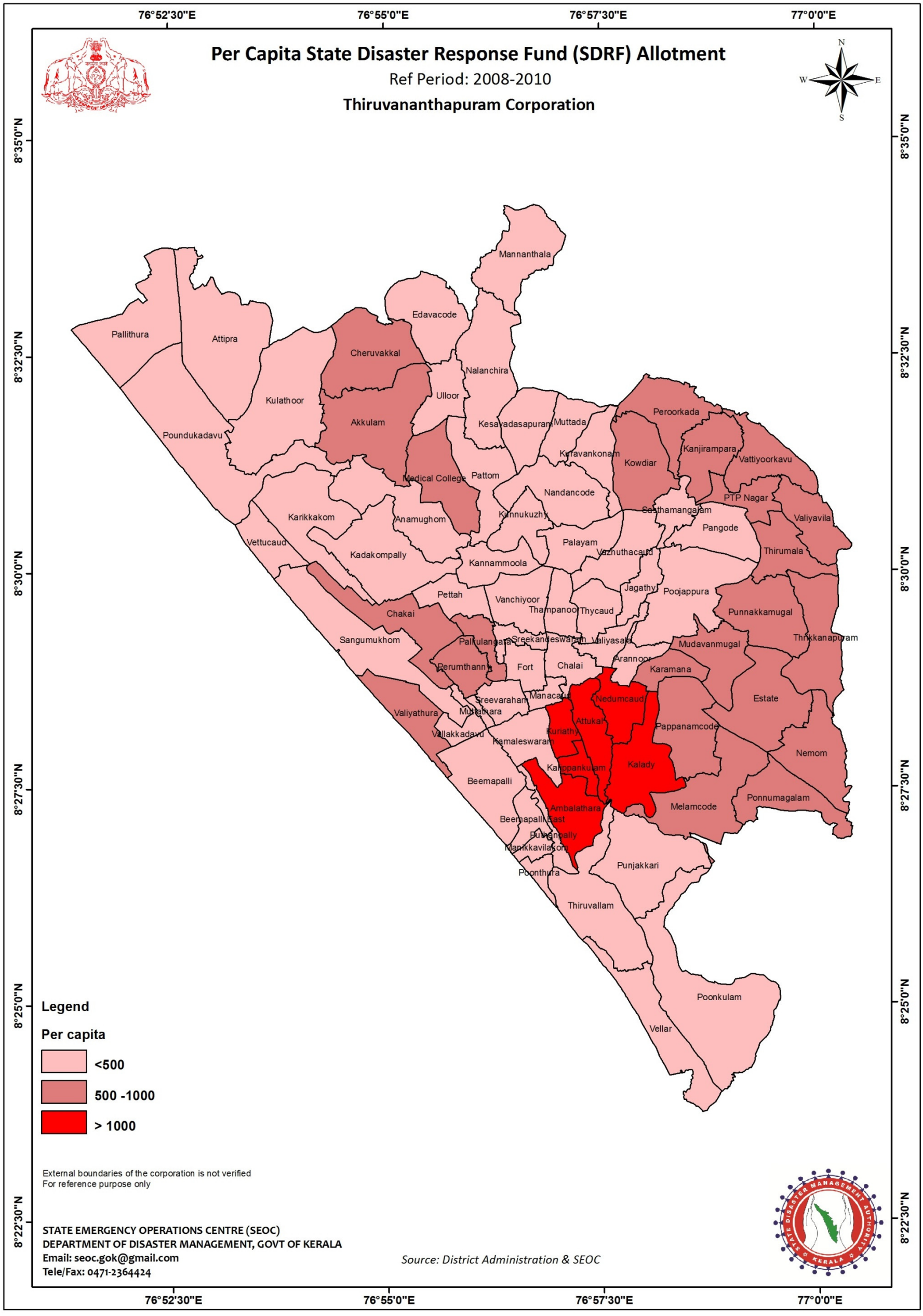


FIGURE 50: PER-CAPITA EXPENDITURE OF SDRF/NDRF IN THIRUVANANTHAPURAM CITY (BOUNDARY AS ON 2010) OVER A PERIOD OF 4 YEARS

8. CLIMATE CHANGE VULNERABILITY

It is impossible to be absolutely certain about all the disaster-related effects of climate change, owing to the intrinsic uncertainty in the climate projections, the diverse and rapidly changing nature of community vulnerability, and the random nature of individual extreme events. However, there is plenty of information on the serious impacts of events that have occurred in past decades, and on this basis alone there is much to be concerned about [1]. The likely consequences were assessed from review of research works and tabulated below in Table 14.

TABLE 14: ANTICIPATED EFFECTS OF GLOBAL CLIMATE CHANGE IN KERALA – TABULATED REVIEW RESULTS

Parameter	Effects	References
Temperature	Annual mean surface temperature increase of 0.5 to 4.5°C in 100 years expected	[8], [12], [13], [14], [15]
Precipitation	Observed decreasing trend based on rainfall data for the last 100 years; extreme events expected to increase in frequency	[4], [8]
Wind	No reference to be found	-
Sea level	Estimate of sea level rise of 1.30 mm/year based on past tide gauge data. Future global projections indicate an average increase of about 4 mm/year. Sea level may rise by 15 to 38 cm by mid-21st century	[6], [15]

Based on this inputs, the anticipated effects of global climate change in the city are as follows:

1. Increase in autumn and winter season's extreme rainfall will increase the probability of urban flooding during the north-east monsoon period.
2. Decrease in spring rainfall would imply that the drinking water shortage faced by Thiruvananthapuram city during the peak summer (April-May) months will intensify.
3. Spring rainfall also has a cooling effect on the general urban temperature. The reduction in extreme rainfall during the period may increase the urban temperature and lead to intensification of urban heat-island effect. An increase in mean surface temperature by 0.5 to 4.5°C may significantly increase the probability of epidemics.
4. Increase in sea-level may increase the intensity and extent of coastal erosion along the thickly populated coastline of Thiruvananthapuram city.

Although the intensity of drought, floods and coastal erosion may increase, it is assumed that the hazard footprint may not increase beyond the worst case scenarios mapped and hence separate hazard foot print assessment in light of climate change scenarios was not conducted.

9. COPING CAPACITY

Any effort to reduce vulnerability to natural disasters should focus on legal and institutional frameworks. Furthermore, vulnerability reduction requires focus on stabilizing factors such as diversity and resilience - that is, the capacity of natural and social systems to absorb both exogenous and endogenous changes. For this purpose, it is not enough to focus on a set of policies and instruments, but also to understand the intimate relationship between natural and social factors. An integral part of any vulnerability report is the coping capacity of the administrative unit in terms of institutional arrangements for responding to various hazards.

Thiruvananthapuram District has a District Disaster Management Authority constituted vide SRO. No. 977/2008 dated 22nd September 2008 with the District Collector as Chairperson and the District Panchayath President as Co-chairperson. The DDMA meets frequently and evaluates the disaster preparedness initiatives of various departments. The district has an approved Disaster Management Plan (Approved vide Minutes of Kerala State Disaster Management Authority held on 5th October 2015). The City also houses a team of State Disaster Response Force under the command of the State Disaster Management Authority.

In addition to these, the City has the presence of multiple battalions of State Police, Fire & Rescue Services, Indian Army, Indian Air Force. Presence of the State Incident Commanders (Chief Secretary and Principal Secretary, Revenue and Disaster Management) and the State Emergency Operations Centre in the City ensures prompt response to L2 and L3 level calamities and direct attention of the State Government, unlike other urban areas of the State. These strengths significantly increase the coping capacity of the city and thereby reduce the vulnerability of Thiruvananthapuram City to various hazards. In 2014 (26th to 30th May), the City has apportioned about Rs. 30 lakhs from its own funds for disaster risk reduction and has trained 25 of its officials in Basic and Intermediate level Incident Response System. The City Administration is actively working towards mainstreaming disaster risk reduction with the support of the GoI-USAID-UNDP Climate Risk Management Programme implemented by the State Disaster Management Authority. Effort for preparing a comprehensive City Disaster Management Plan is in progress. Thus institutional arrangements for disaster management as envisaged in the Disaster Management Act, 2005 (Central Act, 53) is active at the district level. Figure 51 to shows the zone-wise distribution of critical buildings useful for disaster response in the city.

However, at the City level, there is a lack of coordination with the District Disaster Management Authority. As envisaged in Chapter 6 of the Disaster Management Act, 2005, the Local Self Government is to work under the guidance of the District Disaster Management Authority in matters concerning disaster management and hence effective coordination mechanism has to be established by the City Corporation to collaborate with the DDMA to prepare, respond and mitigate disasters.

Cross cutting capabilities of the city for solid waste management, air pollution, sewerage treatment, drinking water supply, power and telecommunications were not accounted in this study.

10. RECOMMENDATIONS

Based on the above analysis, following recommendations are placed before Thiruvananthapuram City Corporation for hazard and vulnerability reduction.

1) The City must, in consultation with the District Disaster Management Authority create a City Disaster Management Committee with necessary fund allocation from the City's own funds for implementing disaster preparedness, climate change adaptation and mitigation projects
2) Permits for new construction in flood prone areas in the City may be restricted to reduce the increase in overall vulnerability of the City. Elevated structures on pillars without affecting the free flow of water may be considered as an option for constructions in flood prone areas.
3) The development of new infrastructure and settlements in coastal areas shall be strictly regulated as per the prevailing Coastal Regulation Zone Notification
4) Following actions for climate change mitigation may be considered:
   - mandatory provisions for rainwater harvesting, storage and utilization
   - minimum requirement of atleast 2 m^2 rainwater percolation area in plots >200 m^2 with slope <20°
   - mandatory provisions for harnessing and utilizing solar energy
   - mandatory provisions for carbon foot print offsetting at organization level by promoting car-pooling, restricting usage of air-conditioners from 11 am to 4 pm, promoting LED lighting, promoting usage of public transport, etc.
   - minimum requirement of atleast 6 m^2 of green cover in individual plots >200 m^2
   - declaring 'pedestrians only' streets
   - ensure atleast a 1:30 green area ratio [16] in the city at plot level, street level, ward level, region level and city level
   - subsidy in taxes for households without vehicles using petroleum fuels
   - promotion of reduce, reuse, recycle and refuse policy
5) All ponds in the City limits may be rejuvenated and protected. Tax subsidy may be given to civil society organizations willing to protect and maintain the ponds without being polluted and silted.
6) The City Corporation may engage with neighbouring panchayaths and ensure that remaining paddy and wetlands in these panchayaths are not infilled or converted to other landuse. The City Corporation may consider financially assisting these panchayaths for maintaining the wetlands and paddy lands such that the City benefits from water retention. Water retention will reduce the magnitude of floods and increase the ground water potential by facilitating for percolation.
7) The City Corporation shall engage with Aruvikkara Grama Panchayath and ensure that the catchment area of Aruvikkar reservoir is maintained pristine without quarrying, the reservoir is not polluted and encroached upon. The City Corporation may consider financially assisting this panchayath for protecting the catchment area and the reservoir.
8) All encroachments along the banks of all streams in the City shall be removed and a no-development zone of 2 meters along both banks of all streams may be considered. Structures that constrain the free flow of water may be identified mapped and removed or redesigned to ensure free flow after ascertaining the Peak Maximum Flood along the water channel.
9) Desilting, deepening and clearing of dumped solid waste from the streams, clearing the crisscrossing communication cables and utility pipelines needs to be undertaken as a priority.

10) The City should continue the implementation of 'Operation Anantha' and undertake the continued maintenance of the structural interventions undertaken as part of the project to ensure continued rapid storm water drainage. Further, the City administration may consider commissioning a detailed engineering study covering the entire sewerage and storm water drainage network of the entire City and revamp it to accommodate the present requirement.
11) A platform of engagement may be created with neighbouring panchayaths to accommodate and distribute the burden of risks. For example, minor check dams along Killy Ar and Karamana River can reduce the magnitude of floods in the City.
12) The City shall establish automated weather stations in upstream panchayaths along the rivers and one each in each City zone with a 15 minutes recording and live streaming facility so as to now-cast flash floods.
13) The City shall establish a high wave, tsunami and cyclone warning facility to forewarn coastal communities, based on inputs from Indian National Centre for Ocean Information Services.
14) The City should develop and implement an annual tree pruning policy such that over grown trees and root damaged trees are culled or thinned in the months of April and May.
15) Petro-chemical accident contingency plan must be prepared for the City. Onsite and offsite plans for every industrial unit in the city must be prepared and a contingency plan for industrial accidents must be prepared
16) An oil spill contingency plan for the coastline of the City needs to be prepared and response measures have to be made ready, especially in light of increased coastal transport owing to the upcoming Vizhinjam International Port
17) Introduce a capacity building programme for government officials and City Councillors in order to enhance understanding and raise awareness about: i) budget allocations for climate change and disaster risk reduction related projects, and ii) the need to monitor actions and implement the plans
18) Build capacity at the community level, in order to plan, propose and implement small-scale projects with community involvement such as through MGNREGA that increase adaptive capacity and resilience and raise awareness at the community level through the dissemination of information about disaster risk reduction, climate change vulnerability and measures that can be taken to increase adaptive capacity
19) Public buildings that are highly physically vulnerable need immediate attention and retro-fitting to increase their disaster resilience. In general public buildings in the physically vulnerable wards may be addressed with priority to increase the overall resilience of the city
20) Develop measures to diversify and support alternative livelihoods for slum dwellers who are highly vulnerable to the impacts of disasters and climate change
21) It is recommended that a Ward Level Calamity Response Fund of Rs. 20,000/ward/year using the own funds of the City may be created to locally manage calamity situations. The utilization of this fund may be vested with the chairperson of the ward level health and sanitation committees. Specific guidelines may be issued for its utilization in consultation with the DDMA.
22) A Civil Defence Voluntary Force with the involvement of Non-Governmental Organizations and Civil Society Organizations such as residents associations may be created. Such a force may primarily be used for first aid, crowd control and triaging.
23) Surrounding every bridge and culvert in the City, a voluntary force in collaboration with civil society organizations such as residents associations may be formed by the City to clean and clear any blockades due to waste dumping or siltation on a daily basis.

24) With the active involvement of National Service Scheme, National Cadet Corps, Scouts & Guides and Student Police Cadets, vigil squads and awareness building squads may be formed to spread and reiterate the message of the necessity to ensure smooth flowing storm water drains and sewerage.

25) Considering the fact that communication networks will be the first to be damaged in the event of natural calamities the City Corporation may specifically direct the public sector and private sector telecommunications company to setup disaster resilient communication towers, exclusively for the use during calamities.

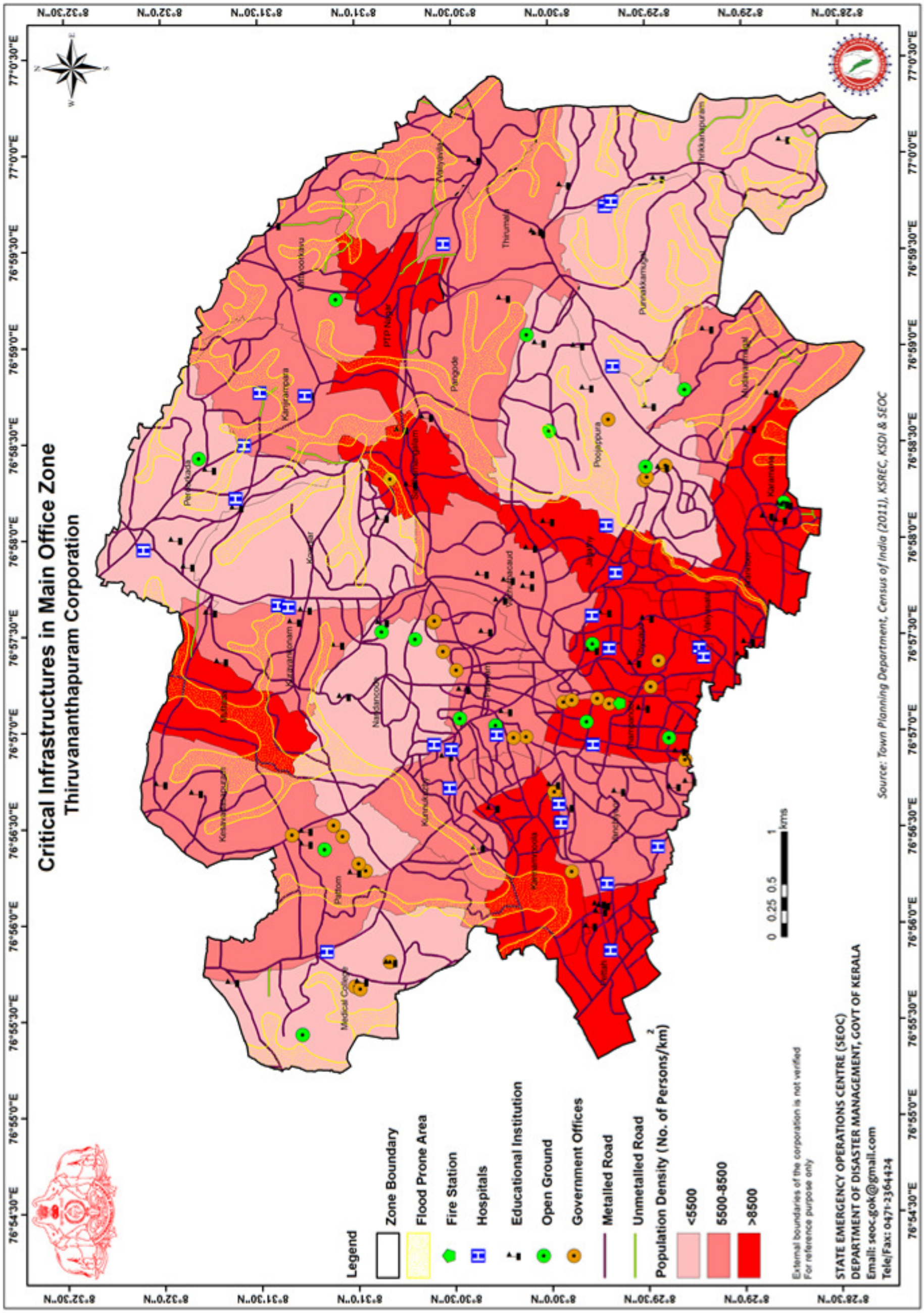


FIGURE 51: CRITICAL INFRASTRUCTURES IN MAIN OFFICE ZONE

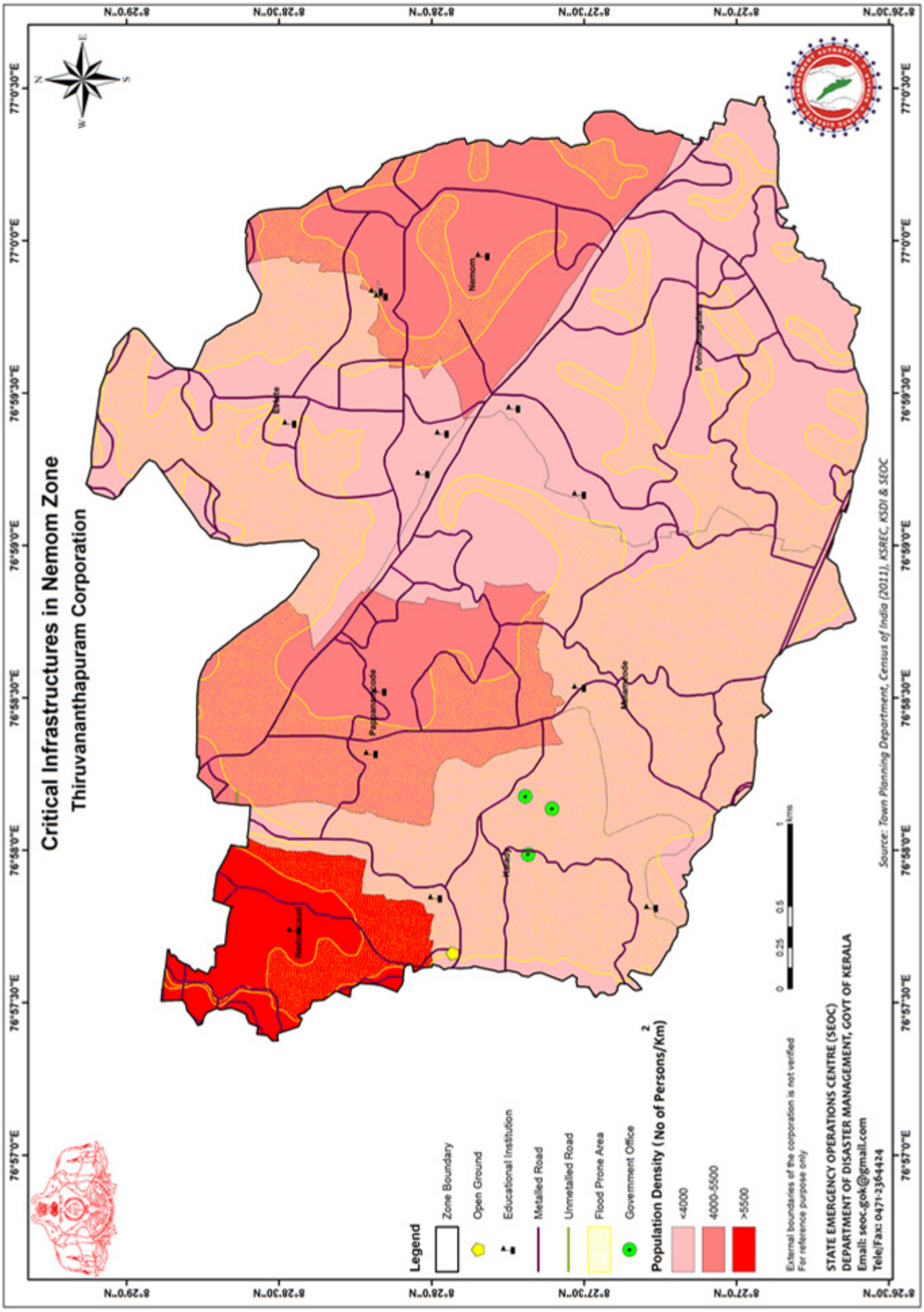


FIGURE 52: CRITICAL INFRASTRUCTURES IN NEMOM ZONE

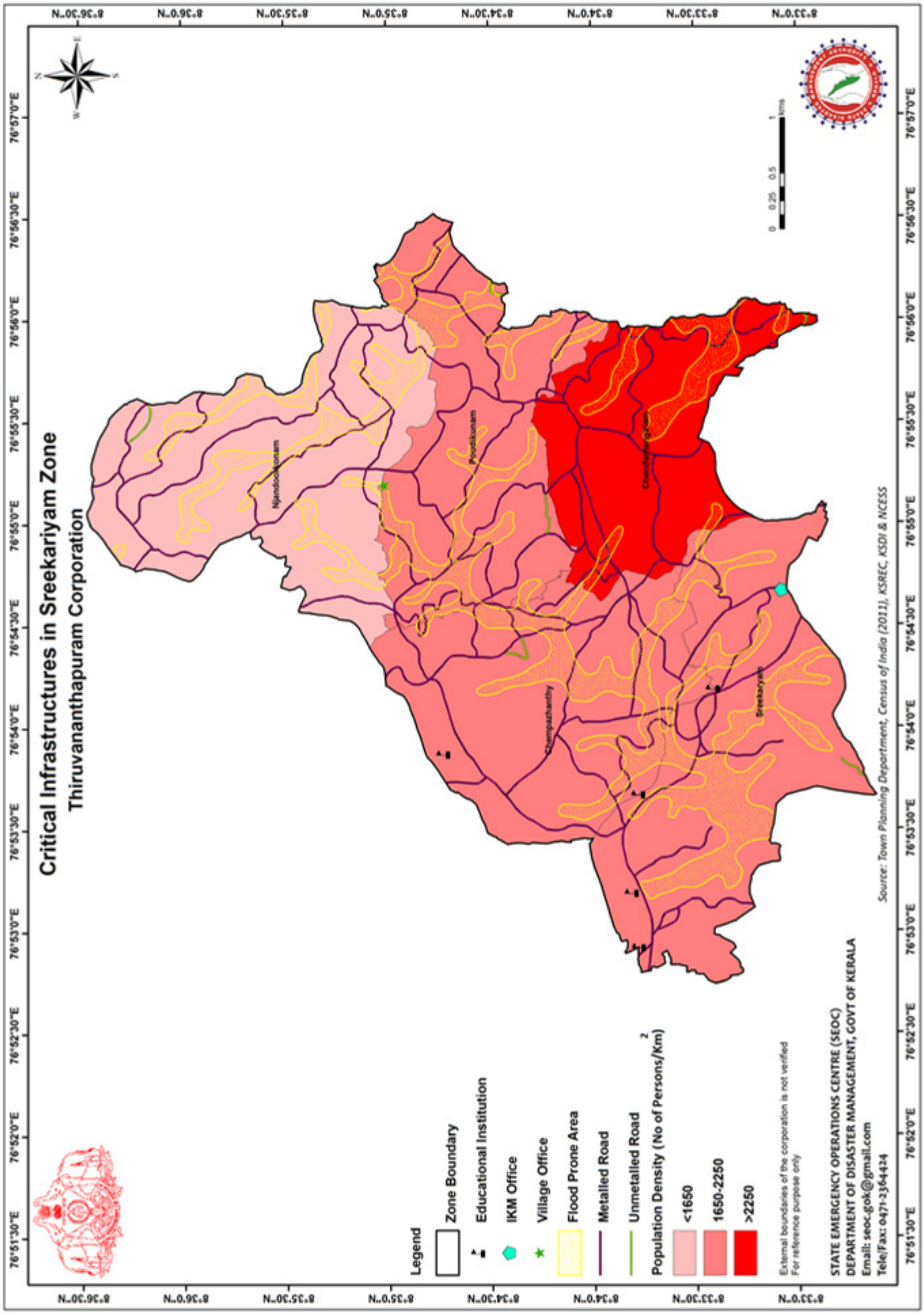


FIGURE 53: CRITICAL INFRASTRUCTURES IN SREEKARIYAM ZONE

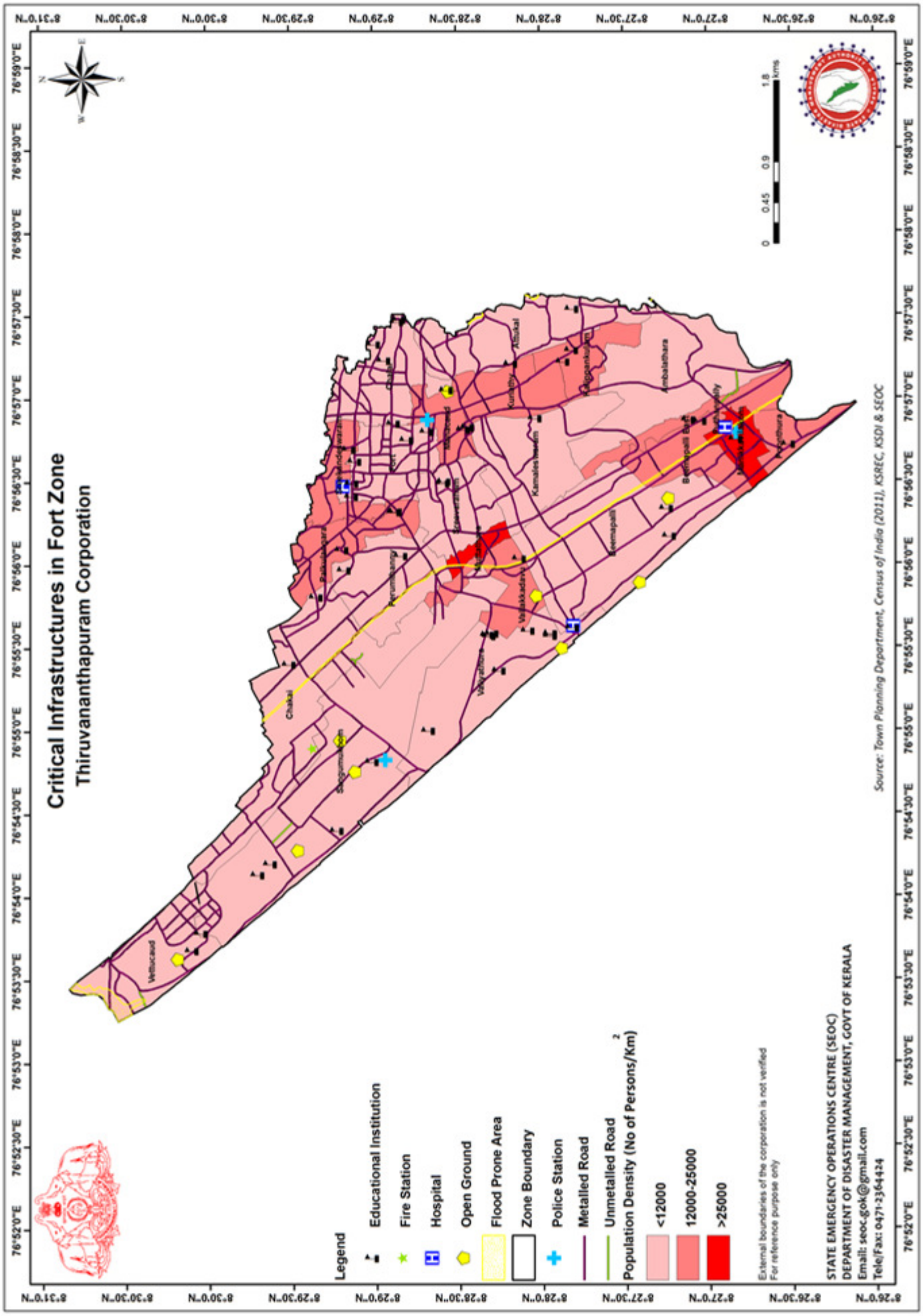


FIGURE 54: CRITICAL INFRASTRUCTURES IN FORT ZONE

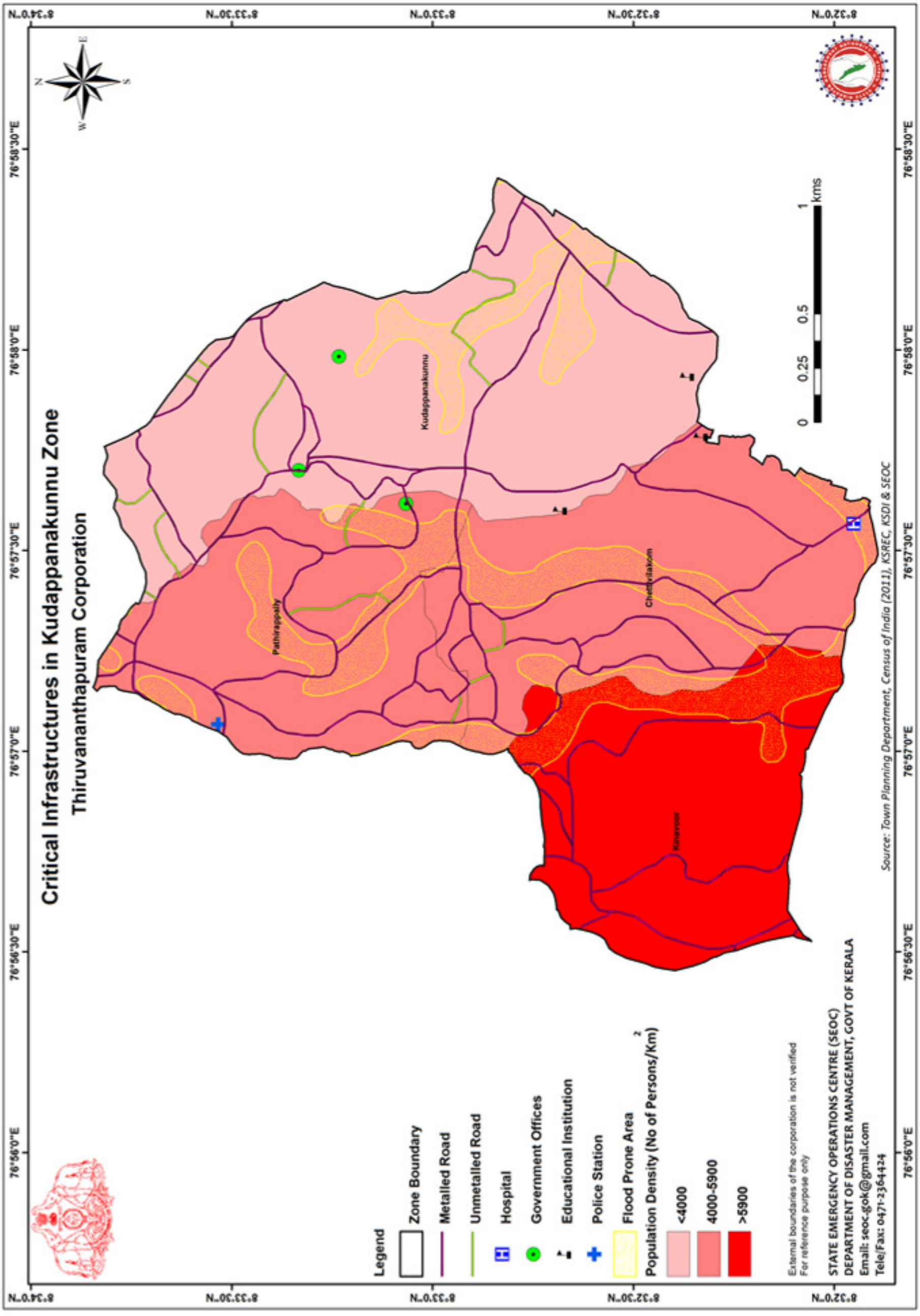


FIGURE 55: CRITICAL INFRASTRUCTURES IN KUDAPPANAKUNNU ZONE

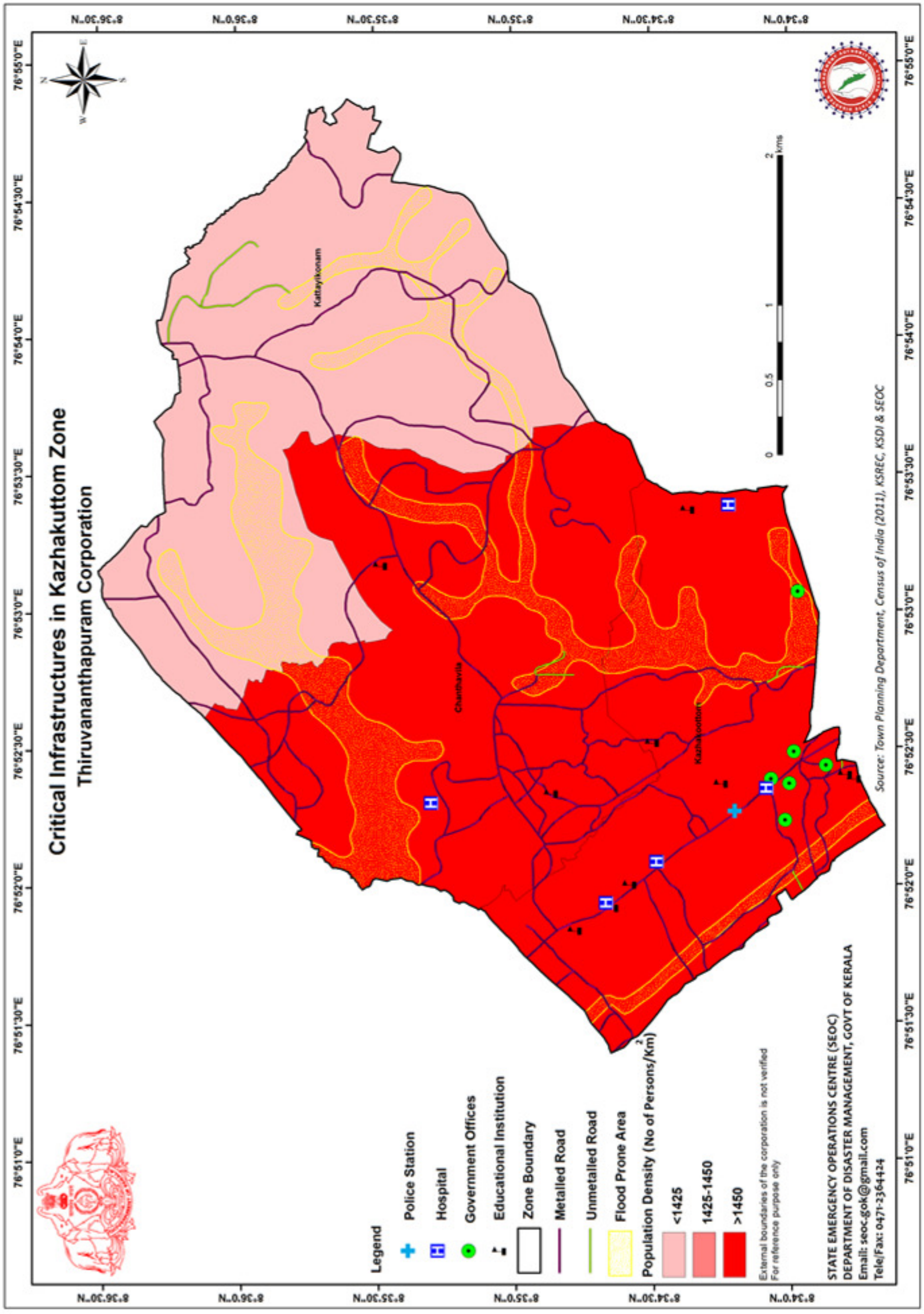


FIGURE 56: CRITICAL INFRASTRUCTURES IN KAZHAKUTTOM ZONE

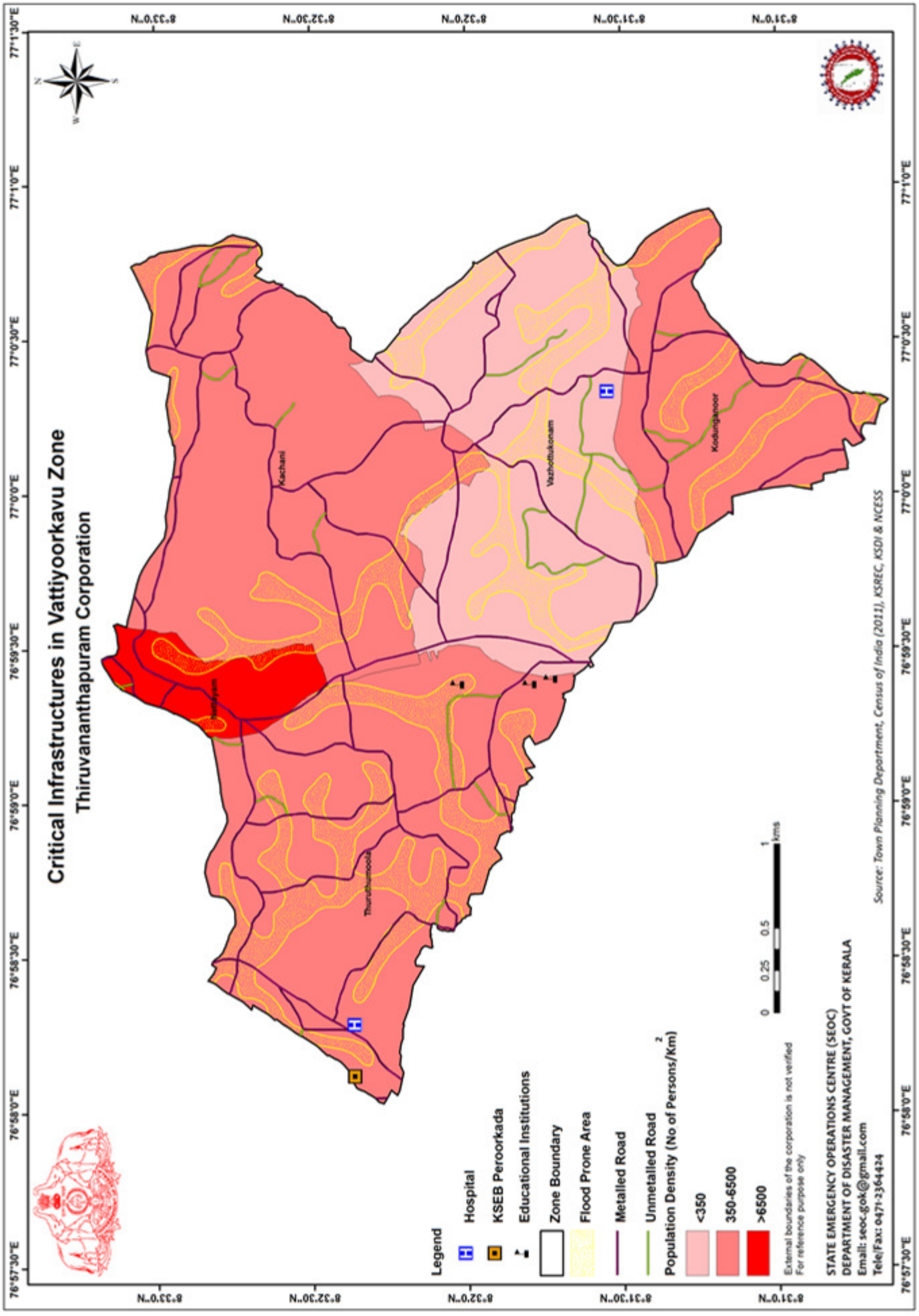


FIGURE 57: CRITICAL INFRASTRUCTURES IN VATTIYOORKAVU ZONE

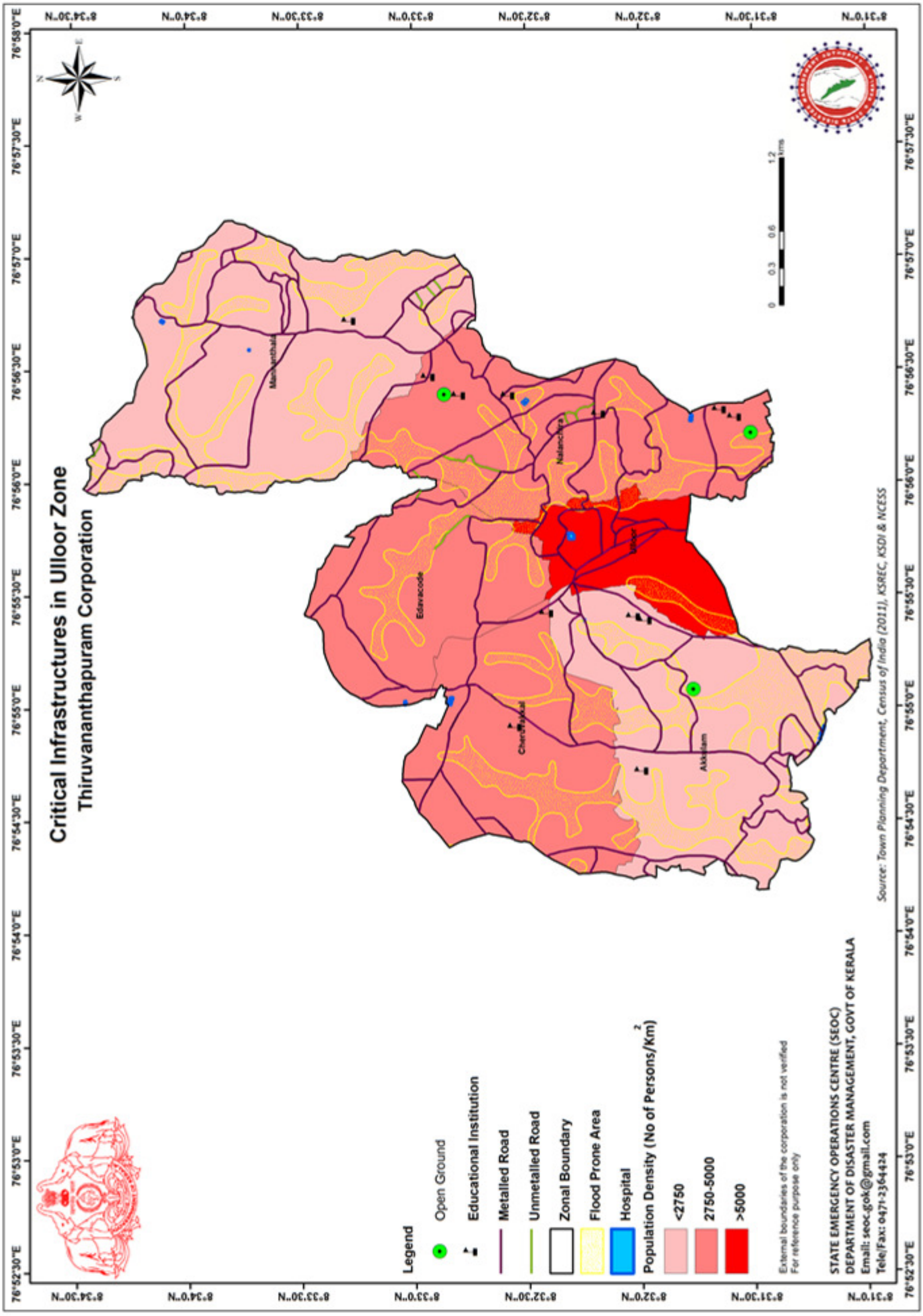


FIGURE 58: CRITICAL INFRASTRUCTURES IN ULLOOR ZONE

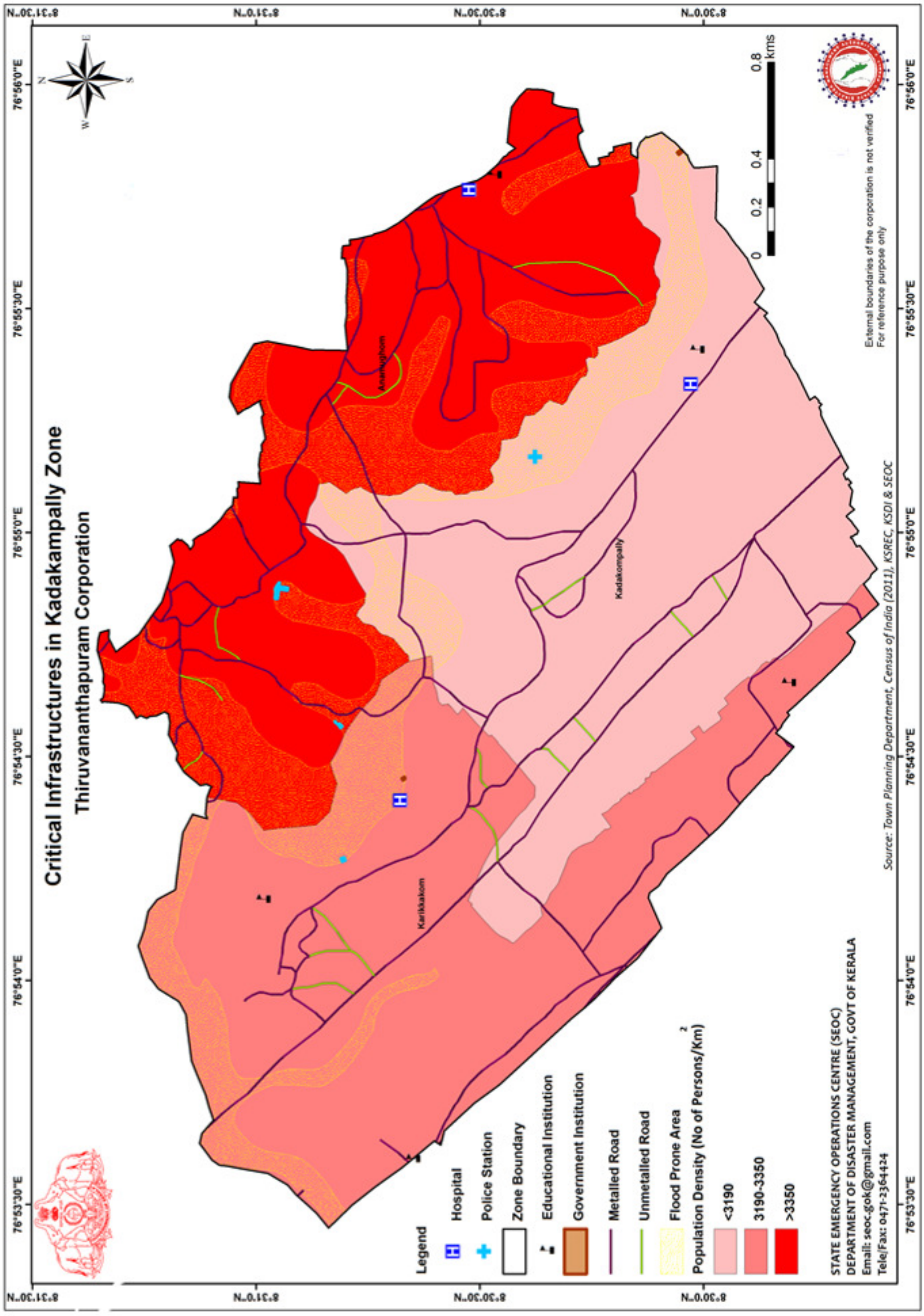


FIGURE 59: CRITICAL INFRASTRUCTURES IN KADAKAMPALLY ZONE

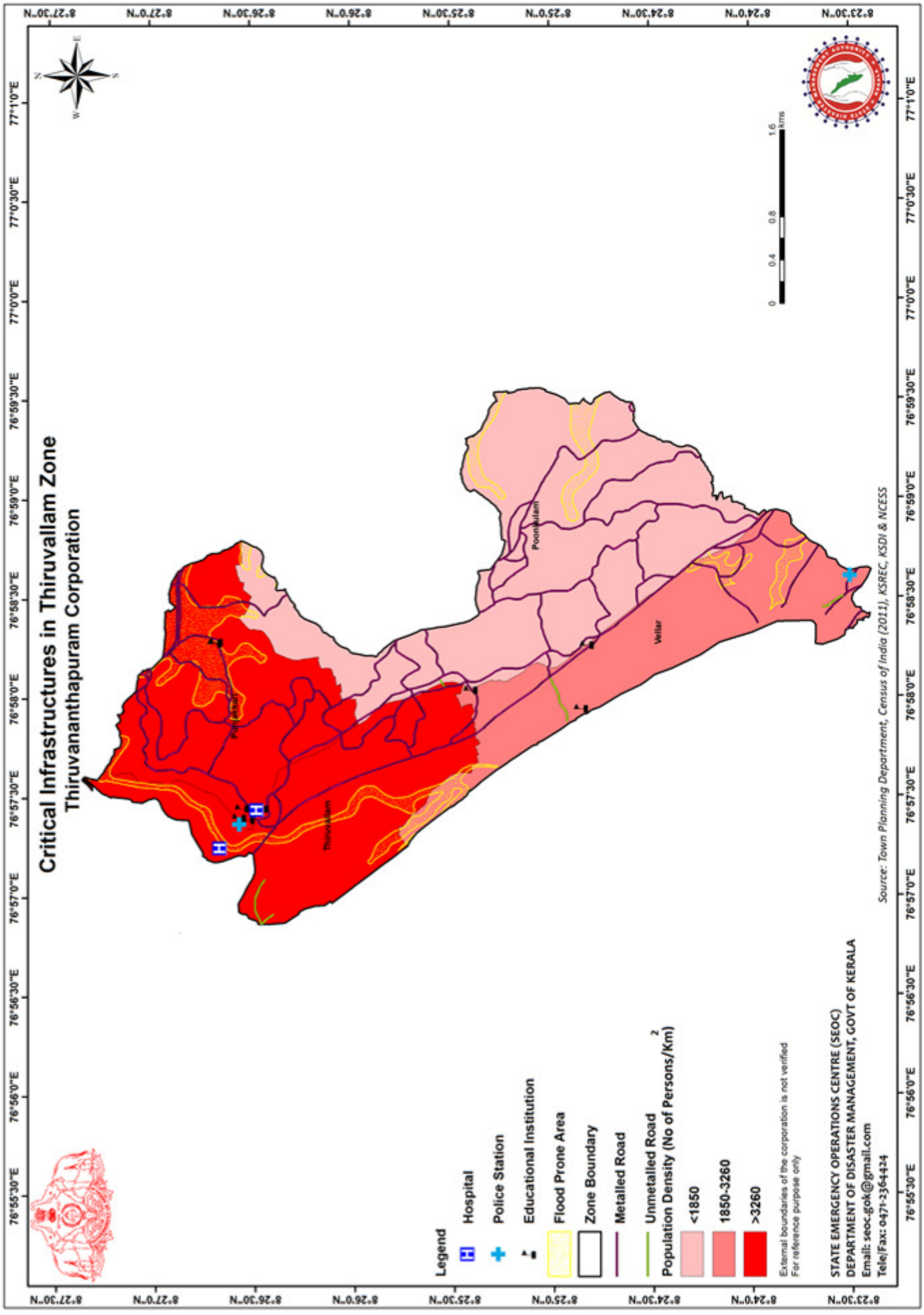


FIGURE 60: CRITICAL INFRASTRUCTURES IN THIRUVALLAM ZONE

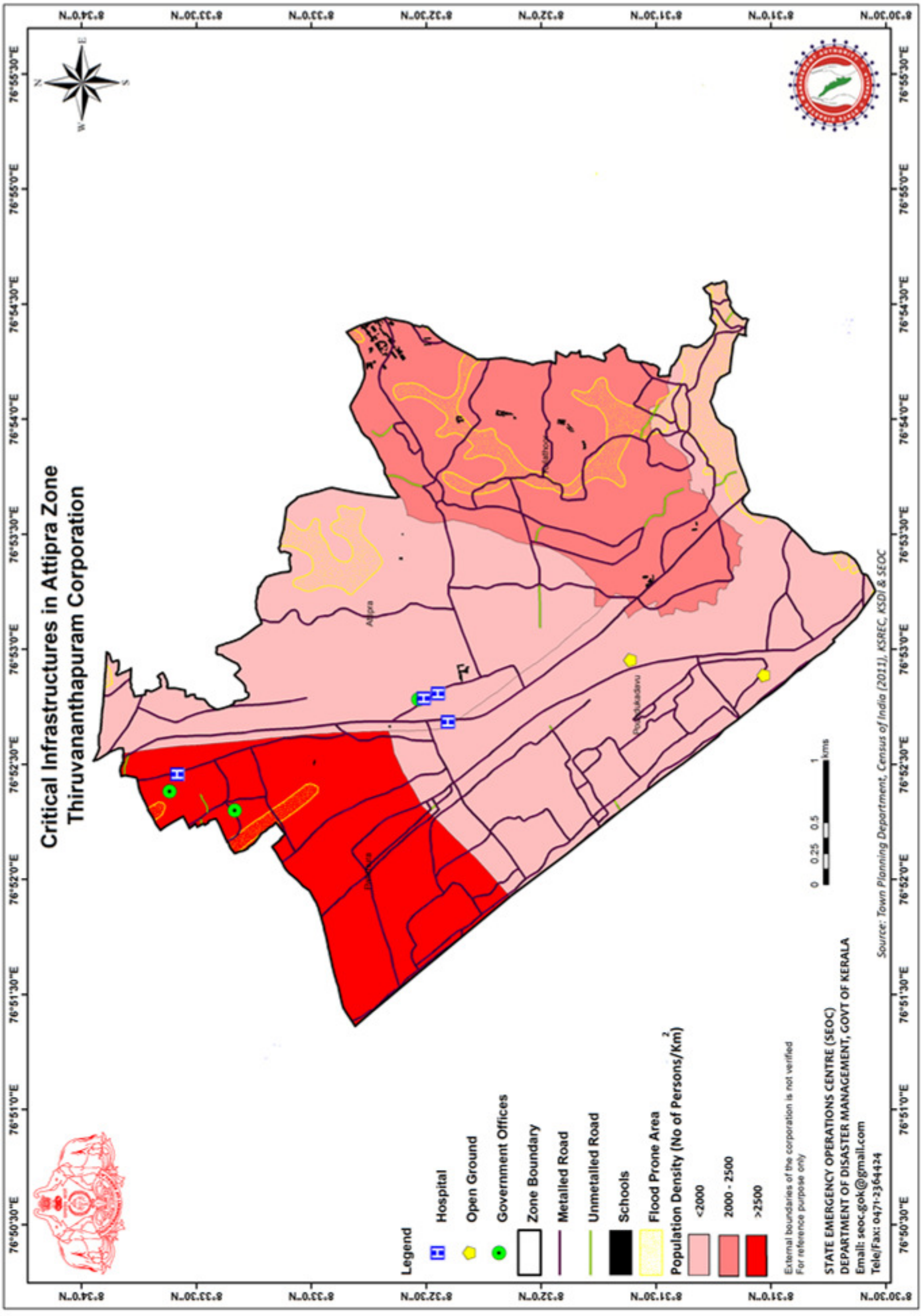


FIGURE 61: CRITICAL INFRASTRUCTURES IN ATTIPRA ZONE

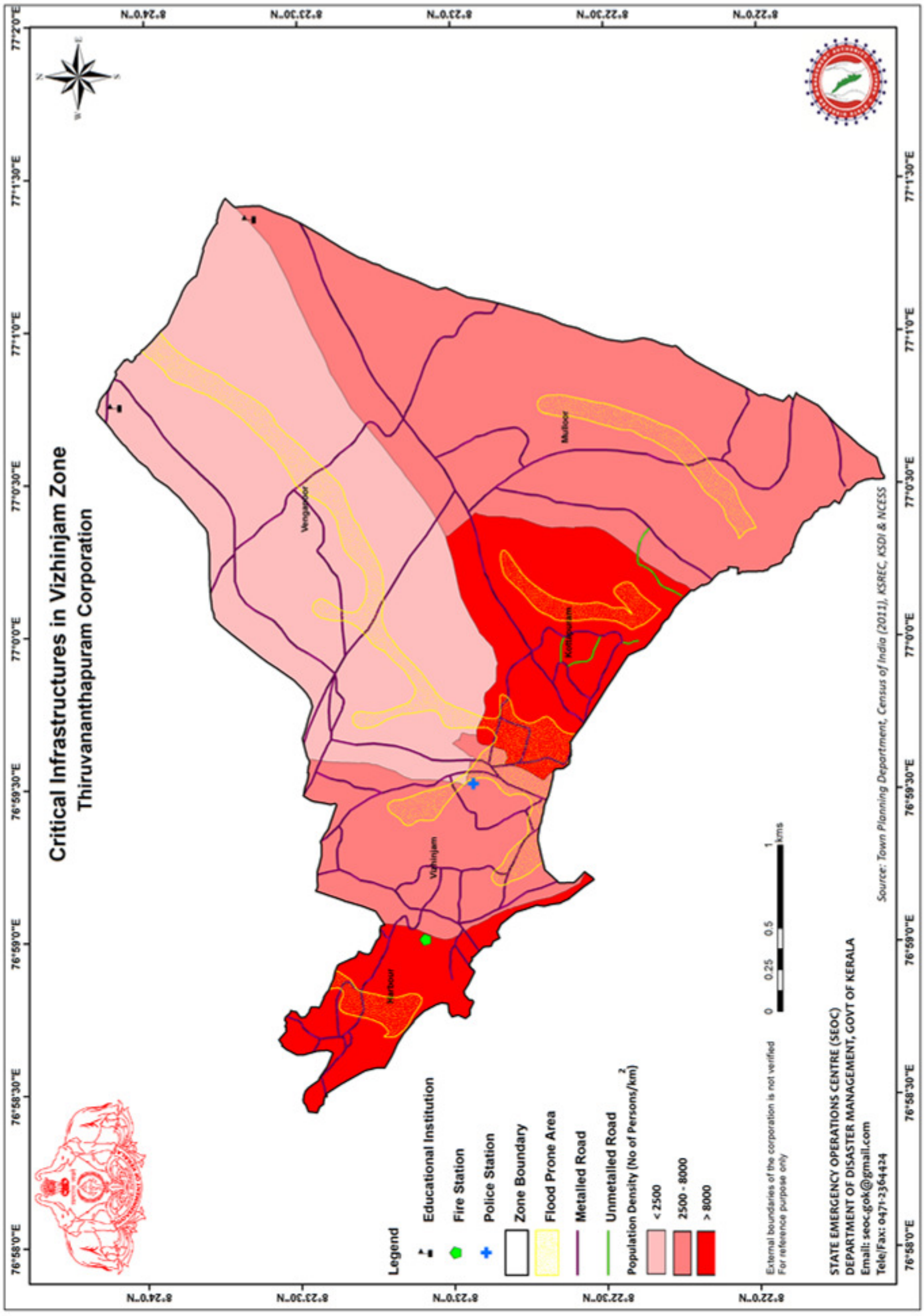


FIGURE 62: CRITICAL INFRASTRUCTURES IN VIZHINJAM ZONE

11. CONCLUSIONS

Thiruvananthapuram City is relatively less vulnerable to natural disasters and possible increase in the magnitude of disasters due to global climate change, presently. However, the situation will develop for worse if the recommendations above are ignored.

As a priority, the City should concentrate on disaster risk reduction and climate change adaptation. The expressions “disaster risk reduction” and “climate change adaptation” represent policy goals, one concerned with an ongoing problem (disasters) and the other with an emerging issue (climate change). While these concerns have different origins, they overlap a great deal through the common factor of weather and climate and the similar tools used to monitor, analyse and address adverse consequences. Climate change adaptation and disaster risk reduction share another common feature – they are not sectors in themselves but must be implemented through the policies of other sectors, in particular, those of agriculture, water resources, health, land use, environment, finance and planning. There are also linkages with other policies, most notably poverty eradication and planning for sustainable development, and education and science. It makes sense, therefore, to consider them and implement them in a systematic and integrated manner [17].

Therefore, climate change adaptation can be understood as: (a) adapting development to gradual changes in average temperature, sea level and precipitation; and (b) reducing and managing the risks associated with more frequent, severe and unpredictable extreme weather events [18].

Rapid urbanization of the periphery of Thiruvananthapuram and the changing landscape of the coastline threaten to affect the city’s long-term environmental sustainability by damaging the natural ecosystems, river networks and water retention wetlands. Short term measures are necessary to restore the city’s medium and long-term ecological balance.

The rural to urban conversion along the peripheries of the city will increase vulnerability to hydro-meteorological hazards if measures are not taken to: a) limit the spread of settlements to areas disconnected from public service networks, b) allocate sufficient resources to areas of rapid population growth and critical systems (i.e. the water supply system), c) ensure traditional activities and the sustainable livelihoods of communities displaced by new developments are able to participate in the city’s development opportunities. Urbanization presents an opportunity to be prepared to face natural disasters and to adapt to local manifestations of global climate change if well planned; haphazard urbanization will drastically increase the vulnerability.

Climate change hazards present challenges at different scales (the community, city and even the bio-region) and so actions are required to meet these challenges at these different scales. Therefore actions that are directed at reducing vulnerability at the city level (such as addressing systemic issues such as water shortages and drainage, and increasing the coordination and technical capacity of city agencies) should be implemented in conjunction with actions targeted at the community scale, at specific vulnerable areas, and for groups. Local communities should be empowered to address their infrastructure needs through local initiatives.

The city government can reduce climate change vulnerability by influencing the sensitivity and adaptive capacity of residents and communities of the city. This is possible through both physical actions (such as improving both natural and man-made systems and building climate proof infrastructure) as well as non-physical actions (such as improving the capacity and administration of public services, supporting local community organizations and improving the coordination of institutions).

In conclusion, three priorities are highlighted and reiterated for the City administration to implement urgently [19]:

Rejuvenation of water bodies: floods are being caused by the uneven distribution of rainfall, rapid urbanization, and the encroachment into and filling up of natural drainage channels and urban lakes due to the construction of buildings on high-value urban land. Thiruvananthapuram has reported its highest number of waterlogging/flooding situations during 2012–2015. Informal settlement colonies have emerged in the cities, and the lack of proper planning of these areas means they lack drainage systems, thus making them particularly vulnerable to flood hazards. By restoring wetlands and urban water bodies, the risk of flooding can be reduced as they act as natural moderators. Restoration may also help provide an alternative water source in a context of growing water scarcity.

Hazard risk-reduction strategies: the analysis of the City's coping capacity shows that there is a lack of hazard-reducing measures being applied by the city government. Existing inadequacies in the implementation of building by-laws and codes, development control regulations and land-use planning guidelines should be addressed and used to strengthen a compliance framework for addressing urban risk reduction issues. The coordination with the District Disaster Management Authority and neighbouring panchayaths in light of disaster preparedness, response, mitigation and climate change adaptation needs to be specifically addressed with urgency.

Addressing the needs of those living in informal settlements: the City has a considerable population living in informal settlements which lack access to basic services including storm drainage and sanitation. Ensuring that these services are supplied will have positive impacts on the lives of the residents, ensuring better health and living conditions, whilst also reducing the vulnerability of residents to future extreme climate events.

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ANNEXURE 1: POPULATION EXPOSED TO FLOODS IN THE WARDS OF THIRUVANANTHAPURAM

Sl. No	Ward Name	Ward population	Flood prone area (km^2)	Population exposed to floods
1	Akkulam	8856	1.27	3109
2	Ambalathara	8659	0.67	3368
3	Anamukham	9873	0.88	3305
4	Arannoor	10004	0.02	354
5	Attipra	8741	0.30	573
6	Attukal	8699	0.19	1335
7	Beemapally	8642	0.29	1046
8	Beemapally East	8790	0.00	21
9	Chackai	9754	0.13	544
10	Chala	8692	0.05	434
11	Chanthavila	9351	1.19	1750
12	Chempazhanthy	10184	0.96	2006
13	Chenllamangalam	10036	0.51	1464
14	Cheruvaikkal	9357	0.56	1957
15	Chettivilakam	10496	0.40	2323
16	Edavacode	8659	0.35	1364
17	Estate	9856	1.50	5381
18	Fort	8888	0.02	199
19	Harbour	8692	0.09	1186
20	Jagathy	9872	0.01	69
21	Kachani	9328	0.36	991
22	Kadakampally	9908	0.50	1581
23	Kalady	8659	2.02	8036
24	Kalippankulam	8708	0.02	378
25	Kamaleswaram	8675	0.05	347
26	Kanjirampara	10004	0.47	2865
27	Kannammoola	9955	0.31	2713
28	Karamana	8856	0.09	1048
29	Karikkakom	9766	0.50	1669
30	Kattayikonam	9229	1.05	1489
31	Kazhakuttom	10528	0.66	1430
32	Kesavadasapuram	9856	0.26	1753
33	Kinavoor	10545	0.27	1828
34	Kodunganoor	10348	0.30	1941
35	Kottapuram	10610	0.27	2130
36	Kowdiar	10069	0.34	1579
37	Kudappanakunnu	9451	0.28	1007
38	Kulathoor	8938	0.53	1102
39	Kunnukuzhi	9512	0.13	1077
40	Kuravankonam	9840	0.16	1327
41	Manacaud	8660	0.00	46
42	Manikyavilakam	8315	0.00	93
43	Mannanthala	9525	1.09	2316
44	Medical College	10528	0.38	2005
45	Melamcode	10354	2.38	7446
46	Mudavanmugal	9020	0.48	2706
47	Mulloor	9778	0.19	480
48	Muttada	10020	0.35	3354
49	Muttathara	10527	0.03	2374
50	Nalanchira	8777	0.85	2354
51	Nanthancode	9512	0.22	957
52	Nedumcaud	10528	0.50	4689
53	Nemom	9950	0.63	2827
54	Nettayam	10509	0.07	1464
55	Njandoorkonam	8501	1.01	1612
56	Palkulangara	9941	0.01	87
57	Pallithura	10044	0.11	329
58	Pangode	10200	0.51	3360
59	Pappanamcode	9872	1.43	6101
60	Pathirappally	8659	0.35	2018
61	Pattom	10545	0.23	1364
62	Peroorkada	9184	0.26	1098
63	Perumthanni	9290	0.08	752
64	Ponnumangalam	10168	1.10	2925

65	Poojappura	8644	0.37	1018
66	Poonkulam	10250	0.29	535
67	Poonthura	8659	0.02	439
68	Powdikonam	9004	0.99	2048
69	Poundkadavu	9676	0.54	967
70	PTP Nagar	10250	0.08	900
71	Punchakkari	10168	0.56	1902
72	Punnakkamugal	10168	0.56	2391
73	Puthenpally	8315	0.18	3142
74	Sanghumugham	10171	0.01	22
75	Sasthamangalam	10490	0.11	1579
76	Sreekandeswaram	9676	0.01	136
77	Sreekariyam	10455	1.24	2441
78	Sreevaraham	8659	0.06	703
79	Thirumala	9905	0.18	1220
80	Thiruvallam	10332	0.25	863
81	Thrikkannapuram	9856	0.52	2229
82	Thuruthumoola	10027	0.99	2953
83	Ulloor	9102	0.19	1496
84	Valiyasala	8774	0.01	175
85	Valiyavila	9348	0.37	2266
86	Vallakkadavu	8790	0.00	13
87	Vattiyoorkavu	9807	0.32	1814
88	Vazhottukonam	1037	0.68	232
89	Vazhuthacaud	9679	0.03	195
90	Vellar	9758	0.23	757
91	Venganoor	9696	0.46	1121
92	Vettucaud	10351	0.27	2650
93	Vizhinjam	8724	0.20	1434
	Total	**8,81,064**	**39.9**	**1,58,476**

ANNEXURE 2: POPULATION EXPOSED TO TSUNAMI AND STORM SURGE IN THE WARDS OF THIRUVANANTHAPURAM

Sl. No	Ward Name	Ward Population	Tsunami & Storm Surge prone area (km^2)	Population exposed to Tsunami & storm surge
1	Poonthura	8659	0.001098	27
2	Thiruvallam	10332	0.812604	2759
3	Vellar	9758	0.628847	2045
4	Vizhinjam	8724	0.011926	84
5	Kottapuram	10610	0.037035	297
6	Vettucaud	10351	0.210119	2069
7	Karikkakom	9766	0.126489	419
8	Poundukadavu	9676	0.283001	509
	Total	**77,876**	**2.1**	**8209**

ANNEXURE 3: POPULATION EXPOSED TO LIGHTING IN THE WARDS OF THIRUVANANTHAPURAM

Sl. No	Ward Name	Area (km^2)	Population
1	Chellamangalam	3.5	10036
2	Nanthancode	2.2	9512
3	Mannanthala	4.5	9525
4	Pathirappalli	1.5	8659
5	Kuriathy	0.6	9266
6	Thycaud	1.0	10399
7	Manikkavilakom	0.3	8315
8	Pappanamcode	2.3	9872
9	Pangode	1.6	10200
10	Vattiyoorkavu	1.7	9807
11	Vizhinjam	1.2	8724
12	Venganoor	3.9	9696
13	Mulloor	3.8	9778
14	Kuravankonam	1.2	9840
15	Palkulangara	0.7	9941
16	Akkulam	3.6	8856
17	Beemapally	2.4	8642
18	Kazhakoottom	4.9	10528
19	Pallithura	3.2	10044
	Total	**44.2**	**181640**

ANNEXURE 4: POPULATION EXPOSED TO LANDSLIDE IN THE WARDS OF THIRUVANANTHAPURAM

Sl. No	Ward Name	Ward Population	Landslideprone area (km^2)	Population exposed to landslide
1	Thirumala	9905	0.05	393

ANNEXURE 5: POPULATION EXPOSED TO INDUSTRIAL ACCIDENTS IN THE WARDS OF THIRUVANANTHAPURAM

Sl. No	Ward Name	Ward Population	Industrial accident prone area (km^2)	Population exposed to industrial accidents
1	Akkulam	8856	3.613865	8856
2	Anamukham	9873	2.61457	9873
3	Attipra	8741	4.568526	8741
4	Beemapally	8642	0.489322	1750
5	Chackai	9754	2.258043	9754
6	Chala	8692	0.095944	900
7	Chanthavila	9351	6.364741	9351
8	Chempazhanthy	10184	3.636478	7580
9	Chenllamangalam	10036	0.3459	994
10	Cheruvaikkal	9357	2.670192	9357
11	Edavacode	8659	2.066407	8111
12	Fort	8888	0.668605	8014
13	Kadakampally	9908	3.110744	9908
14	Kamaleswaram	8675	0.072027	489
15	Kannammoola	9955	1.150057	9955
16	Karikkakom	9766	2.947648	9766
17	Kattayikonam	9229	5.323141	7571
18	Kazhakuttom	10528	4.890854	10528
19	Kesavadasapuram	9856	1.326261	8905
20	Kinavoor	10545	0.184075	1266
21	Kulathoor	8938	4.301968	8938
22	Kunnukuzhi	9512	1.136798	9512
23	Kuravankonam	9840	0.00251	20
24	Manacaud	8660	0.012357	291
25	Medical College	10528	2.010303	10528
26	Muttada	10020	0.287069	2777
27	Muttathara	10527	0.140307	10527
28	Nalanchira	8777	2.39686	6675
29	Nanthancode	9512	1.401089	6102
30	Palayam	9761	0.59254	4401
31	Palkulangara	9941	0.652371	9941
32	Pallithura	10044	3.241645	10044
33	Pattom	10545	1.763963	10545
34	Perumthanni	9290	0.988693	9290
35	Pettah	10859	0.99629	10859
36	Poundkadavu	9676	5.375288	9676
37	Sanghumugham	10171	3.441289	10171
38	Sreekandeswaram	9676	0.463632	9676
39	Sreekariyam	10455	5.295599	10455
40	Sreevaraham	8659	0.691498	8050
41	Thampanoor	9184	0.557974	6416
42	Ulloor	9102	1.172683	9102
43	Valiyathura	8856	1.546991	8856
44	Vallakkadavu	8790	0.56054	8790
45	Vanchiyoor	9498	1.468787	9498
46	Vazhuthacaud	9679	0.005549	34
47	Vettucaud	10351	1.051036	10351
	Total	**4,50,346**	**90**	**3,53,191**

ANNEXURE 6: POPULATION EXPOSED TO ATTUKAL PONGALA RELATED ACCIDENTS IN THE WARDS OF THIRUVANANTHAPURAM

Sl. No	Ward Name	Ward Population	AttukalPongala prone area (km^2)	Population exposed to Attukal Pongala related accidents
1	Ambalathara	8659	0.01	64
2	Beemapalli	8642	0.33	1172
3	Beemapalli East	8790	0.05	772
4	Chakai	9754	1.45	6242
5	Chalai	8692	0.52	4916
6	Fort	8888	0.50	5989
7	Jagathy	9872	0.00	26
8	Kadakompally	9908	1.10	3516
9	Kamaleswaram	8675	0.08	557
10	Kannammoola	9955	0.09	801
11	Karikkakom	9766	0.14	456
12	Kesavadasapuram	9856	0.25	1711
13	Kowdiar	10069	0.03	149
14	Kunnukuzhy	9512	0.99	8252
15	Kuravankonam	9840	0.31	2560
16	Medical College	10528	0.25	1296
17	Muttathara	10527	0.14	10500
18	Nalanchira	8777	0.28	776
19	Nandancode	9512	0.83	3598
20	Palayam	9761	1.06	7863
21	Palkulangara	9941	0.63	9582
22	Pattom	10545	0.95	5692
23	Perumthanny	9290	0.90	8435
24	Pettah	10859	0.61	6641
25	Puthanpally	8315	0.04	719
26	Sangumukhom	10171	0.09	275
27	Sasthamangalam	10490	0.06	854
28	Sreekandeswaram	9676	0.46	9676
29	Sreevaraham	8659	0.14	1588
30	Thampanoor	9184	0.80	9184
31	Thycaud	10399	0.68	6986
32	Valiyasala	8774	0.13	1731
33	Vallakkadavu	8790	0.12	1948
34	Vanchiyoor	9498	1.38	8897
35	Vazhuthacaud	9679	0.52	3146
	Total	3,34,253	15.93	1,36,568

ANNEXURE 7: LIST OF PUBLIC BUILDINGS IN THIRUVANANTHAPURAM CITY WHICH WERE RAPIDLY SCREENED FOR PHYSICAL VULNERABILITY

Sl. No	Name	Ward	Vulnerability
1	Govt. U.P.School, Cheruvaikal	Akkulam	2
2	Ananthapuri Public School		1
3	Al-Arif Hospital	Ambalathara	1
4	National College of Arts & Science		2
5	KendriyaVidyalaya, Akkulam	Anamugom	1
6	Corparation Zonal Office Kazhakuttom	Attipra	2
7	Corparation Zonal Office Kulatoor		2
8	Kulathoor Govt. L.P.School		1
9	Village Office, Attipra		1
10	Our Own English Medium School		1
11	Govt. H.S.School, Kulathur		1
12	BSNL Telephone Exchange, Manacaud	Attukal	2
13	Govt. U.P.School, Beemapalli	Bheemapally	2
14	Govt. U. P School, Chakkai	Chakai	1
15	Govt. L.P.School, Kuriyathi	Chalai	2
16	Kerala Water Authority, South Subdivision		2
17	Govt. Girls High School, Chala		2
18	Govt. U.P.& Nursery School, Chala		2
19	Sainik School	Chanthavila	1
20	Ayurvedic Dispensary Amballor		2
21	Kinfra Film & Video Park		2
22	Chanthavila HS		2
23	St: Thomas Institute of Science & Technology		2
24	Madhavavilasom .H.S	Chempazanthy	2
25	Indian Institute of Science, Education and Research, Chavadimukku	Cheruvaikal	1
26	Loyola School		2
27	Bethlehem English Medium School		2
28	Mary Nilayam English Medium School		1
29	Govt. L.P School, Pongummood		2
30	Chinmaya Viswa Vidyalayam	Chettivilakom	3
31	Santhwana Hospital		1
32	Seventh day adventist UP school	Estate	2
33	Food Corporation India	Kazhakuttom	3
34	Christ Nagar College of Engineering	Fort	3
35	The Kerala Agro Industries Corporation Ltd, Office Of The District Soil Conservation		1
36	Fort Girls Mission High School		1
37	Fort High School		1
38	Technical Education Directrate		1
39	Vizhinjam Police Station	Harbour	1
40	Vizhinjam Light House		2
41	Vzhinjam 66 KV Sub station		1
42	Fire and Rescue service station		1
43	Inspection Banglow		2
44	Office of the Health Inspector, Jagathy	Jagathy	2
45	Govt. High School	Kalady	2
46	R K D, Sasthamangalam	Kanjirampara	2
47	Butterflies Kindergarten		3
48	Centre for Environment & Development		2
49	Sivodaya Hospital		2
50	Post Office		3
51	City Rationning Office		3
52	Govt.LPS Kanjirampara		3
53	Govt. ITI, Anchamala		3
54	BPM English Medium School	Kannamoola	2
55	Devayani Memorial Govt.L.P.School	Karikakom	1
56	Urban Wholesale Agricultural Market		1
57	All Saints College		1
58	Govt. H.S School, Karikkarom		2
59	VFPCK	Kazhakuttom	2
60	Krishi Bhavan		2
61	Al Ulsuman School		2

62	Nikunjam		1
63	Regional Vocational Training Institute		2
64	A J School		2
65	St Antony's LPS		3
66	AL Saj		1
67	CSI Hospital		1
68	A J Hospital		2
69	Police Station		2
70	Women's ITC		2
71	Jyothi Central School		3
72	Alan Feldman School		1
73	Karyavattom Govt.College		2
74	Kerala Highway Research Center		2
75	Kazhakuttam High School		2
76	Village Office		2
77	Sub-Registrar Office		2
78	Transport Office		2
79	Health Center, Pangappra		1
80	Govt.Teacher's Training Center, Karyavattom		2
81	INCPE		1
82	Electricity Office, Kazhakuttam		2
83	Pothencode, Block Office		2
84	Govt. Veterinary Hospital, Kazhakuttom		2
85	NSS H.S. School	Kesavadasapuram	1
86	St Mary's HSS Vizhinjam	Kottapuram	2
87	Trivandrum Golf Club	Kowdiar	2
88	Income Tax Commissioner Office		2
89	National Informatics Centre		2
90	Farm Information Bureau		2
91	PSNM Govt. HSS	Kudapanakunnu	2
92	Kerala State SC/ST Federation		3
93	Ayurdhara Panchakarma Centre		2
94	Kolath Hospital		2
95	Punarjani Hospital		2
96	Kerala State Veterinary Council		2
97	Chempaka Kindergarten		2
98	Trivandrum Corporation Zonal Office, Kudappanakunnu		3
99	PSNMG, GHSS Peroorkada		3
100	Concodia School		1
101	Civil Station		1
102	Trivandrum Zonal Office, Kudappanakunnu		2
103	Dooradarshan Kendram		2
104	Livestock Management and Training Centre		2
105	BNV Hospital		1
106	Karakulam Panchayat Ofiice		2
107	Karakulam HS		2
108	Karakulam LPS		2
109	Veterinary Hospital		2
110	KWA Pumb House		2
111	Keltron		2
112	School of The Good Shepard	Kulathoor	1
113	Dr.Ambedkar Memorial Residential School		2
114	College of Engineering, Thiruvananthapuram		2
115	The Holy Trinity English Medium H.S.School		1
116	Govt. U.P.School, Kuzhivila		1
117	Mar Gregorious Memorial Central Public School		1
118	Dioscores College of Pharmacy		1
119	Model Hostel Boy's Vellayambalam	Kuravankonam	3
120	Air India office, Vellayambalam		1
121	Nirmala Bhavan		3
122	Salvation Army School		2
123	Income tax		3
124	VIT Kuravankonam		1
125	Soil Conservation Department		3
126	Nimala Bhavan Higher Secondary School		2

127	Kerala State Commission for Backward Class		2
128	Kerala Financial Corp		1
129	The Zonza Hospital	Manacaud	1
130	SUT Hospital		1
131	Oxford School		3
132	KSRTC Department		2
133	National Hospital		2
134	District Jail, Trivandrum		2
135	Post office		3
136	Corporation Office		3
137	KBM Hospital		3
138	Post Office		1
139	Chinmaya Vidhyalam School		1
140	Medical College	Medical College	2
141	Central Diagonstical Laboratary		2
142	Sree ChithiraThirunal Institute of Imaging		2
143	Avittom Thirunal Hospital		2
144	Directorate of Medical Education		2
145	Dental College		1
146	Kerala Irrigation Infrastructure Development Corporation		1
147	Govt. U.P.School, Ulloor		1
148	GVHSS UP School	Ulloor	2
149	St. Mary's H.S. School, Pattom	Nalanchira	1
150	Bureau of Indian Standards, BSNL		1
151	Directorate of Mining & Geology		1
152	Directorate of Survey	Nanthancode	1
153	Govt.Model Boy's HSS Vazhuthacadu		2
154	Kalabhavan		2
155	IHRD,Vazhuthacaud		2
156	Devasom Board		3
157	Kerala Sate Transport Project office		3
158	Christ Nagar HS		2
159	Christ Nagar HSS		2
160	Kerala Road Fund Board		2
161	Sandeepini School		1
162	Keltron, CDAC		2
163	Devasom Board Headquarters		2
164	Central Bureau of Investigation		3
165	Employees Privident Fund Organisation, Ministry of Labour Govt of India		1
166	Vidyuthi Bhavan		1
167	Kerala Womens Commission		2
168	Village Office	Nemom	3
169	Shree Vidhyaraja Homoeopathic Medical College		2
170	Karakamandapam Govt. Hospital		2
171	Govt: LPS		2
172	Govt. HSS Ayiroorpara	Njandoorkonam	2
173	Public Sector Re-Structuring Internal Audit Board	Palayam	2
174	Jubilee Mission Hospital, Palayam		1
175	RBI		3
176	University Hostel for Women		1
177	KERAFED		2
178	KWA		2
179	Tourism Information Centre		1
180	PWD		3
181	Sate Land Bank		3
182	KFC		2
183	Fine Arts College		3
184	State Library		2
185	Institute of Engineers		3
186	Panchayat Assosiation hall		3
187	University College, Trivandrum		1
188	MLA Quarters		1
189	Kerala Police Housing & Construction		1
190	Public Library		1
191	Post & Telecom Audit Office		2

192	Corporation Office, Trivandrum		1
193	Office of Electrical Inspector		1
194	Kerala Water Authority		2
195	Keltron		1
196	NSS Public School, Perumthanni, NSS H.S. School, NSS Art's College For Women	Palkulangara	1
197	IITM K	Pallithura	1
198	KINFRA Apard Park		1
199	Marian Eng. College		1
200	Marian Teacher's Institute		2
201	St' Xavier's College		2
202	Jyothivilayam H.S.S		2
203	St.Jude H .S		3
204	Pallithura H.S		3
205	Food Corporation of India		1
206	Govt. L.P.School, Attinkuzhi		1
207	Food Corporation Of India		1
208	Veterinary Hospital	Pangode	2
209	NSS College	Papanamcode	3
210	Kerala Police HQ	Pathirapally	1
211	Peroorkada Panchayat Office		2
212	P A Aziz College of engineering and tchnology		2
213	District Panchayath Office	Pattom	1
214	Kendriya Vidyalaya, Pattom		1
215	Kerala PSC		1
216	Pattom Village Office		1
217	Govt. Model Girls H.S.School, Pattom		1
218	Institute of Paramedical Science		1
219	Kerala Low Acadamy	Peroorkada	2
220	J.J Hospital Peroorkada		2
221	Amardeep Eye Hospital		1
222	KSRTC Peroorkada		1
223	ESI Hospital		1
224	Oolanpara Hospital		2
225	Peroorkada K.S.R.T.C. Bus Depot.		3
226	Village Office Kudappanakunnu		3
227	Kerala Water Authority		3
228	Post Office Peroorkada		2
229	Peroorkada Police Station		2
230	Trivandrum Peroorkada District Panchayat Hospital		2
231	Indira Gandhi National Open University		3
232	Health Inspector Diploma Course (Government Of Kerala)		3
233	All India Institute of Local Self Govt.(University Of Kerala)		3
234	ESI Dispensary Peroorkada		3
235	G.H.S.L.P.S. Peroorkada		2
236	GHSS Girls Peroorkada		1
237	BSNL Customer Service Centre, Ambalamukku		2
238	Lecode Chempaka	Perumthanni	2
239	Govt. U.P. School, Enchakkal		1
240	Kerala Poultry Development Corporation	Pettah	1
241	Govt. Girls Vocational Higher Secondary School, L.P. School, Pettah		2
242	Govt. Boys High School, Pettah		2
243	St. Anne's U.P School		1
244	Vectory Girl''s& Boy's HS	Ponnumangalm	3
245	Vectory VHSE		3
246	Spinning Mill		3
247	Govt UPS		3
248	Govt Health Center		2
249	Govt LPS Pangode	Poojapura	1
250	Nath Memorial School		1
251	Hindu Mahila Mandiram GHSS		1
252	Nrithalaya Hospital		1
253	Police Station, Pujappura		2
254	HLL Lifecare Ltd, Pujappura		2
255	SBT , Pujappura		2
256	Panchakarma Hospital		2

257	BSNL		2
258	SCERT and Pareekshabhavan		2
259	LBS Centre for Science and Technology		2
260	Central Prison		2
261	Social Justice Board and Juvenile home		2
262	SamsthanaVigalanga Kshema Corporation		2
263	Panchakarma hospital		2
264	Govt UPS, Pujappura		2
265	Vigilance and Anti Corruption Bureau		2
266	KSEB Pujappura		3
267	Rajiv Gandhi Centre for Biotechnology		1
268	Village Office Uliythara	Poudikonam	1
269	BNV College of teacher education	Punchakkari	2
270	ACE College of engineering		1
271	MG College of Engineering		1
272	BNV School		1
273	C-Dit Campus		1
274	IIMR	Puthanpalli	3
275	St. Marys H.S. School	Sangumukham	1
276	Private L. P School, Shangumukham		2
277	V.O,SAS	Sasthamangalam	2
278	Sree Ramakrishna Hospital		1
279	Sree Ramakrishna Vidyamandir,Maruthumkuzhi		1
280	Govt. Sasthamangalam		2
281	Kerala Chalachitra Acadammy		2
282	Sri Mookambika School Sasthamangalam		3
283	Govt. LPS Sasthamangalam		2
284	Kerala State Beverages Corporation Office		3
285	Sri Mookambika Public School		2
286	Kerala State Chalachitra Academy		2
287	Post Office Sasthamangalam		2
288	Haree Sree School		2
289	Kerala State Social Welfare Board		2
290	Health Inspector Office		2
291	Pettah Village Office	Sreekandeswaram	1
292	Govt. U.P.Girl School, Fort		1
293	Passport Office, SBT		2
294	Campus	Sreekariyam	1
295	University Teacher's Hostel		2
296	Information Kerala Mission		2
297	Govt. High School, Sreekaryam		2
298	Mar Gregorious Memorial School		2
299	Govt: UP School Karyavattom		2
300	Seventh Day Adventist Secondary school		1
301	Govt. College of Teacher Education, Thycaud	Thampanoor	1
302	SMV H.S School		1
303	NABARD		2
304	AG'S Office Trivandrum		1
305	K.V Pangode	Thirumala	1
306	Thirumala Village Office		1
307	AMHSS Thirumala		1
308	SBT Thirumala		2
309	Akshaya Centre		1
310	Sreekrishna Hospital		1
311	Post Office, Thirumala		1
312	Vijayamohini Mill		1
313	Viswaprakash Central School		2
314	Govt. LPS Thiruvallam	Thiruvallam	3
315	Karibhagam Coir Vyavasaya Sahakarana Sangam		2
316	Punarjani Hospital	Thuruthumoola	2
317	KSEB Peroorkada		2
318	Govt.Vocational HSS		2
319	Central Polytechnic College Vattiyoorkavu		2
320	Swathi Thirunal Music College	Thycaud	2
321	Govt. Model boy's School Thycaud		2

322	Directorate Public Instruction		2
323	Sisuvihar Centre,Vazhuthacaudu		2
324	Jagathy Postoffice		3
325	Kerala State Cooperative Consumer Fed	Ulloor	1
326	Govt. Model H.S. School For Boys Chalai, Office of the Deputy Director For Education	Valiyasala	2
327	Govt. Dispensary		3
328	Govt. Model H.S. School For Boys Chalai, Office of the Deputy Director For Education		2
329	Trivandrum Corporation Malstya Bhavan, Valiyathuraya	Valiyathura	3
330	Govt. U.P.School, Valiyathura		3
331	Vallakkadavu L.P. School		1
332	Food Corporation Of India		1
333	Govt. U.P.School, Valiyathura		1
334	St. Antony's H.S.School		1
335	Govt. V.H.S School, Valiyathura		2
336	Ponnara Sreedhar Memorial U.P. School	Vallakadavu	1
337	Magistrate Court	Vanchiyoor	2
338	St. Joseph H.S. School		1
339	Govt. High School, Vanchiyoor		1
340	Sree Sankaracharya University of Sanskrit		2
341	Kerala State IT Mission		2
342	Urban Resource Center		2
343	District Court		1
344	Fast Track Court		1
345	SN Public School Venpalavattom	Vattiyoorkavu	2
346	KSEB vattiyoorkavu		3
347	Govt. LPS Vattiyoorkavu		3
348	Primary Health Center		2
349	Police Station		2
350	Village Office		2
351	Kerala State FC		2
352	TVM corparation ward committee		2
353	Mother - Baby Care Centre		2
354	Health Inspector Office		2
355	Shirdhi Sai Day Care & Nursery School		3
356	Post Office Vattiyoorkavu		3
357	Cotton Hill GHSS	Vazhuthucaud	2
358	Cotton Hill GLPS		2
359	Forest HQ		2
360	Forest Office		2
361	Women's College		2
362	Kerala Social Welfare Board		3
363	Govt. Arts College		3
364	Carmel GHSS		2
365	Sarvavikjanakosha Institute		2
366	Ulloor Smarakam		2
367	TRIDA		2
368	Family Welfare Centre	Vellar	2
369	C-DAC	Vellayambalam	2
370	Agricultural University	Venganoor	3
371	Vizhinjam SVLPS		2
372	Santhinikethen school		3
373	KSRTC, Vizhinjam	Vizhinjam	2
374	Coastal Police Station, Vizhinjam		1
375	Govt. HALPS		2
376	Indian ost Guard		1
377	Vhinjam Post Office		3
378	Govt: Model HSS Kalliyoor		2

1: Least Vulnerable

2: Moderately Vulnerable

3: Highly Vulnerable

ANNEXURE 8: LIVELIHOOD WISE POPULATION OF THIRUVANANTHAPURAM CITY

Sl. No	Ward	Main Cultivator Population	Main Agricultural Labourers Population	Main Household Industries Population	Main Other Workers Population	Marginal Worker Population
1	Sanghumugham	2	5	0	1318	195
2	Puthenpally	1	4	4	1088	80
3	Valiyavila	6	13	11	1579	201
4	Pazhanchira	3	2	11	1429	140
5	Secretariate	4	42	14	1798	202
6	Thampanoor	3	26	76	1874	56
7	Chala	2	8	91	1677	197
8	Akkulam	3	11	11	2134	157
9	Palayam	10	21	6	2123	139
10	Kowdiar	7	8	17	1776	333
11	Vettukadu	4	5	28	1133	1247
12	Fort	4	5	41	1717	542
13	Muttada	5	5	16	1913	376
14	Ambalathara	11	22	30	1835	366
15	Thiruvallam	16	110	38	2124	393
16	Palkulangara	6	11	12	2092	503
17	Nanthancode	7	5	27	2356	154
18	Sasthamangalam	5	9	30	2397	154
19	Sreevaraham	11	14	37	1963	654
20	Vazhuthacaud	5	16	37	2338	244
21	Kesavadasapuram	7	15	34	2377	106
22	Manacaud	4	4	28	1983	556
23	Kulathoor	12	61	29	1980	286
24	Pangode	8	5	20	2442	354
25	P T P Nagar	7	18	15	2400	227
26	Vellar	7	16	263	1650	1235
27	Kunnukuzhy	3	22	21	2583	216
28	Poonthura	1	6	5	2669	154
29	Beemapally East	3	14	12	1902	242
30	Pettah	5	38	49	2316	414
31	Thycaud	7	10	54	2482	402
32	Medical College	4	7	36	2654	507
33	Kalippankulam	9	18	34	2098	248
34	Jagathy	13	14	49	2242	531
35	Kuriathy	43	67	52	2542	240
36	Poundkadavu	6	9	11	2663	301
37	Attukal	17	102	40	2308	511
38	Pongummoodu	8	37	15	2814	256
39	Sreekanteswaram	1	41	104	2566	113
40	Vanchiyur	7	15	7	2765	396
41	Mannammoola	7	6	20	2918	228
42	Ponnumangalam	15	41	24	2269	313
43	Mannanthala	6	37	27	2562	449
44	Arannur	2	12	23	2655	420
45	Attipra	12	83	28	2747	427
46	Pallithura	2	28	167	2840	279
47	Chenkalloor	2	15	133	3711	266
48	Manikyavilakam	6	24	18	2334	587
49	Peroorkada	9	13	36	3056	235
50	Kannammoola	17	22	56	3041	308
51	Valiyasala	27	38	75	2798	479
52	Chakka	6	79	66	2542	340
53	Edavakkod	19	18	50	2735	354
54	Karikkakom	2	9	25	2500	656
55	Goureesapattom	7	8	13	3043	332
56	Pachalloor	9	52	78	2627	736
57	Estate	9	26	27	2530	576
58	Pappanamcode	8	23	40	3054	326
59	Nalanchira	73	88	56	2759	551
60	Nemom	16	90	86	2818	287
61	Poonkulam	29	83	24	3028	583
62	Kamaleswaram	21	83	112	2574	309

63	Punchakari	4	84	16	2664	806
64	Pattom	1	34	53	3329	259
65	Melamcode	14	32	34	2651	877
66	Anamugham	12	126	42	3152	415
67	Thrikkannapuram	11	58	38	3138	449
68	Kanjirampara	10	20	31	3295	449
69	Karamana	7	14	68	3203	340
70	Kuravankonam	5	9	76	3337	253
71	Vattiyoorkavu	12	14	35	2657	671
72	Perunthanny	9	37	36	3330	343
73	Kalady	37	48	75	3387	336
74	Punnakkamugal	7	48	33	3232	480
75	Mudavanmugal	5	44	32	3732	346
76	Kadakampally	12	40	152	3330	366
77	Ulloor	5	5	26	3356	588
78	Poojappura	12	26	45	3902	314
79	Valiyathura	6	112	23	3616	440
80	Vallakkadavu	4	11	32	2719	858
81	Cheruvaikal	6	29	42	2618	1442
82	Nedumgadu	10	21	106	4020	625
83	Thirumala	13	48	38	3769	927
84	Kannanthura	8	98	30	3500	1096
85	Muttathara	5	30	89	4124	621
86	Beemapally	3	11	24	4240	975

ANNEXURE 9: COMMERCIAL CLUSTERS AND MARKETS IN THIRUVANANTHAPURAM CITY

Sl. No	Place Name	Type
1	Chalai	Main Market
2	Manacaud	Sub market
3	Palayam	Sub market
4	Vizhinjam	Sub market
5	World market	Sub market
6	Kazhakuttom	Main Zonal Market
7	Pangod	Main Zonal Market
8	Peroorkada	Main Zonal Market
9	Pettah	Main Zonal Market
10	Poojapura	Main Zonal Market
11	Thirumala	Main Zonal Market
12	Vattiyoorkavu	Main Zonal Market
13	Aniyoor	Local Market
14	Balanagar	Local Market
15	Chandavila	Local Market
16	Chengottukonam	Local Market
17	Cheruvaykkal	Local Market
18	Kalippankulam-Kuthukalinmoodu	Local Market
19	Kanjirampara	Local Market
20	Karamana	Local Market
21	Karaykkamandappam	Local Market
22	Illipod	Local Market
23	Kizhamkkumkara	Local Market
24	Koliyoor	Local Market
25	Kulathoor	Local Market
26	Kumarichantha	Local Market
27	Kunnupuzha	Local Market
28	Kuravankonam	Local Market
29	Mananthala	Local Market
30	Manvila	Local Market
31	Maruthankuzhy	Local Market
32	Mudavanmugal	Local Market
33	N S Depot Market	Local Market
34	Nalanchira	Local Market
35	NandancodeJn	Local Market
36	Near Cheruvaykkal LPS	Local Market
37	Nettayam	Local Market
38	Oolamkuzhy-nadakavu	Local Market
39	Pachalloor	Local Market
40	Panathura	Local Market
41	Pappanamcode	Local Market
42	Parappachanvila	Local Market
43	Paundukadavu	Local Market
44	Perunneli	Local Market
45	Poonthura	Local Market
46	Poundikonam	Local Market
47	Prasanth Nagar	Local Market
48	Pulayanarkotta	Local Market
49	Puthen road	Local Market
50	SreeChitranagar	Local Market
51	Sreekariyam	Local Market
52	Sreevaraham	Local Market
53	Therakam	Local Market
54	Thycaud	Local Market
55	Ulloor	Local Market
56	Valiyathura	Local Market
57	Vettucaud	Local Market
58	Vetturoad	Local Market
59	Illipod	Road side Market
60	Kaithamukku	Road side Market
61	Kanjirampara	Road side Market
62	Secretariate	Road side Market

ANNEXURE 10: CONSOLIDATED STATISTICS OF SLUMS IN THIRUVANANTHAPURAM CITY

Slum Conditions in Trivandrum Corporation	
Illiterate Population	20%
SC Population	29%
No Household	834
Total Population (numbers)	3320
Total Working Population	37%
Total Marginal Working Population	11%
Total Non-Working Population	62%

ANNEXURE 11: WARD-WISE PER CAPITA ALLOTMENT OF SDRF/NDRF DURING THE PERIOD 2008-2010, EXTRACTED FROM VILLAGE WISE AGGREGATE USING GEOGRAPHIC INFORMATION SYSTEMS OVERALY OPERATION

Sl. No	Ward Name	Per-capita	Village
1	Attipra	1	Attipra
2	Kulathoor	1	Attipra
3	Pallithura	1	Attipra
4	Poundukadavu	1	Attipra
5	Akkulam	2	Cheruvaikal
6	Cheruvakkal	2	Cheruvaikal
7	Medical College	2	Cheruvaikal
8	Anamughom	1	Kadakompally
9	Kadakompally	1	Kadakompally
10	Karikkakom	1	Kadakompally
11	Vettucaud	1	Kadakompally
12	Kesavadasapuram	1	Kowdiar
13	Kuravankonam	1	Kowdiar
14	Muttada	1	Kowdiar
15	Nandancode	1	Kowdiar
16	Ambalathara	3	Manacaud
17	Attukal	3	Manacaud
18	Chalai	1	Manacaud
19	Kalady	3	Manacaud
20	Kalippankulam	3	Manacaud
21	Kuriathy	3	Manacaud
22	Manacaud	1	Manacaud
23	Nedumcaud	3	Manacaud
24	Beemapalli	1	Muttathara
25	Beemapalli East	1	Muttathara
26	Kamaleswaram	1	Muttathara
27	Manikkavilakom	1	Muttathara
28	Muttathara	1	Muttathara
29	Poonthura	1	Muttathara
30	Puthanpally	1	Muttathara
31	Sreevaraham	1	Muttathara
32	Vallakkadavu	1	Muttathara
33	Estate	2	Nemom
34	Melamcode	2	Nemom
35	Nemom	2	Nemom
36	Pappanamcode	2	Nemom
37	Ponnumagalam	2	Nemom
38	Pattom	1	Pattom
39	Kanjirampara	2	Peroorkada
40	Kowdiar	2	Peroorkada
41	Peroorkada	2	Peroorkada
42	Chakai	2	Pettah
43	Perumthanny	2	Pettah
44	Sangumukhom	1	Pettah
45	Valiyathura	2	Pettah
46	Pangode	1	Sasthamangalam
47	Poojappura	1	Sasthamangalam
48	Sasthamangalam	1	Sasthamangalam
49	Vazhuthacaud	1	Sasthamangalam
50	Karamana	2	Thirumala
51	Mudavanmugal	2	Thirumala
52	Punnakkamugal	2	Thirumala
53	Thirumala	2	Thirumala
54	Thrikkanapuram	2	Thirumala
55	Poonkulam	1	Thiruvallam
56	Punjakkari	1	Thiruvallam
57	Thiruvallam	1	Thiruvallam
58	Vellar	1	Thiruvallam
59	Arannoor	1	Thycaud
60	Jagathy	1	Thycaud
61	Thycaud	1	Thycaud
62	Valiyasala	1	Thycaud

63	Edavacode	1	Ulloor
64	Mannanthala	1	Ulloor
65	Nalanchira	1	Ulloor
66	Ulloor	1	Ulloor
67	Fort	1	Vanchiyoor
68	Kannammoola	1	Vanchiyoor
69	Kunnukuzhy	1	Vanchiyoor
70	Palayam	1	Vanchiyoor
71	Palkulangara	2	Vanchiyoor
72	Pettah	1	Vanchiyoor
73	Sreekandeswaram	1	Vanchiyoor
74	Thampanoor	1	Vanchiyoor
75	Vanchiyoor	1	Vanchiyoor
76	PTP Nagar	2	Vattiyoorkavau
77	Valiyavila	2	Vattiyoorkavau
78	Vattiyoorkavu	2	Vattiyoorkavau

Government of Kerala

Department of Disaster Management

Kerala State Disaster Management Authority (KSDMA)

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