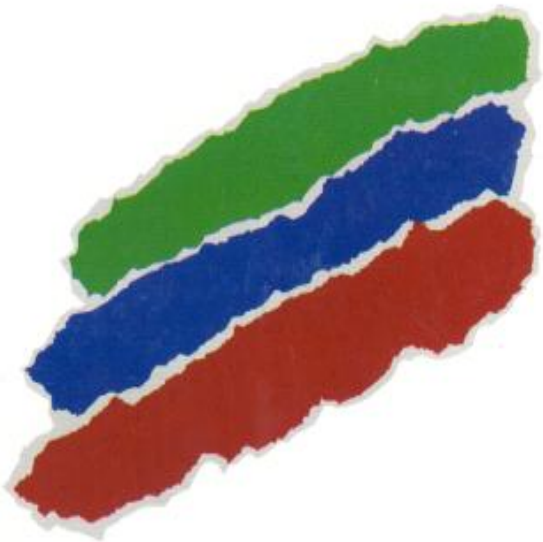
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Study of Land Reclamation and its Influence on Mumbai's Coastline and Implications for Proposed Projects

Sponsored by

Mumbai Transformation Support Unit (MTSU),
All India Institute of Local Self Government (AIILSG)



Final report

Part 2 of 4

January 2016

सीएसआईआर – राष्ट्रीय समुद्र विज्ञान संस्थान
CSIR-NATIONAL INSTITUTE OF OCEANOGRAPHY
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http:// www.nio.org

4.4 Results

4.4.1 Shoreline change 1879-1954

Highest erosion of 1137 m and the highest accretion of 1291 m are observed on the mouth of Mahul creek. The highest accretion is occured because of the construction of the port. Higher level of accretion is found from Juhu till Mahim bay, the port region and colaba. Erosion is mainly focused along Thane creek.

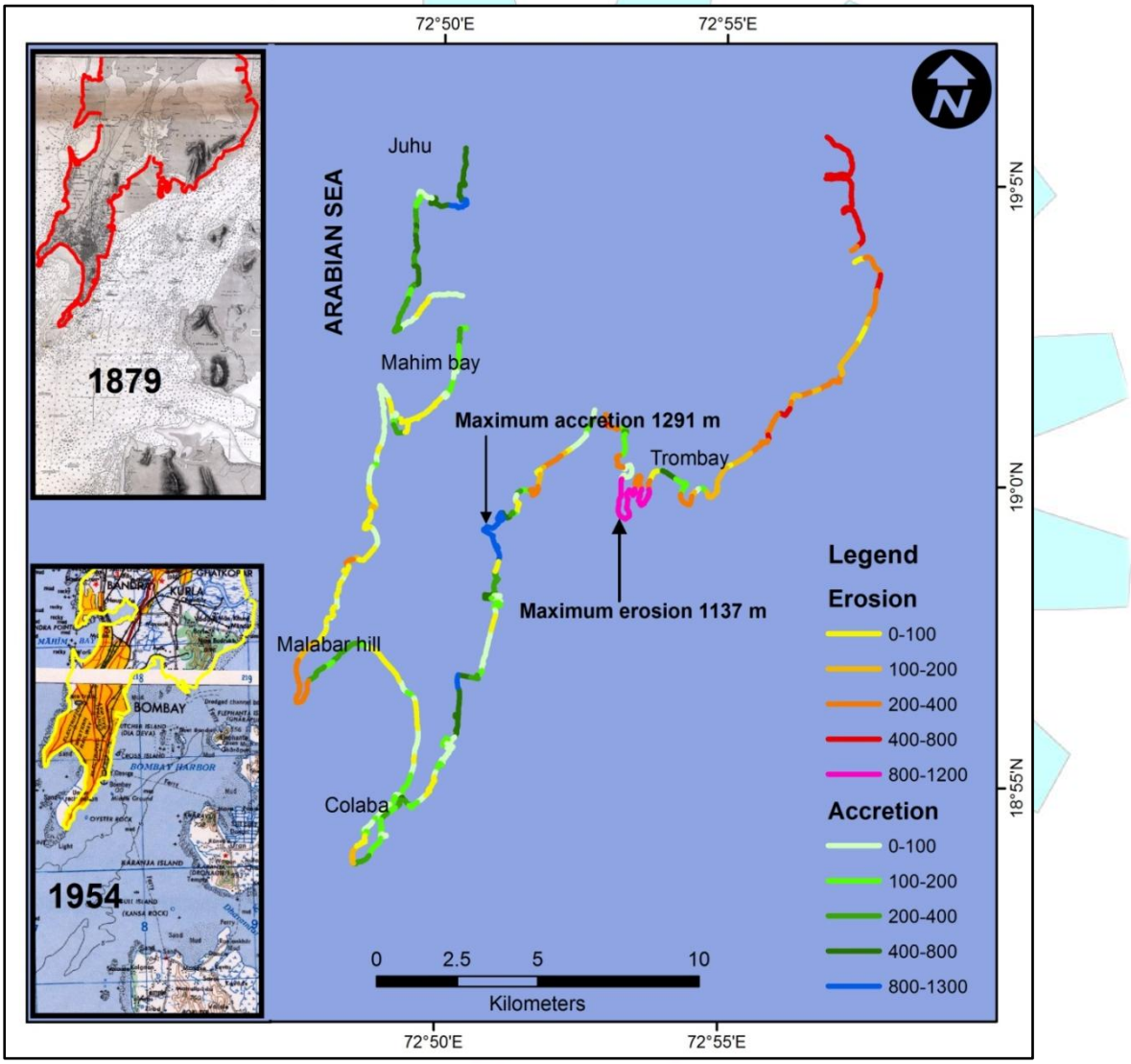


Fig. 4.6. Shoreline change from 1879 to 1954

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4.4.2 Shoreline change 1926-1954

Accretion is observed mainly along the open sea side and erosion found mainly through the Vasai creek. The highest accretion of 336 m as well as highest erosion of 293 m is observed in almost same region near Mira bhayandar.

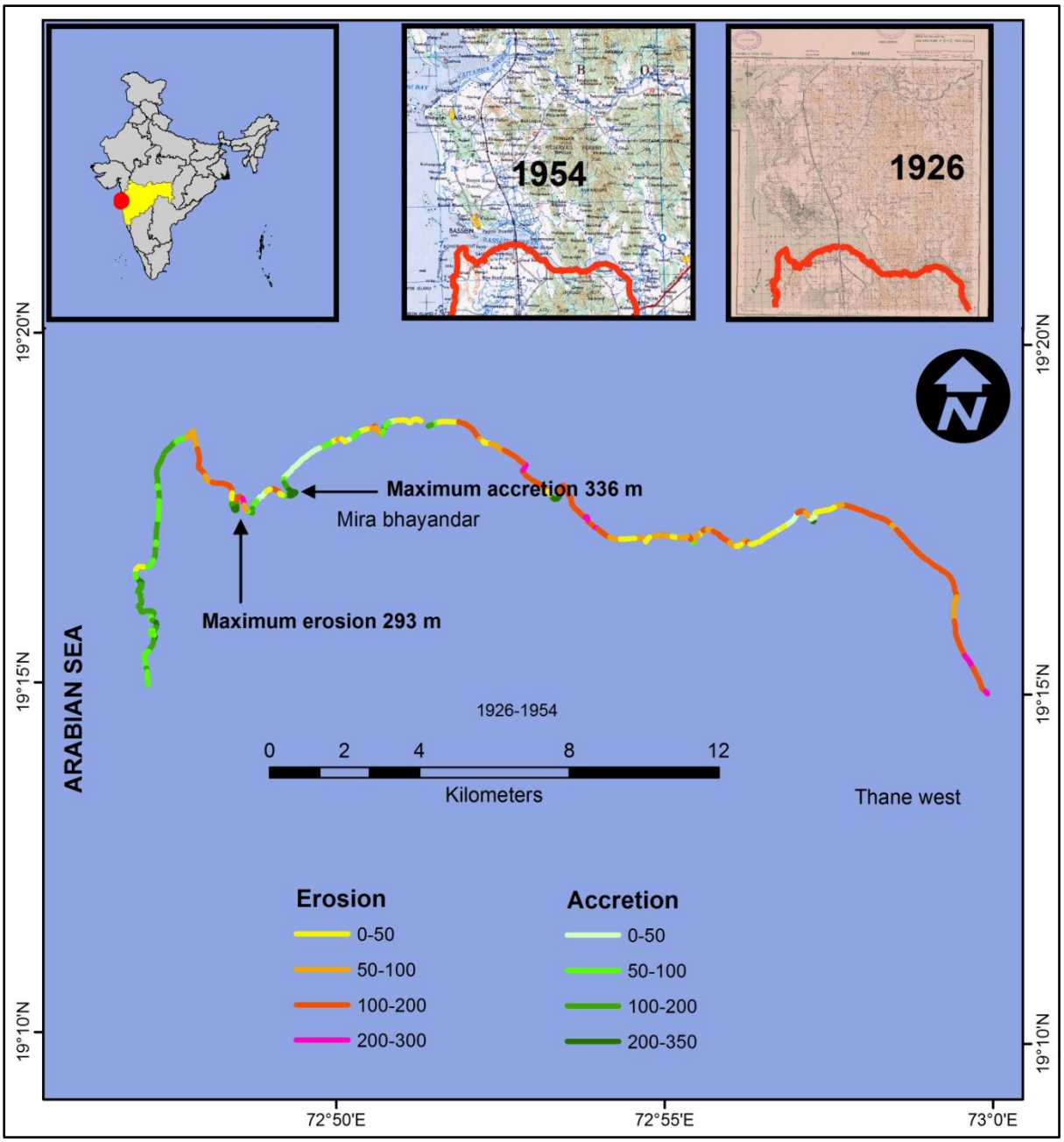


Fig. 4.7. Shoreline change from 1926 to 1954

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4.4.3 Shoreline change 1954-1970

The highest accretion of 1137 m as well as the highest erosion of 302 m is observed in the Colaba region. Higher levels of accretion are found on the Colaba region as well as near Nariman point. Other places are showing accretion/ erosion of lesser rates. The major eroded regions are North of Malabar hill, Cuffe parade and the northern side of Colaba region.

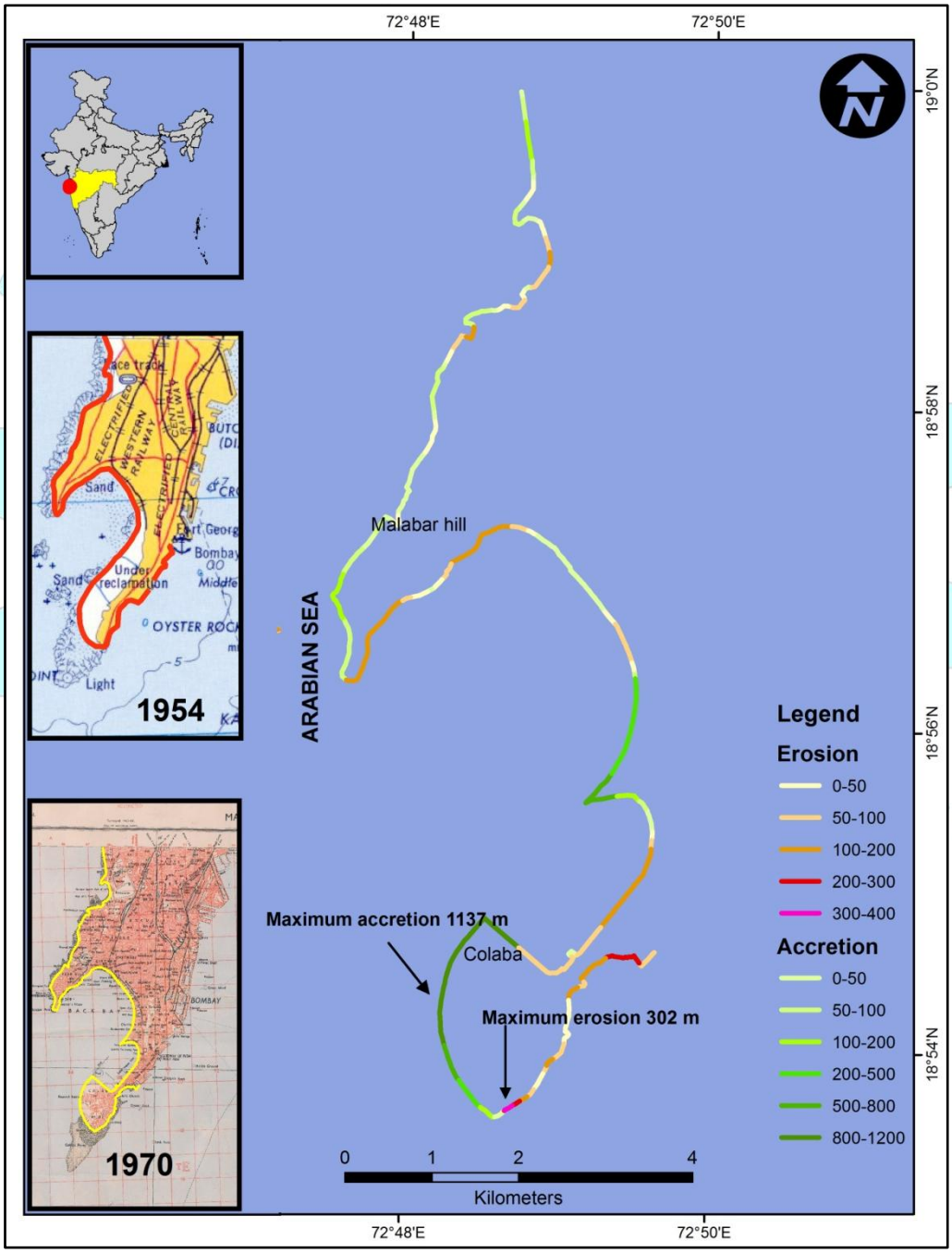


Fig. 4.8. Shoreline change from 1954 to 1970

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4.4.4 Shoreline change 1944-55

The open sea region is mainly composed of accretion of different ranges and the Thane creek is having mainly erosion values of different ranges. The highest erosion of 249 m is observed near Thane west and highest accretion of 404 m is observed above Mahim bay.

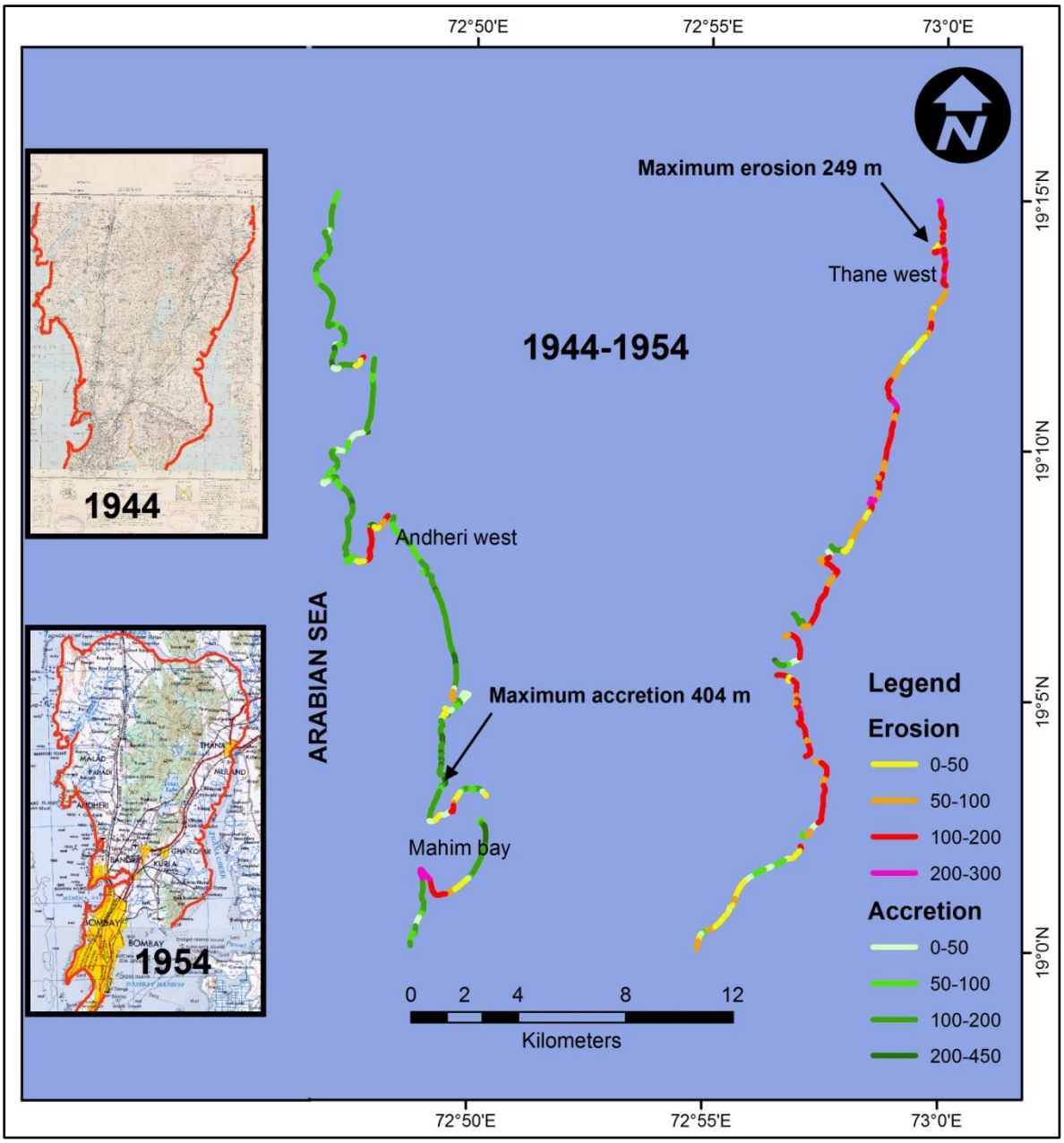


Fig. 4.9. Shoreline change from 1944 to 1954

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4.4.5 Shoreline change 1879-2015

The overall shoreline change from 1879 to 2015 is produced in the fig.4.10. Accretion is dominating over erosion even in the open sea area. The maximum accretion of 1718 m is found near the Juhu beach and maximum erosion of 224 m is found along the Thane creek. Higher ranges of accretion are mostly along the creeks. In the open sea stretches the range of accretion is less comparing to the creeks. Also erosion is observed near Malabar hils. The major accreted spots are Juhu beach, Colaba and along creeks.

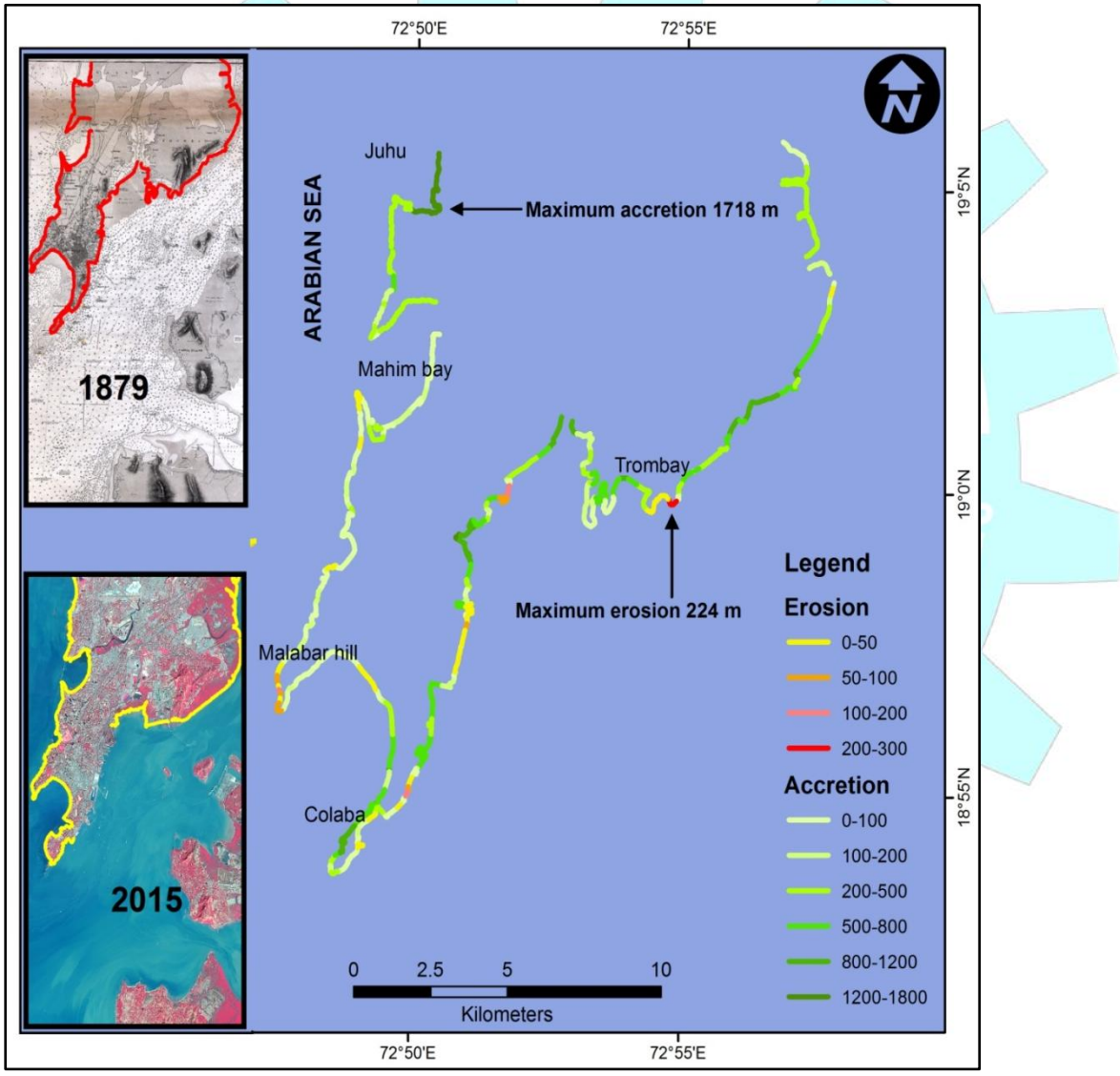


Fig. 4.10. Shoreline change from 1879 to 2015

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4.4.6 Shoreline change 1972 - 1977

Highest accretion of 325 m is observed at Colaba region (Fig. 4.11). The shorelines of 1972 (red) and 1977 (yellow) on the images of 1972 (left) & 1977 (right) provides a clear visibility to the landfill of the accreted region (Fig. 4.11). Highest erosion of 132 m is observed at Versova, near Andheri west. Vervosa is a highly dynamic region, showing the seasonal changes in the sand deposition along the shoreline. Fig 4.7 shows the various accretions and erosions accross the study area.

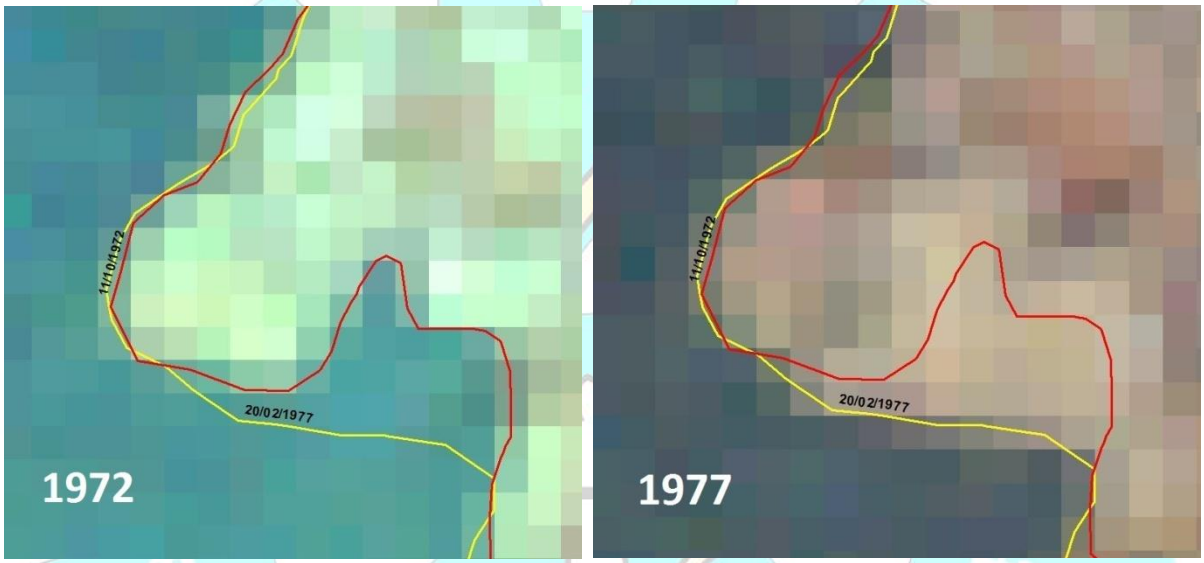


Fig. 4.11. Shorelines of the years overlaid on the source satellite images in the highest accreted region.

Majority of the study regions are on erosion to the tune of less than 50 m (Fig. 4.12). Northern regions are showing accretion of less than 50 m primarily. This accretion is due to the growth of mangroves around the Vasai creek. South-West region is showing high variability in the shoreline change statistics. This region is abundant in mangroves and the change in mangrove growth causes the shoreline change. Some portions of Colaba as well as the region down to the Manori creek mouth are showing accretion in the 50 to 100 m range.

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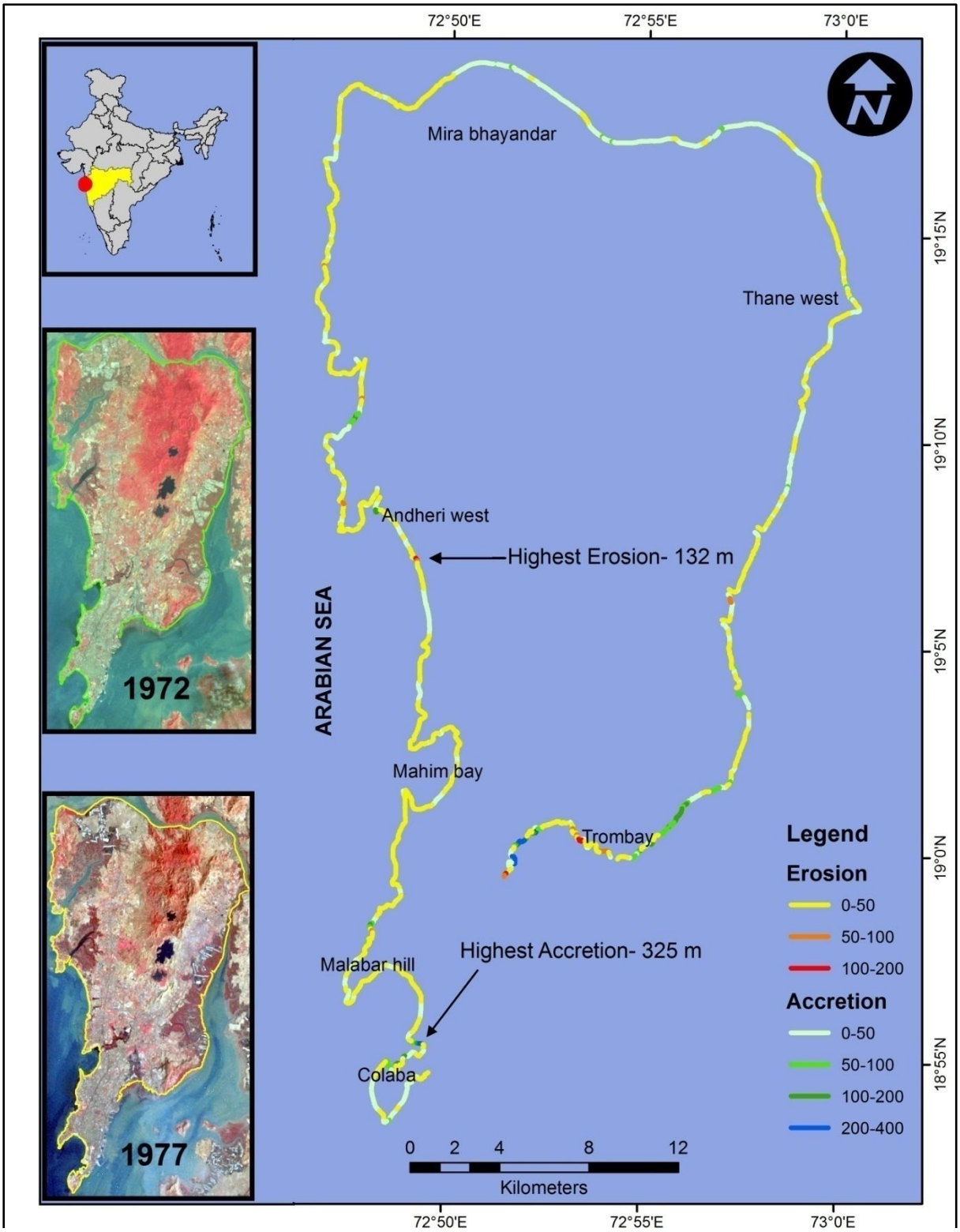


Fig. 4.12. Shoreline change from 1972 to 1977

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4.4.7 Shoreline change 1977 - 1991

Highest erosion of 396 m is observed at the juncture of Thane creek and vasai creek. From the images (Fig. 4.14), erosion is clearly visible from 1977 to the 1991 shoreline. This is a natural erosion due to the flow of water between the two creeks. The highest accretion of 735 m is observed near Trombay (Fig. 4.13). The growth of mangroves as well as reclamation activities triggered this big change in shoreline. Most of the regions are showing less than 50 m erosion. South- East region is mostly showing accretion due to the growth of mangroves towards the creek. A notable portion of mangroves were removed near Mira bhayandar triggering erosion. Other major changes by way of erosion have occured in the Aksa beach, north of Andheri west. This is a dynamic region showing the severe shoreline changes and in Juhu beach, erosion was in between 50 to 200 m. Fig 4.10 shows the full picture for that study area with details of erosion during 1977-1991.

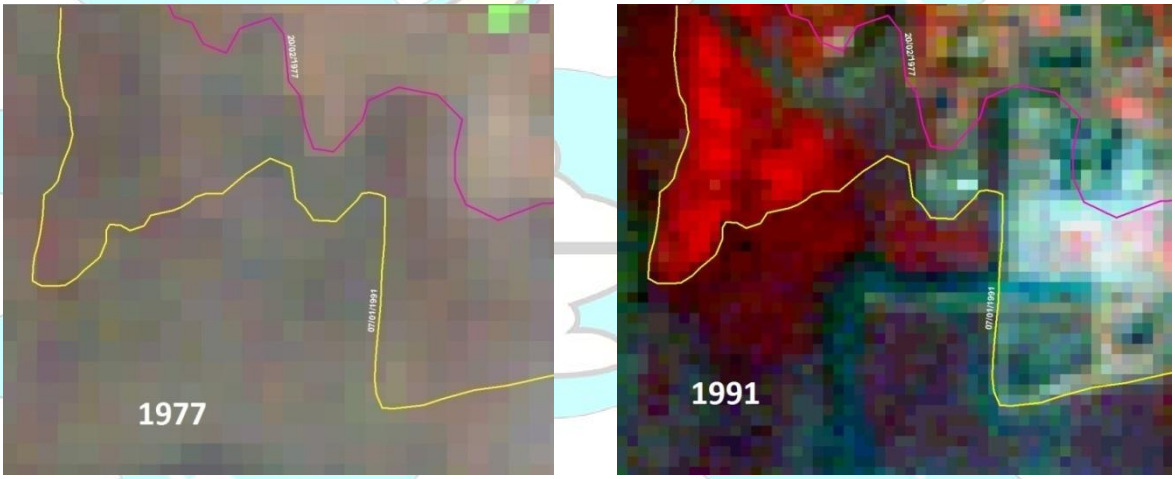


Fig. 4.13. Shorelines of the years overlaid on the source satellite images in the highest accreted region

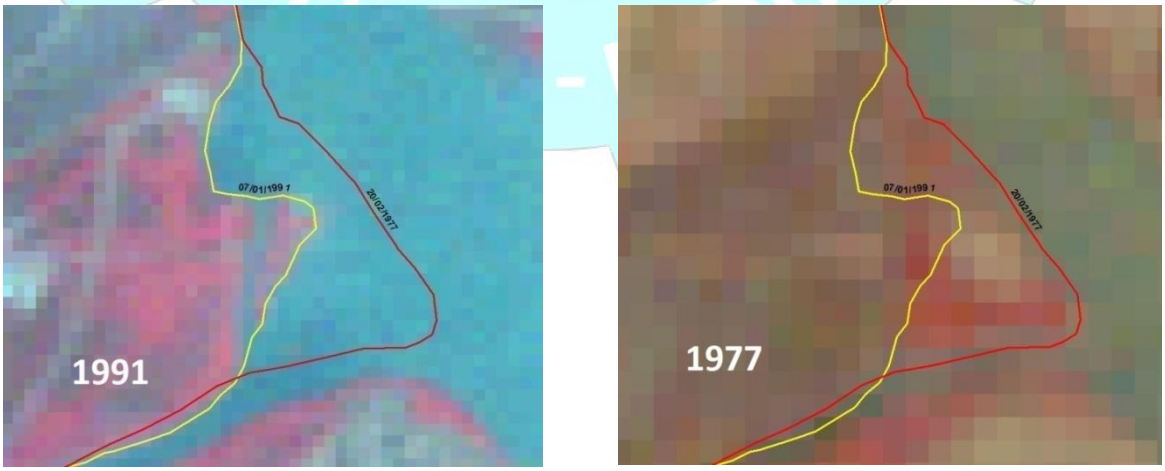


Fig. 4.14. Shorelines of the years overlaid on the source satellite images in the highest eroded region

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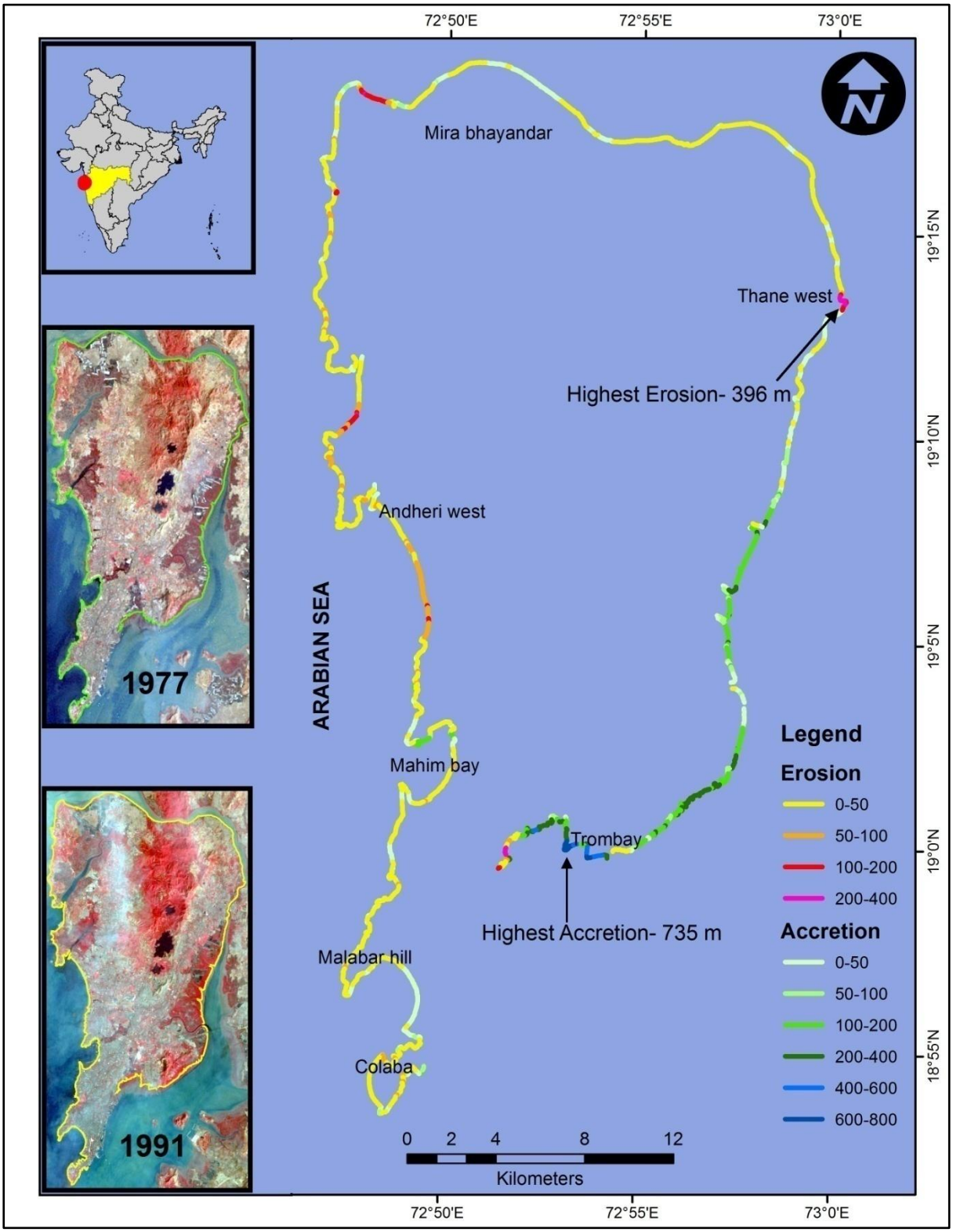


Fig. 4.15. Shoreline change from 1977 to 1991

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4.4.8 Shoreline change 1991 - 1998

Southeast zone is mainly showing accretion reaching the range of 384 m (Fig. 4.16) due to the mangrove growth along the creeks. Eastern regions as well some patches near Mira bhayandar also showing accretion upto 200 m. Highest erosion of 396 m is observed near Andheri west at the mouth of Malad creek (Fig 4.12). This region is influenced by seasonal variations in the shoreline by the deposition and depletion of sands. Most of the other stretches are exhibiting erosion and accretion lesser than 50 m. Fig 4.13 shows the full picture of the study area.

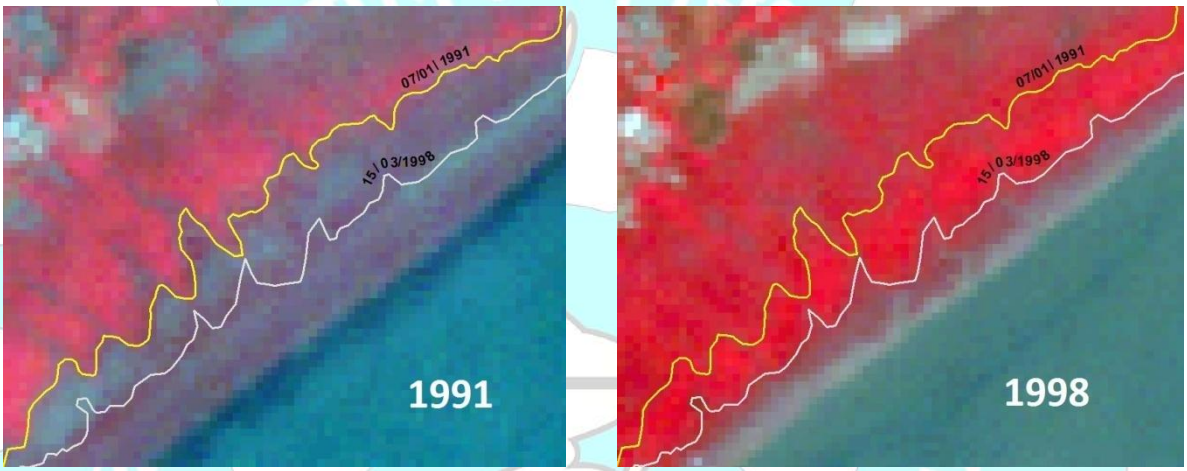


Fig. 4.16. Shorelines of the years overlaid on the source satellite images in the highest accreted region

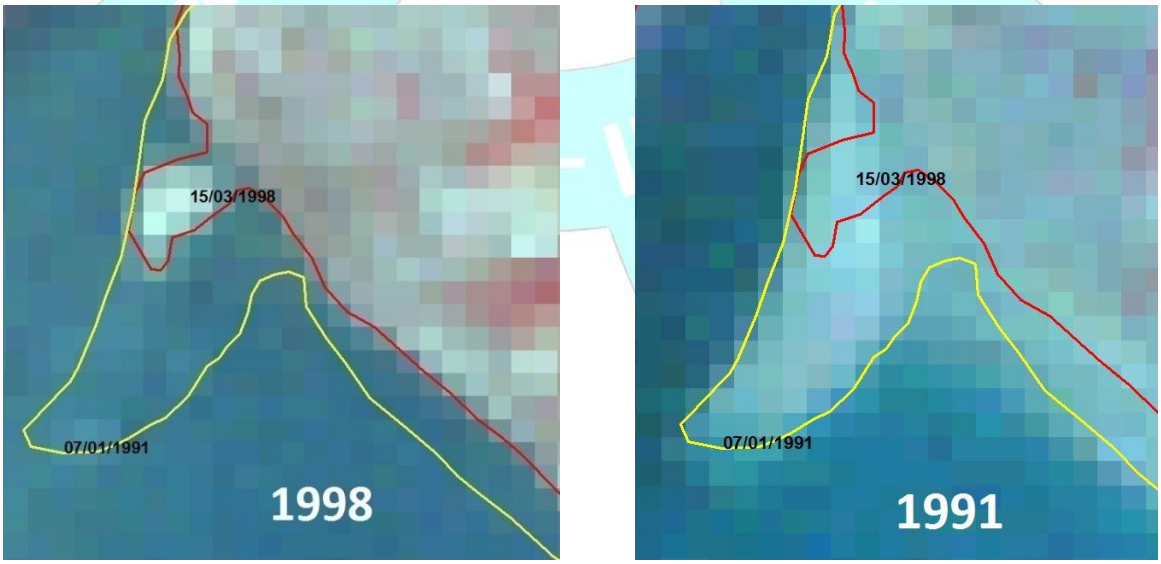


Fig. 4.17. Shorelines of the years overlaid on the source satellite images in the highest eroded region

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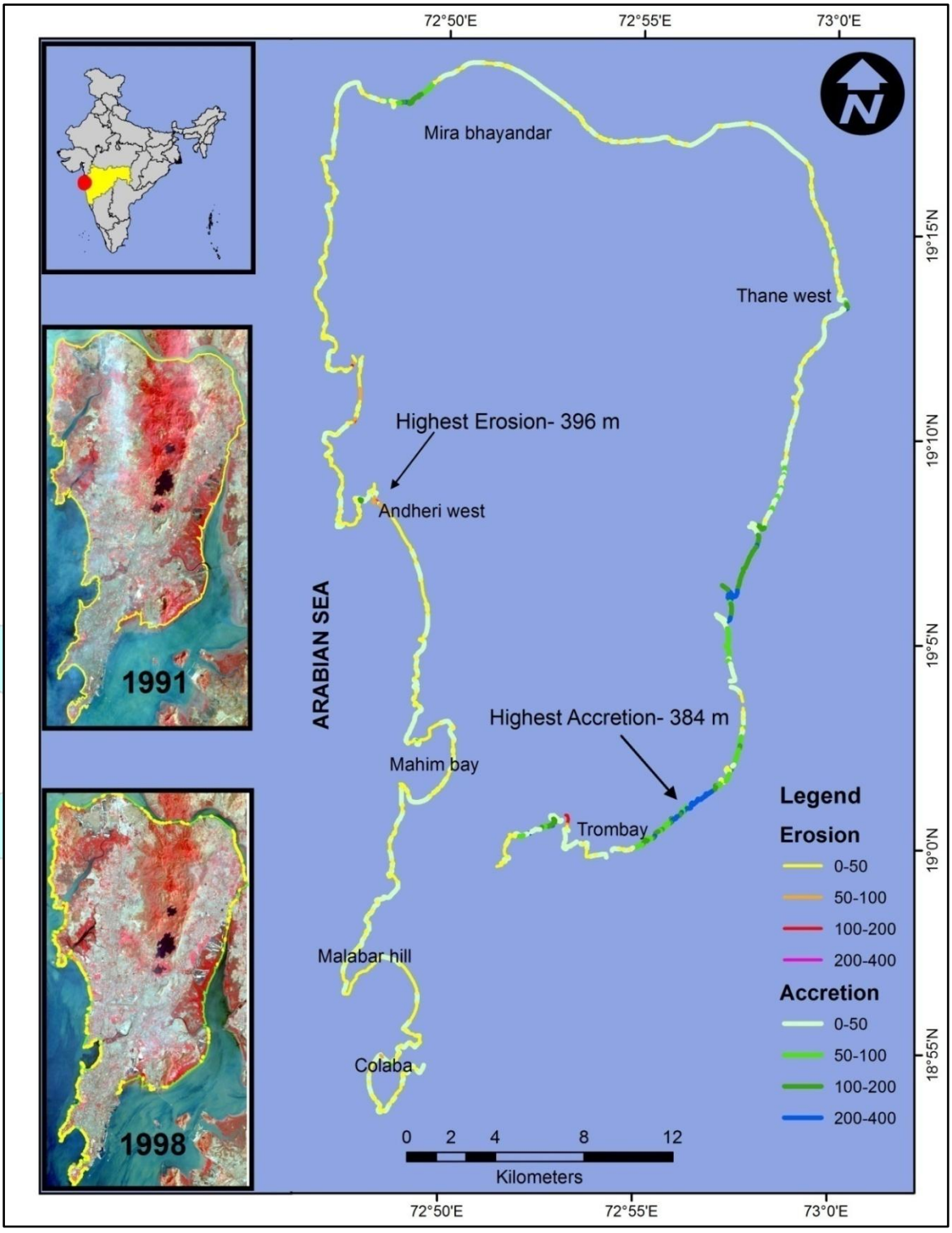


Fig. 4.18. Shoreline change from 1991 to 1998

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4.4.9 Shoreline change 1998-1999

Highest accretion of 136 m is observed on the south-east region. Within this time, mostly accretion and erosion were within the range 30 m and few patches of accretion with more than 50 m were observed. The highest erosion was observed at the mouth of Malad creek near Andheri west. This change in shoreline is due to the dynamic nature of the region. Most of other places are showing less than 30 m erosion and accretion with some patches at eastern side recording higher accretion rates due to the mangrove growth (Fig 4.14).

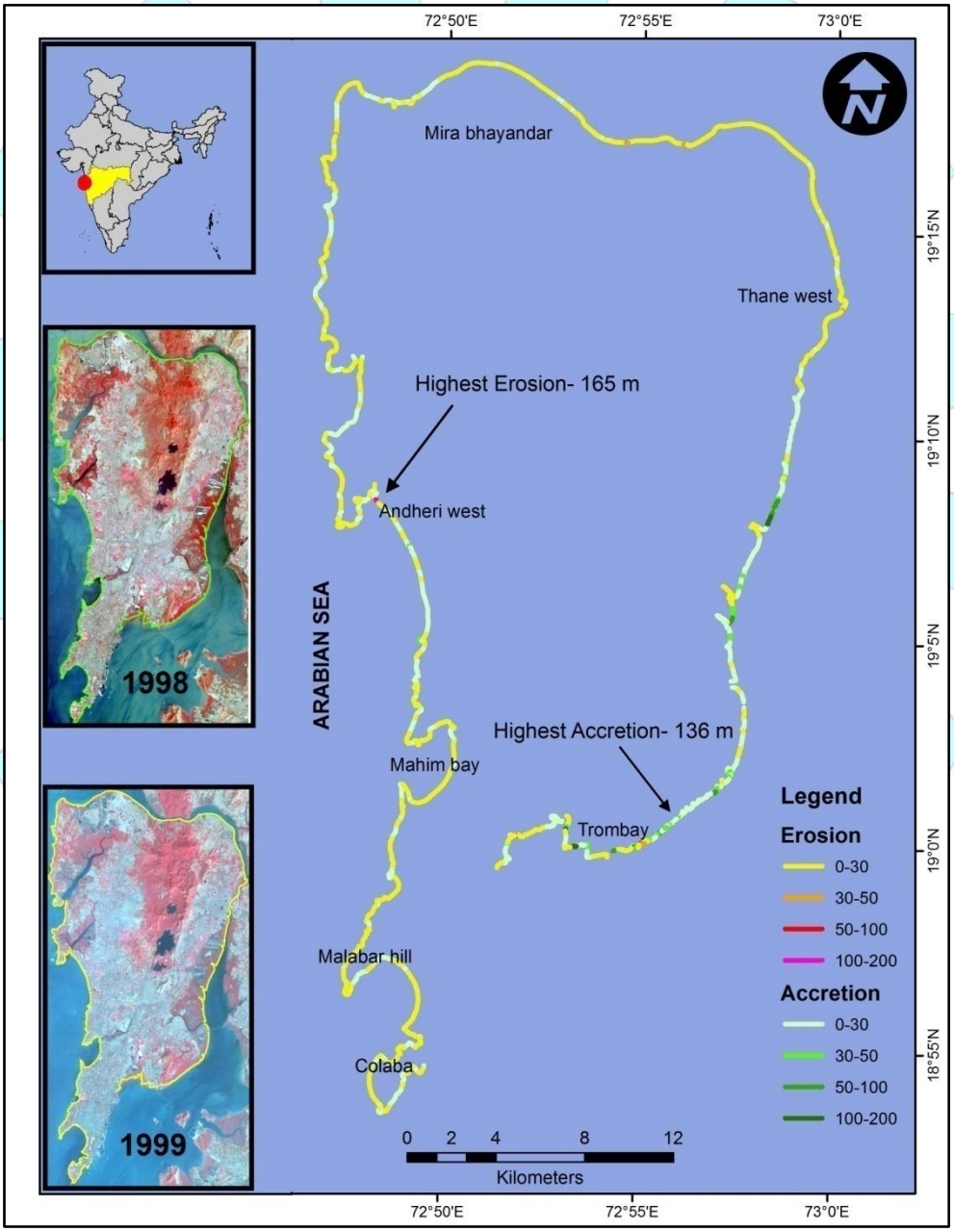


Fig. 4.19. Shoreline change from 1998 to 1999

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4.4.10 Shoreline change 1999-2000

Highest accretion of 261 m is observed on the mouth of Malad creek near Andheri west. This region is dynamic and deposition and reduction of sand causes the shoreline changes in this region (Fig. 4.21). Highest erosion of 75 m was observed near Trombay. Another notable change was observed in the Mahim creek (Fig. 4.20). Other coastal stretches are showing less than 50 m erosion and accretion while south-east region is showing higher accretion with the range of 50 to 100 m due to the mangrove growth. Fig 4.17 shows the over all picture for the study area.

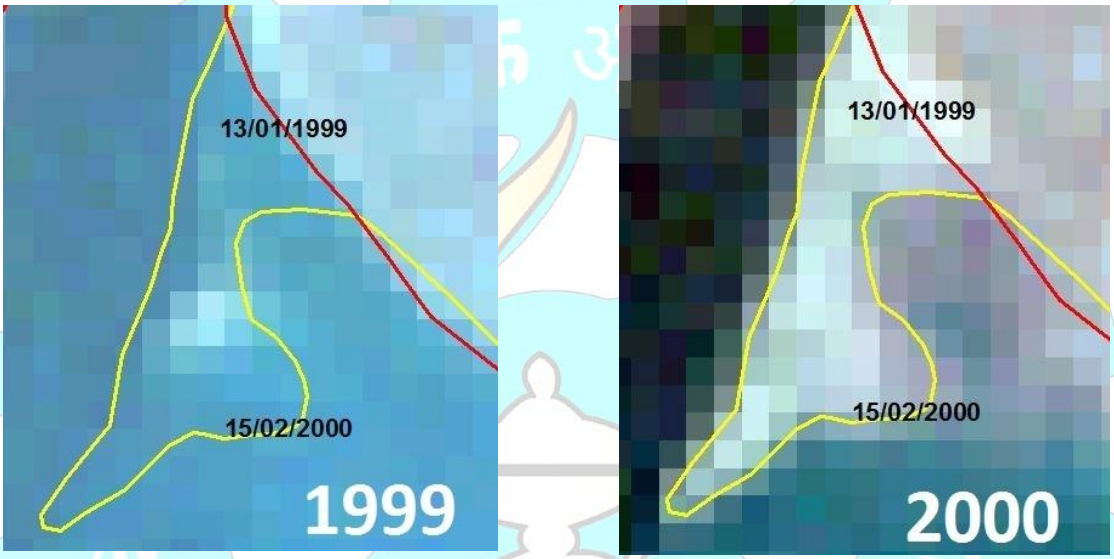


Fig. 4.20. Shorelines of the years overlaid on the source satellite images in the highest accreted region

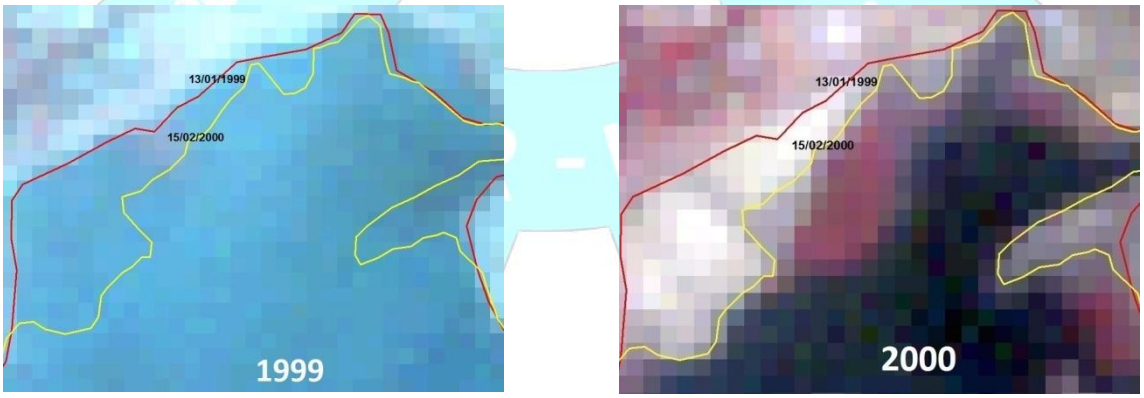


Fig. 4.21. Shorelines of the years overlaid on the source satellite images in a Mahim creek

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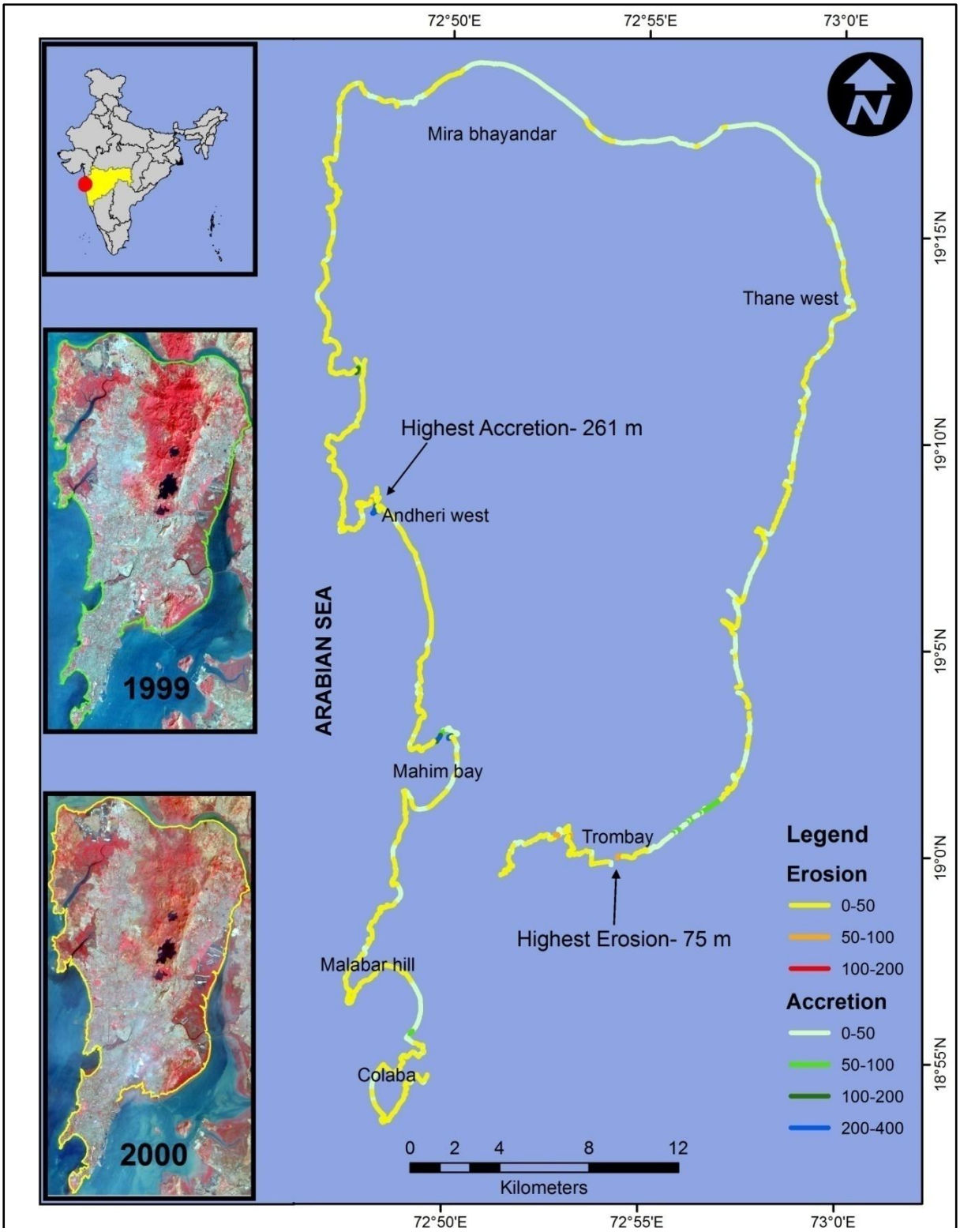


Fig. 4.22. Shoreline changes from 1999 to 2000

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4.4.11 Shoreline change 2000-2001

The highest erosion of 54 m was observed in Aksa beach. Most of the sea facing coastal stretches are showing erosion with less than 30 m and around creeks it is observed less than 30 m erosion and accretion. The south-east region is mostly composed of accretion less than 30 m. The highest accretion of 166 m is observed in the Mahim creek (Fig. 4.23). Andheri west and some stretches in the eastern parts were eroded within the range of 30 to 50 m. Trombay region shows accretion to the tune of 50 to 100 m. Over all picture for Mumbai is shown in Fig 4.19.

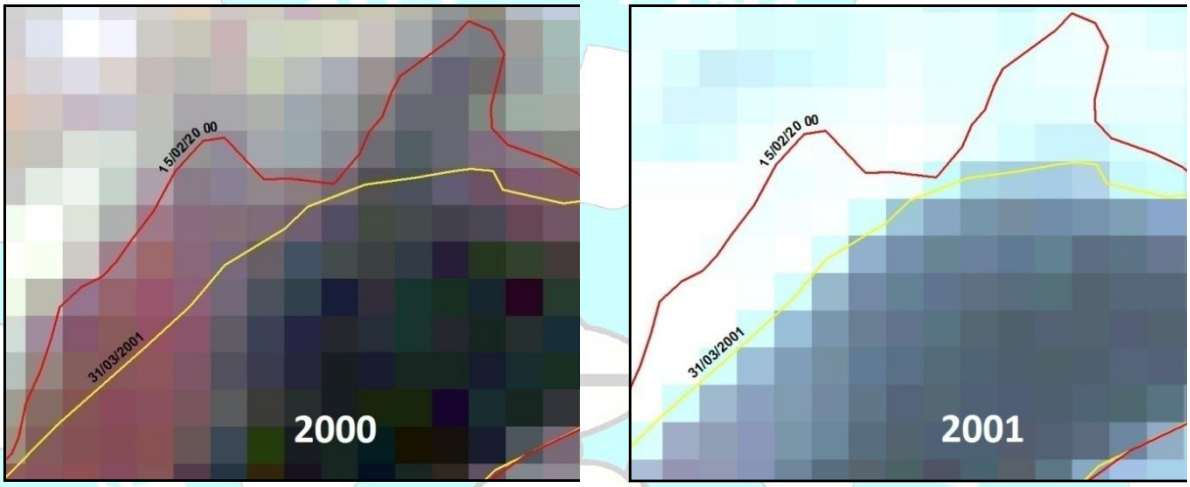


Fig. 4.23. Shorelines of the years overlaid on the source satellite images in the highest accreted region

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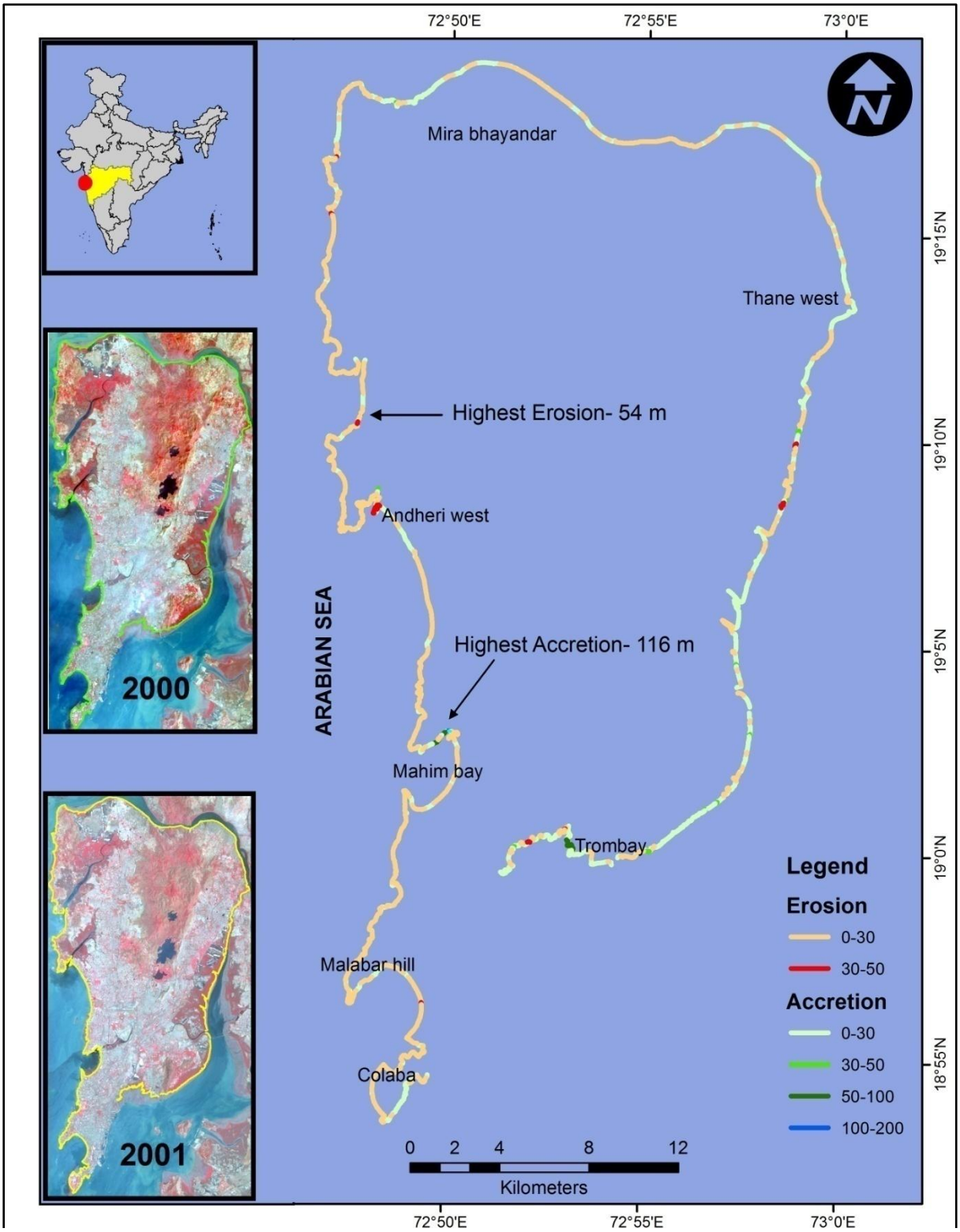


Fig. 4.24. Shoreline change from 2000 to 2001

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4.4.12 Shoreline change 2001-2002

Highest accretion of 64 m is spotted near the Mira bhayandar region; this indicates the growth of mangroves in the region. Highest erosion of 118 m is observed at Manori creek mouth (Fig. 4.25). Most of the other regions are composed of erosion and accretion less than 50 m during this time. The over all picture for the entire study area is shown in fig 4.21.



Fig. 4.25. Shorelines of the years overlaid on the source satellite images in the highest eroded region

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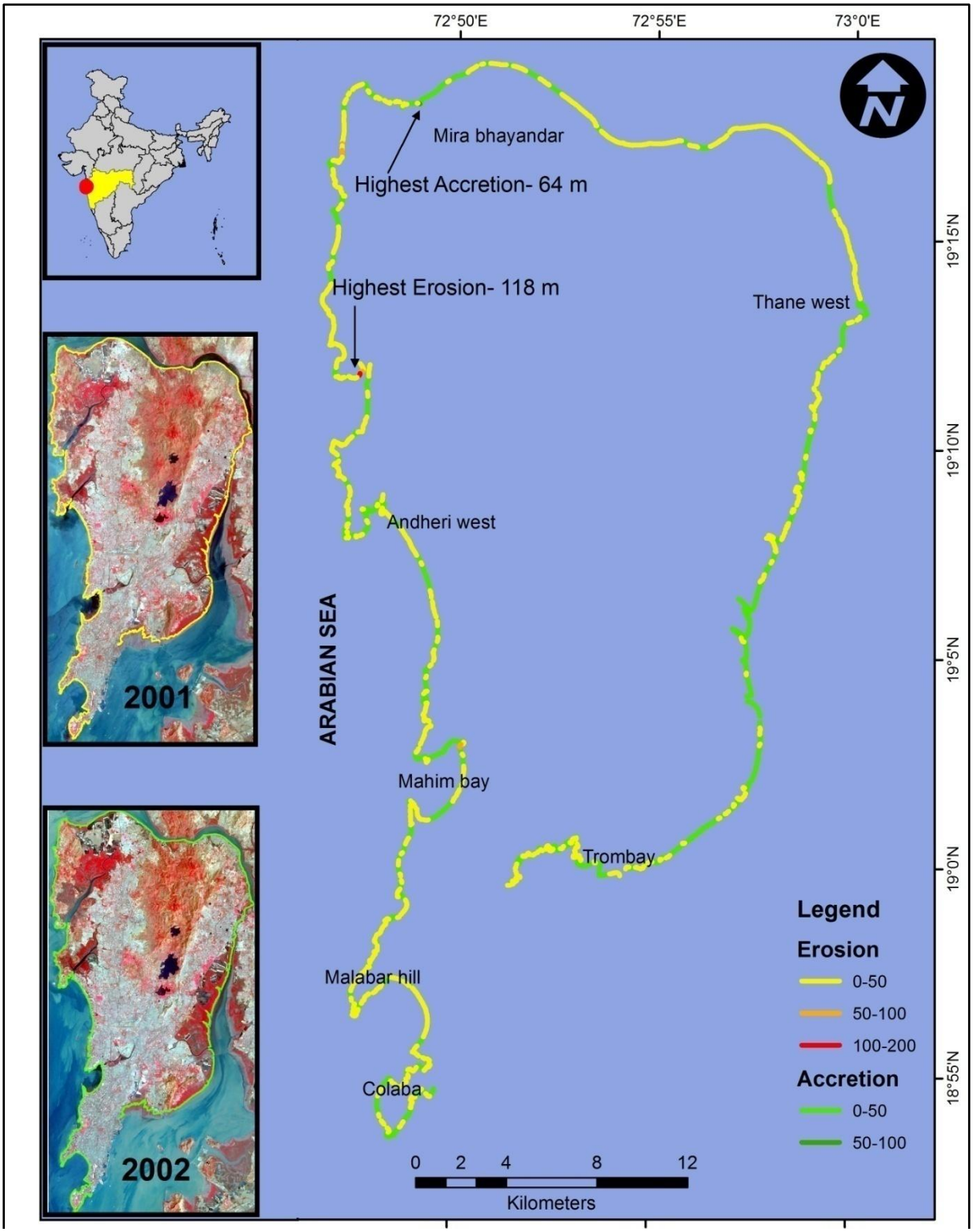


Fig. 4.26. Shoreline change from 2001 to 2002

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4.4.13 Shoreline change 2002-2003

The highest erosion of 195 m is observed at a dynamic shoreline region near Andheri west (Fig. 4.27). Few patches near Trombay shows accretion of 50 to 100 m. Over all picture is shown in Fig 4.23.

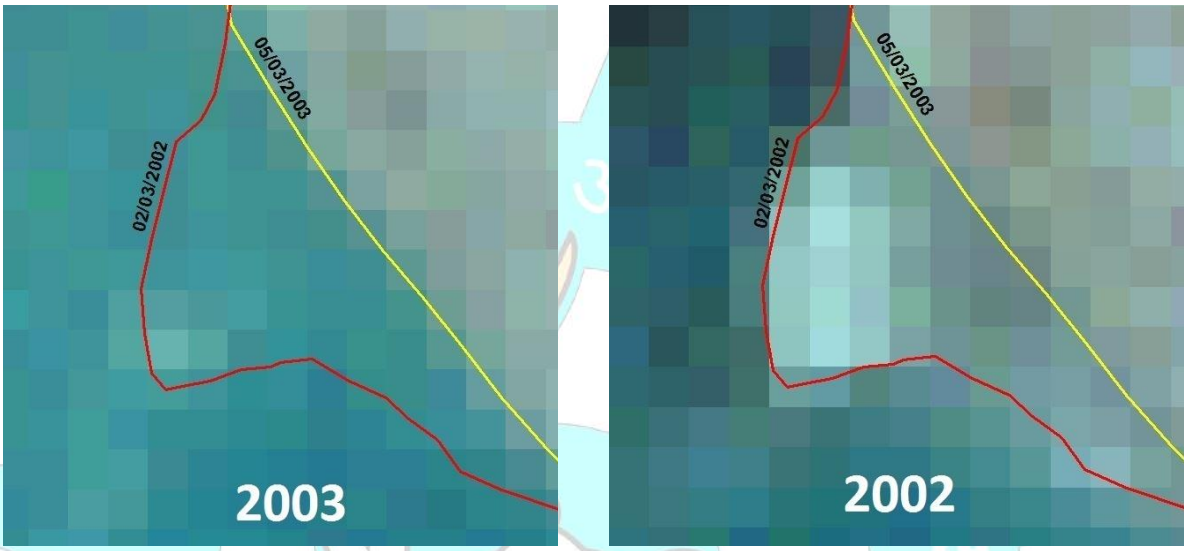


Fig. 4.27. Shorelines of the years overlaid on the source satellite images in the highest eroded region

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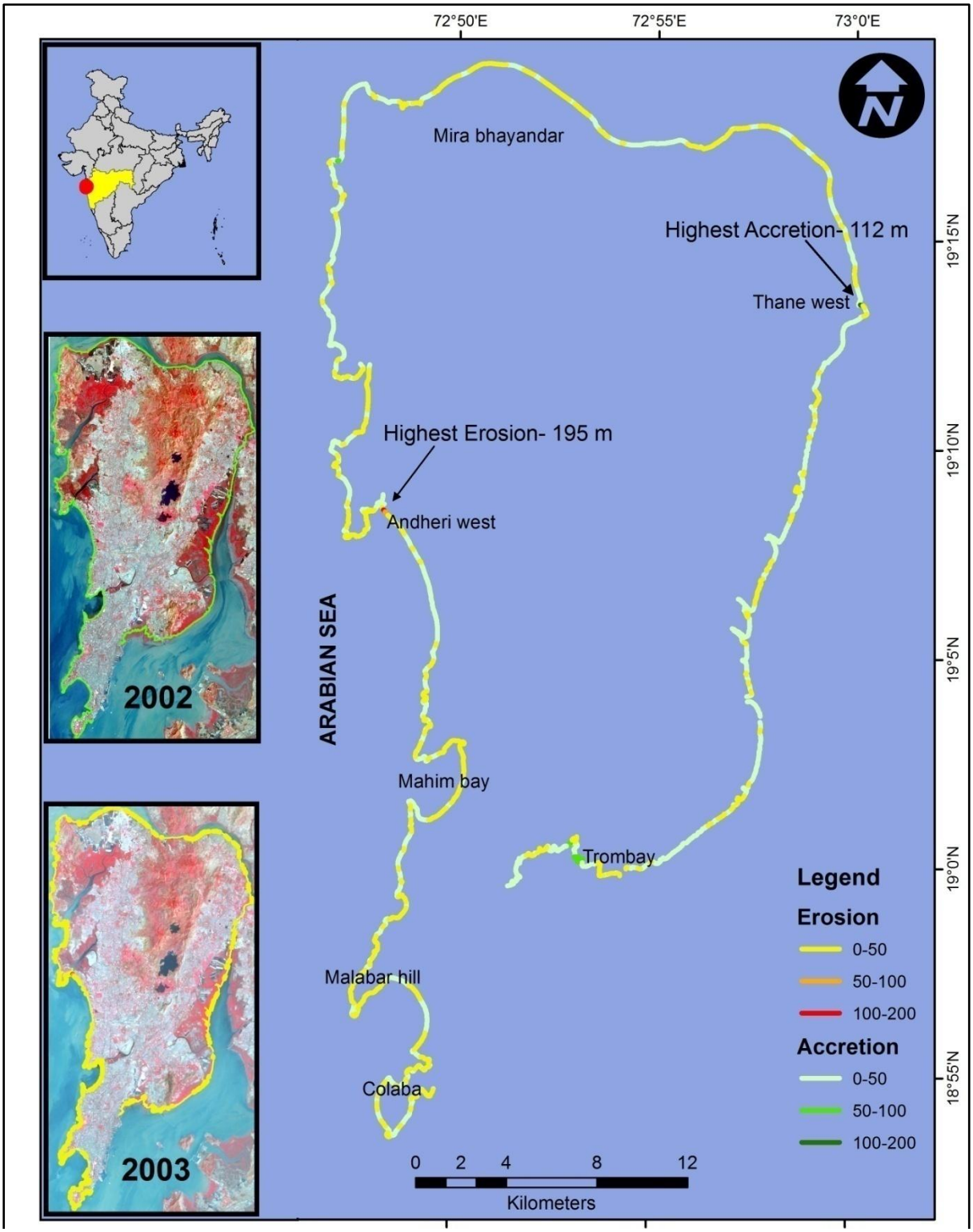


Fig. 4.28. Shoreline change from 2002 to 2003

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4.4.14 Shoreline change 2003-2005

Highest accretion of 264 m is found in a dynamic region in the study area near Andheri west (Fig. 4.29). Highest erosion of 52 m is noticed in the eastern parts. The sea facing coastal stretches (west sides) are noticed with less than 30 m erosion and accretion. Northern sides show deposition up to 100 m . Fig 4.25 shows the over all position of the study area.

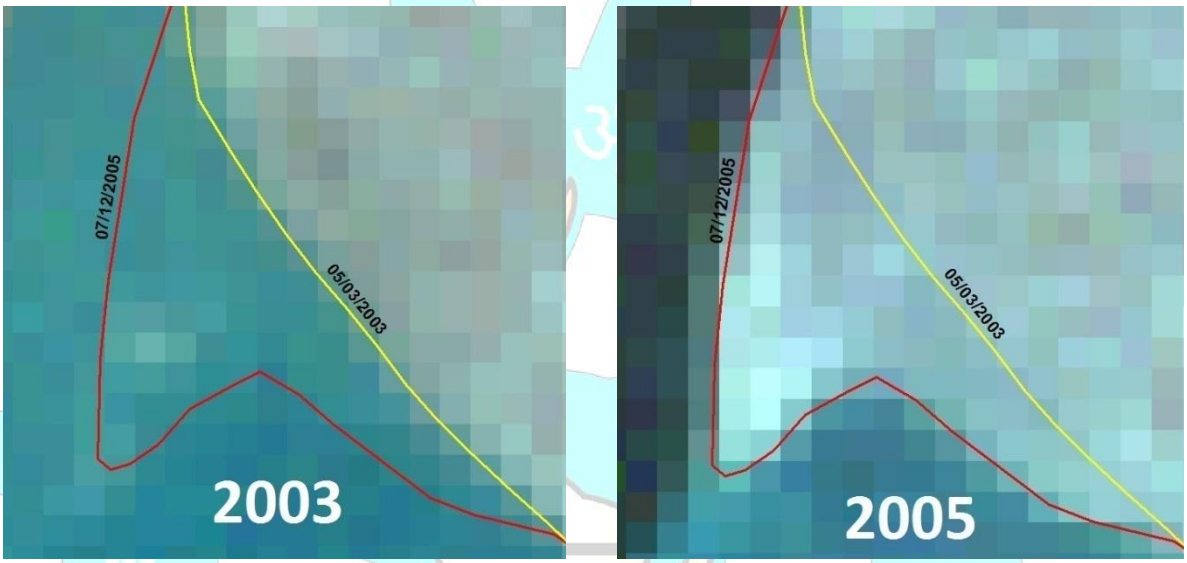


Fig. 4.29. Shorelines of the years overlaid on the source satellite images in the highest accreted region

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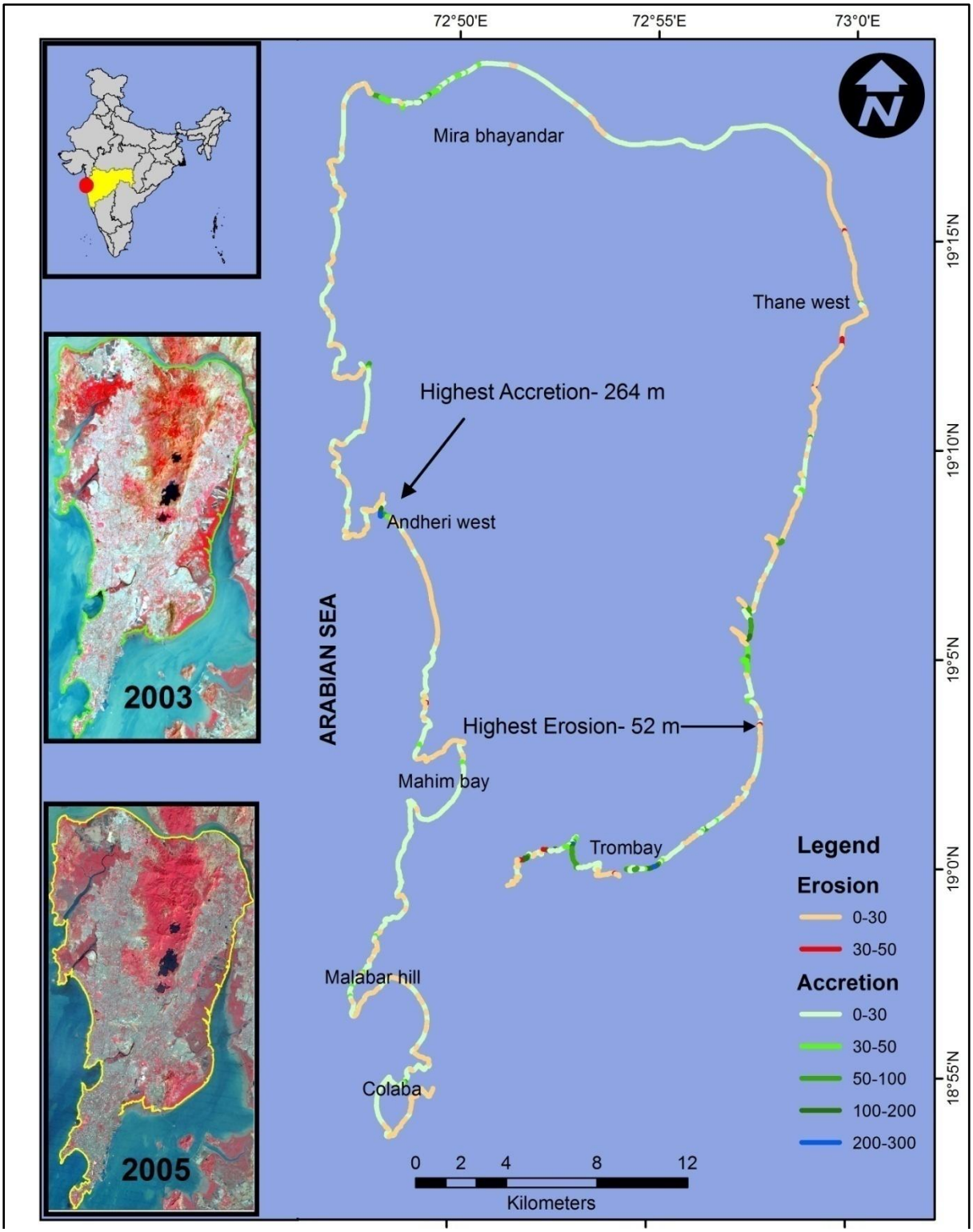


Fig. 4.30. Shoreline change from 2003 to 2005

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4.4.15 Shoreline change 2005-2009

Highest accretion of 619 m is observed at Trombay region due to the creation of a new bund (Fig. 4.31). Highest erosion of 60 m is observed in the eastern region due to removal of mangroves near Sion-Panvel express highway (Fig. 4.27). Eastern parts deposited upto 100 m and the sea facing stretch had mixed erosion as well as accretion with less than 30 m. Fig 4.28 shows the position for the whole of study area.



Fig. 4.31. Shorelines of the years overlaid on the source satellite images in the highest accreted region



Fig. 4.32. Shorelines of the years overlaid on the source satellite images in the highest eroded region

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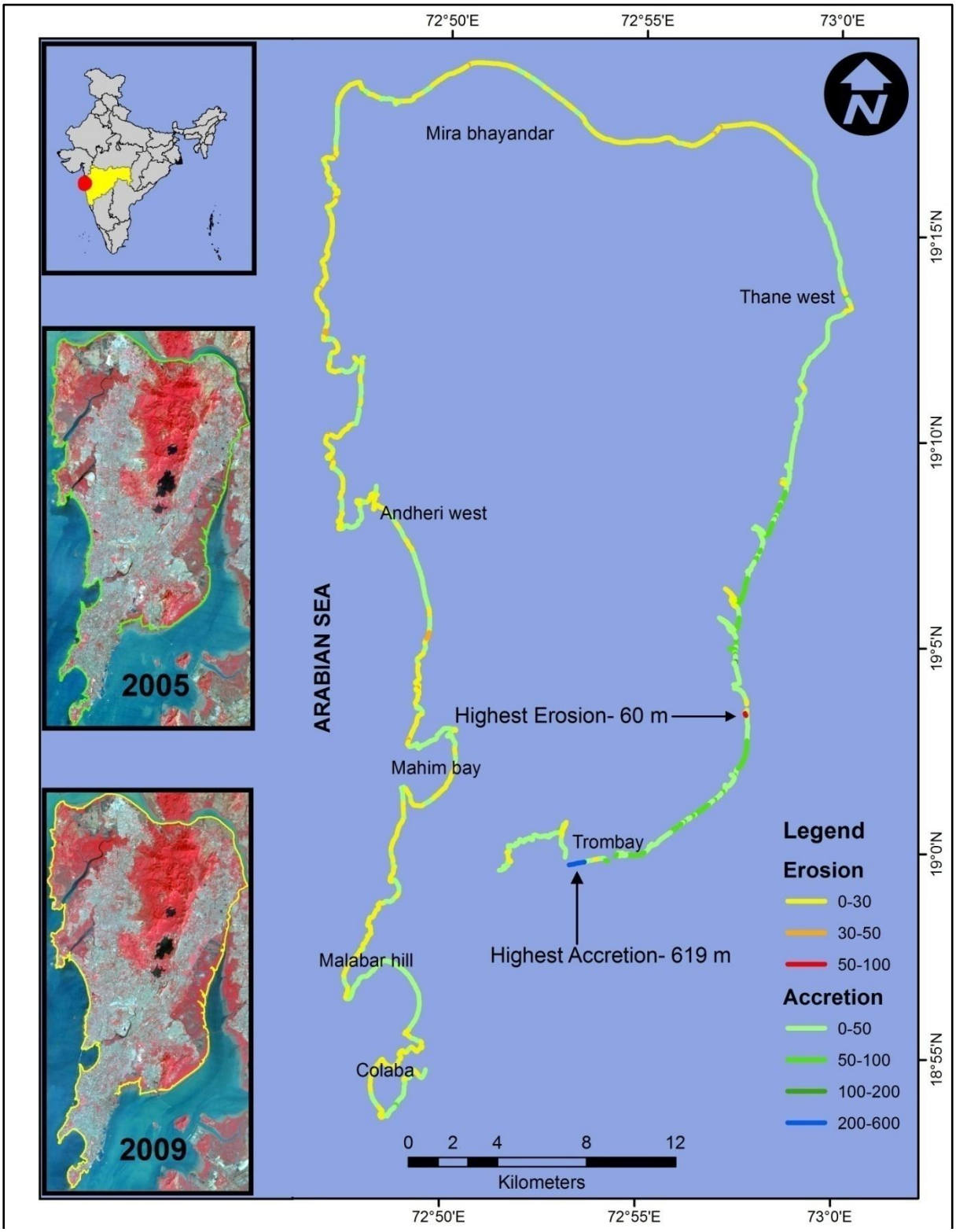


Fig. 4.33. Shoreline change from 2005 to 2009

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4.4.16 Shoreline change 2009-2011

Highest erosion (42 m) is observed near Andheri west. Highest accretion is noticed near Trombay, where a new bund was constructed. Direct sea facing coastal stretches eroded to the tune of less than 30 m with some patches showing accretion at the same rate. Thane creek regions (eastern side) deposited with the growth of mangroves (Fig 4.29).

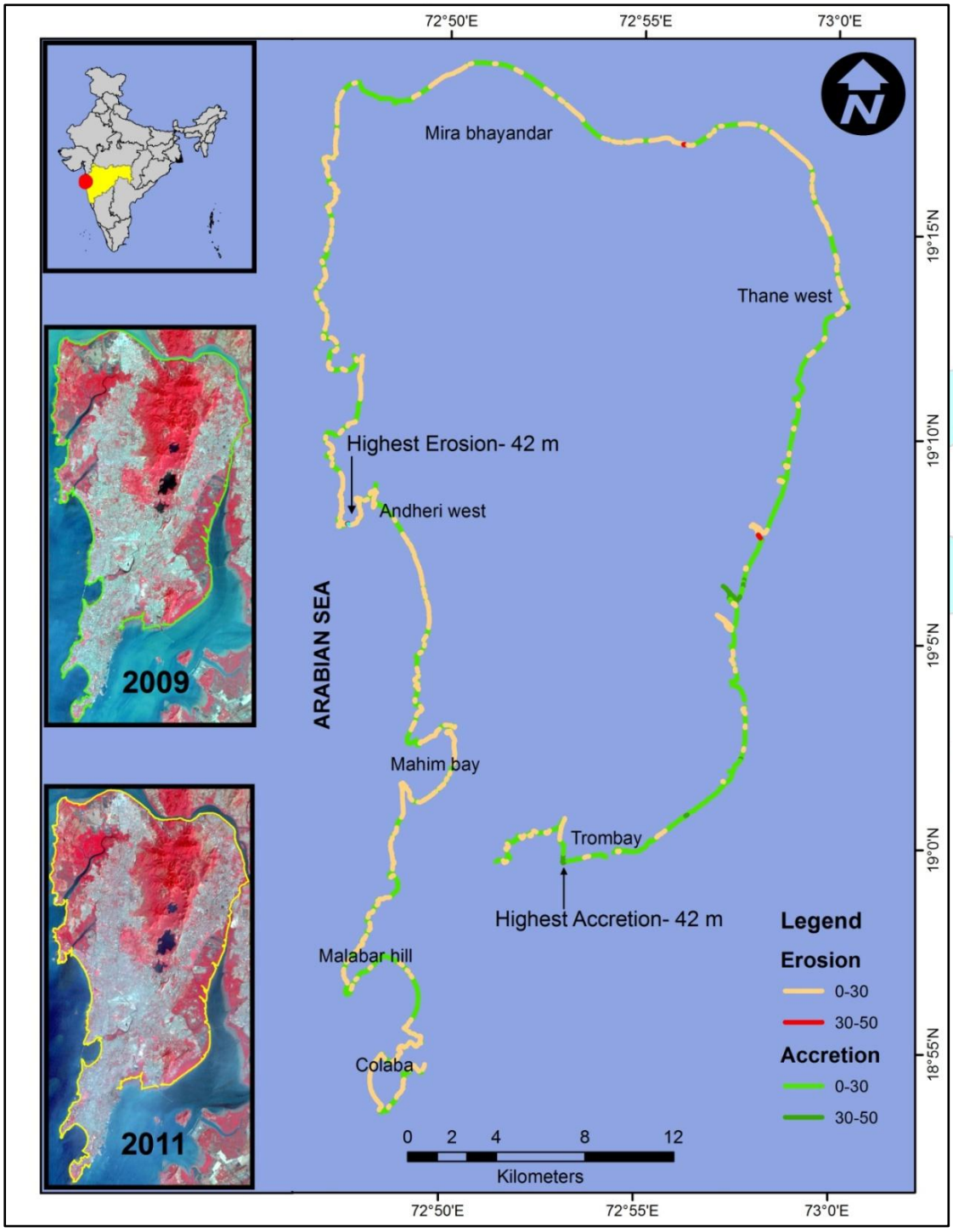


Fig. 4.34. Shoreline change from 2009 to 2011

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4.4.17 Shoreline change 2011-2013

Highest erosion of 239 m is observed on a dynamic shoreline region near Andheri west (Fig. 4.35). Highest accretion of 68 m is observed on the northern region near Mira bhayandar due to the growth. Erosion and accretion of less than 50 m is observed on other regions. The full picture of the study area is shown in Fig 4.31.

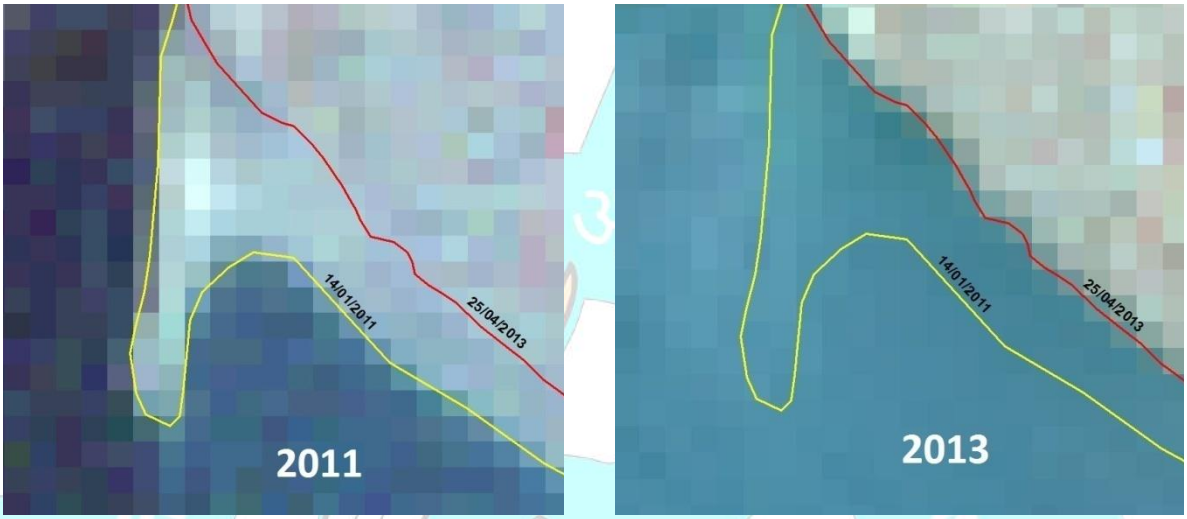


Fig. 4.35. Shorelines of the years overlaid on the source satellite images in the highest eroded region

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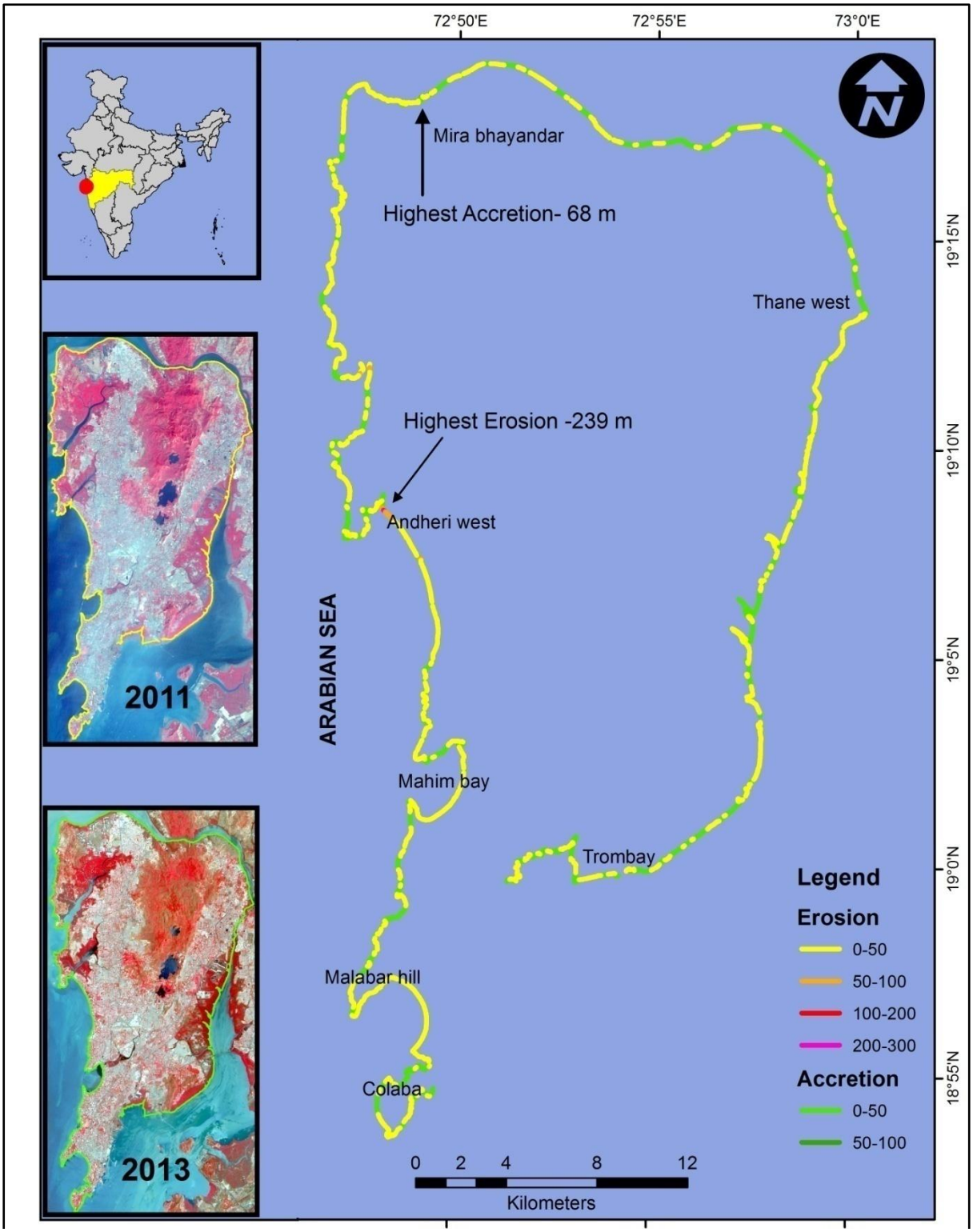


Fig. 4.36. Shoreline change from 2011 to 2013

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4.4.18 Shoreline change 2013-2014

Highest accretion of 56 m is observed near Andheri west on the mouth of Malad creek due to the deposition of sand. Highest erosion of 77 m is observed near Trombay. All other regions show erosion and accretion of less than 30 m. (Fig 4.32).

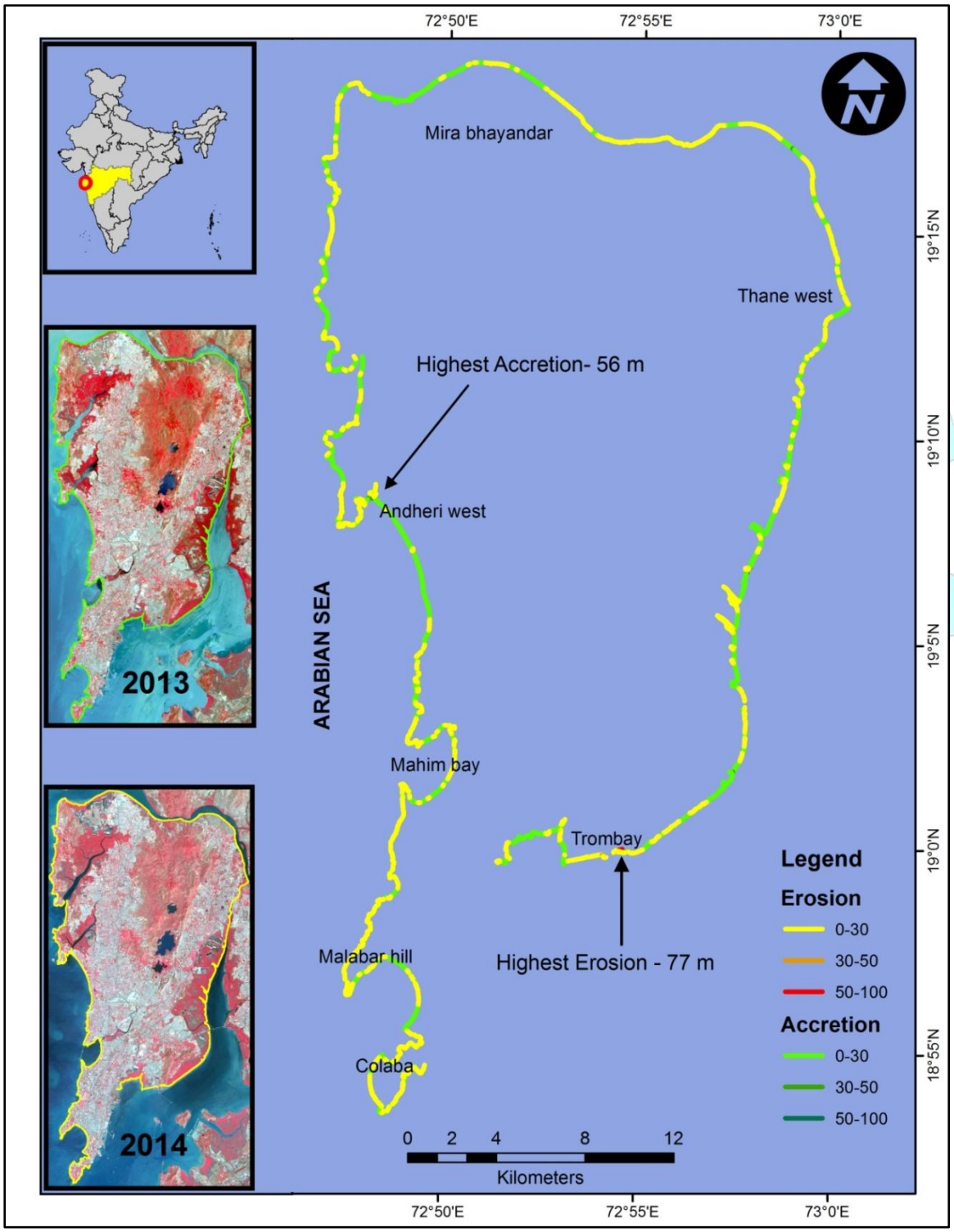


Fig. 4.37. Shoreline change from 2013 to 2014

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4.4.19 Shoreline change 2014-2015

Most of the regions are showing erosion and accretion of less than 30 m all around the Mumbai. In that, the south-eastern regions are showing more accretion than erosion. The highest erosion of 46 m is observed in the north region. (Fig. 4.33)

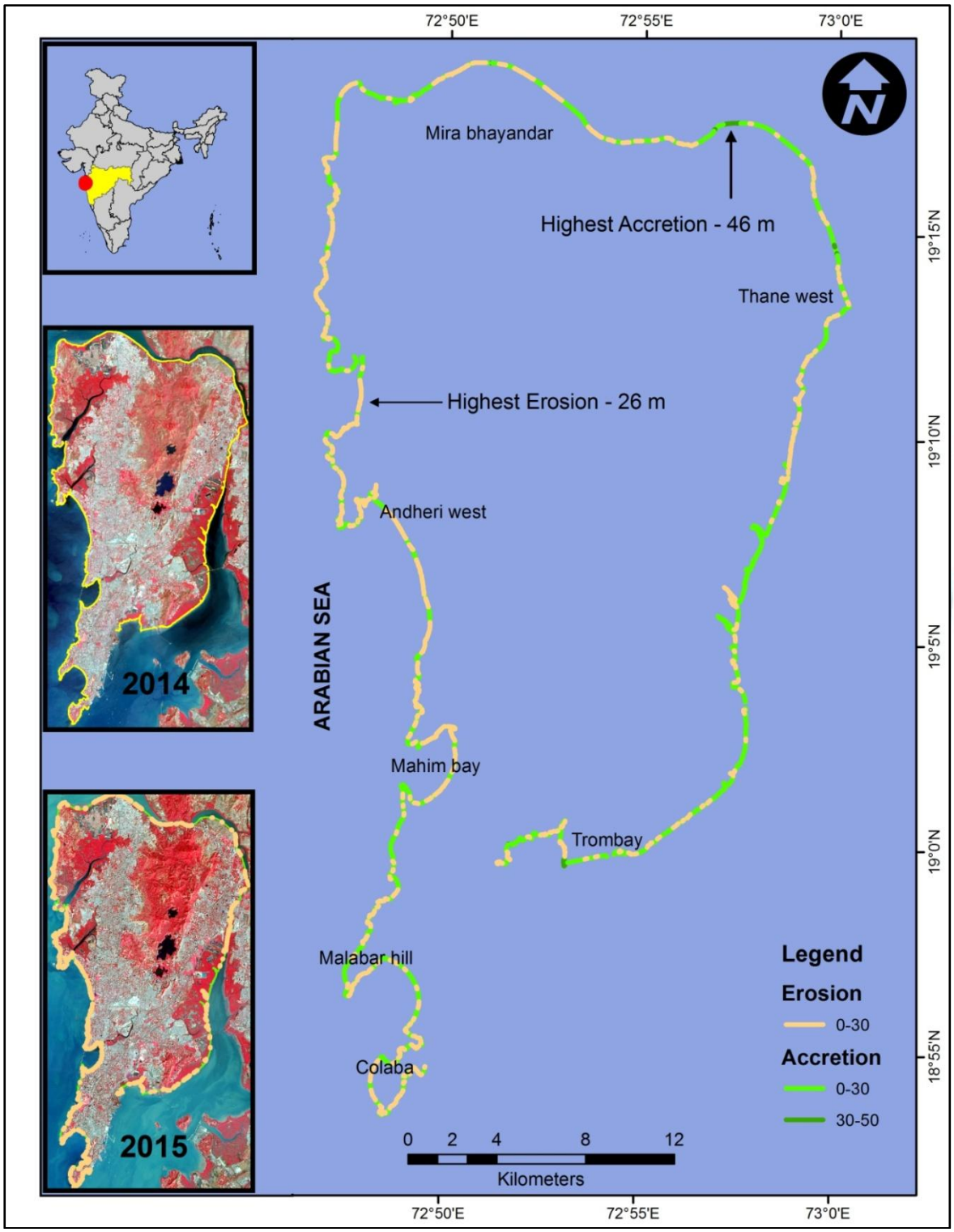


Fig. 4.38. Shoreline change from 2014 to 2015

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4.4.20 Net shoreline change (1972-2015)

The net shoreline changes from 1972 to 2015 provide a clear idea about the shoreline changes of the study area. Thane creek is experiencing high accretion due to the growth of mangroves around the creek. The north-west regions have eroded at different rates; particularly from the mouth of Malad creek to Juhu beach have undergone significant erosion at different rates. South-west parts show combination of accretion and erosion but within 50 m range. This indicates a stable coastline in these regions. Apart from a few patches of mangrove growth, the northern parts can also be defined as stable coast. A few patches of higher erosion can be seen in the north-east region, having the highest erosion of 182 m (Fig. 4.39). Highest accretion is observed near Trombay due to the creation of a new bund. Over all shoreline change in the study area is shown in fig. 4.35.

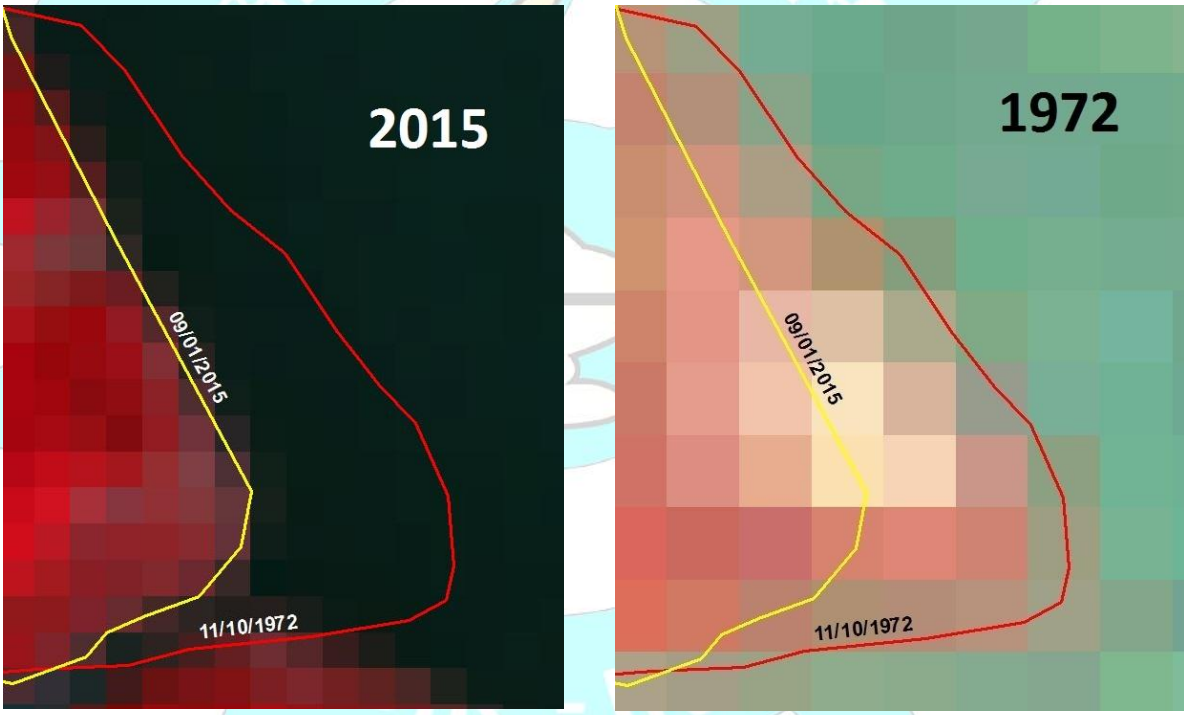


Fig. 4.39. Shorelines of the years overlaid on the source satellite images in the highest eroded region

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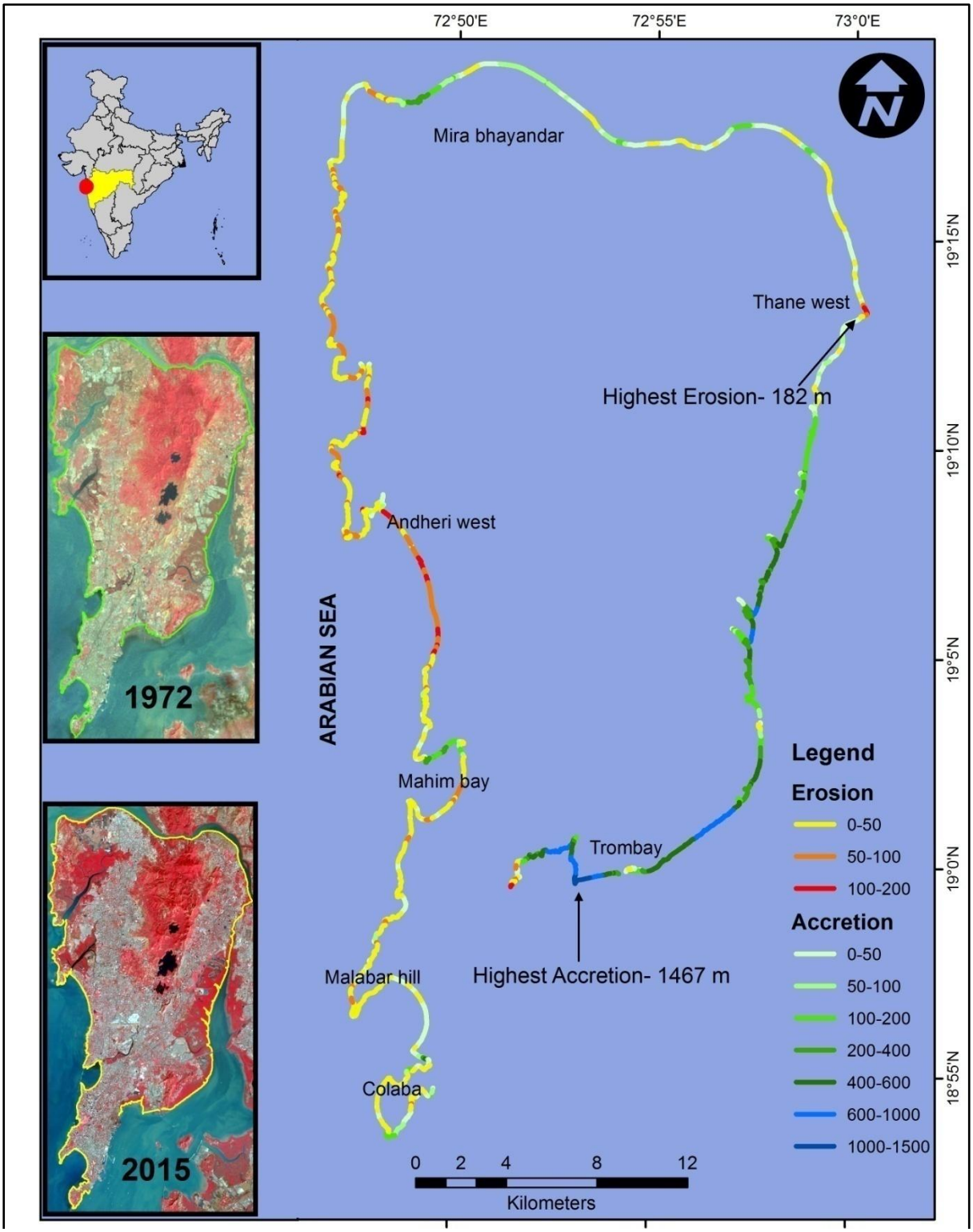


Fig. 4.40. Overall shoreline change from 1972 to 2015

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4.4.21 Low tide line change 1975- 2014

Highest erosion as well as the highest accretion is found in the south-east region of the study area. This region is mostly of accreted coastline due to the growth of mangroves and the mudflat deposition with maximum accretion of 451 m (Fig. 4.42). The mudflat region is found to be eroded in the Mahul creek with a maximum erosion of 699 m (Fig. 4.41). It is also found that the mudflat deposition is eroded throughout the Mahim bay (Fig. 4.43). Other two hotspots of accretion are mouth of Malad creek to the south of Juhu beach and the southern tip of the study area. The open sea coastal stretches are showing different levels of erosion and south-east regions as well as some patches in the northern region are showing different levels of accretion. The over all position of lowtide accretion and erosion is shown in Fig. 4.39.

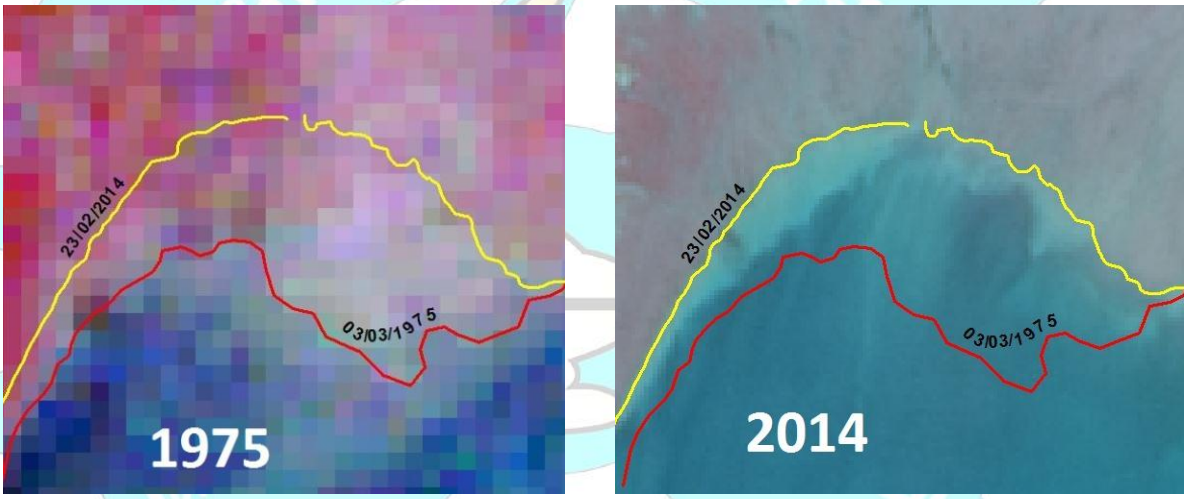


Fig. 4.41. Low tide lines of the years overlaid on the source satellite images in the highest eroded region

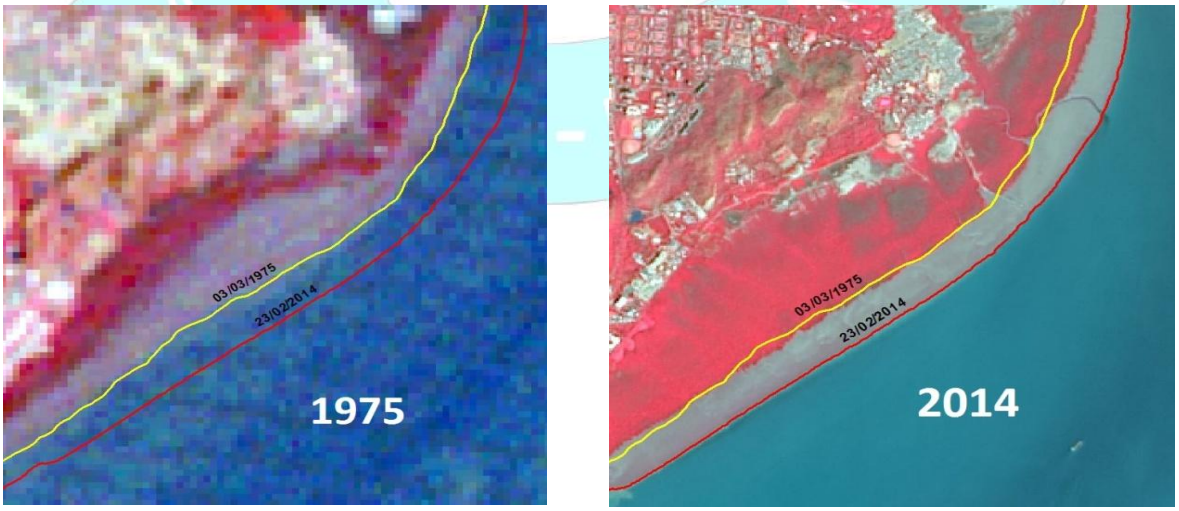


Fig. 4.42. Low tide lines of the years overlaid on the source satellite images in the highest accreted region

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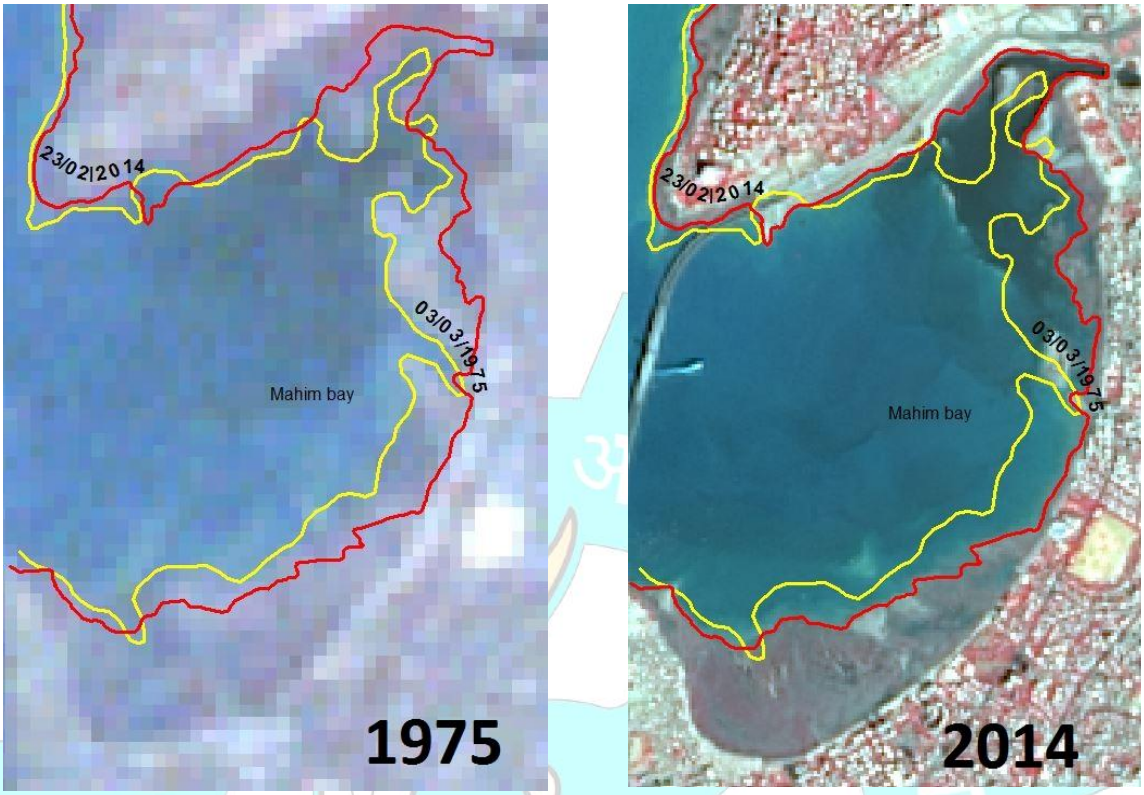


Fig. 4.43. Low tide lines of the years overlaid on the source satellite images in the Mahim region

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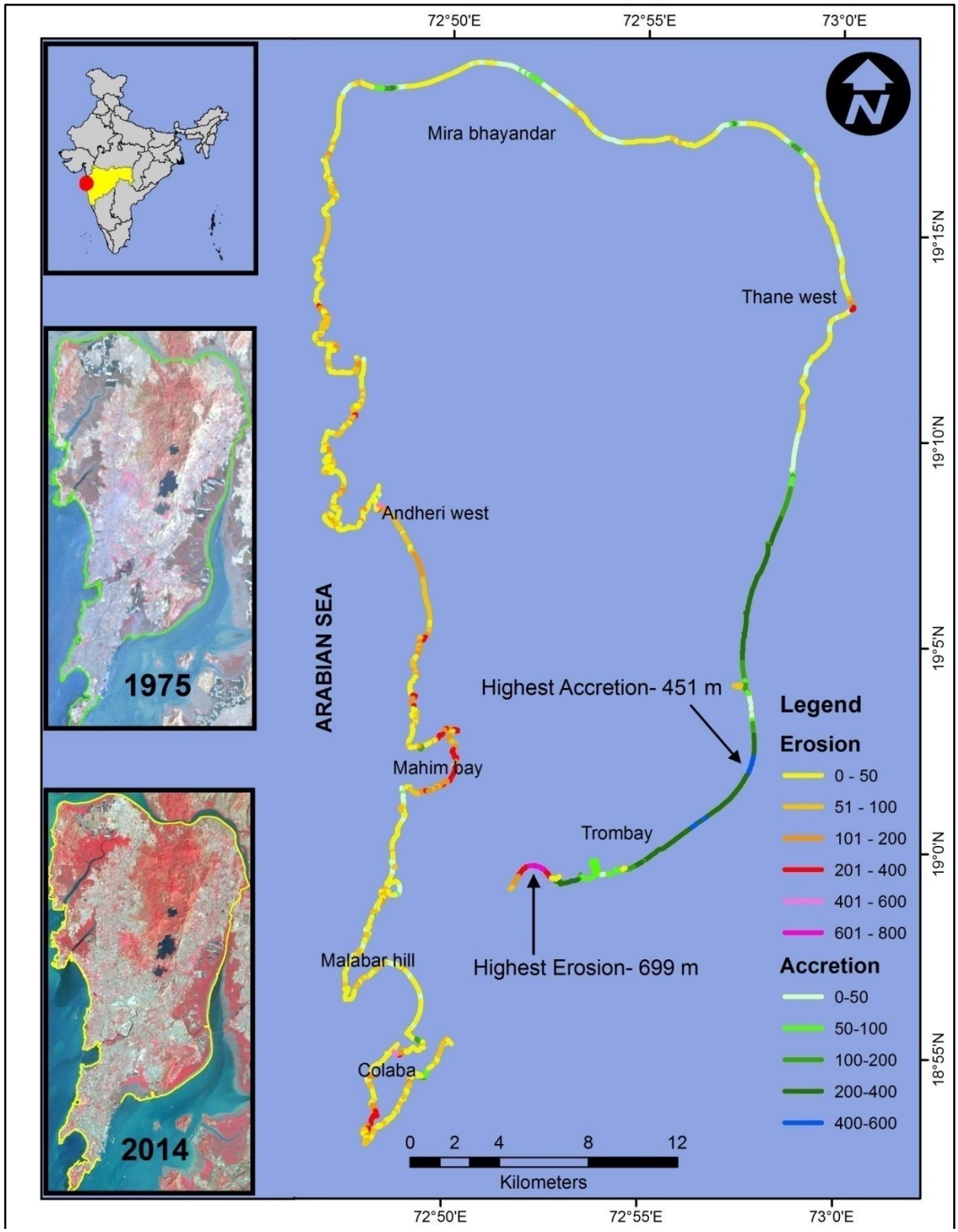


Fig. 4.44. Low tide line change from 1975 to 2014

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4.4.22 Impact of reclamation activity on Mahim bay

In the northern side of Mahim bay, land is reclaimed as part of the Bandra- Worli sea link and its recreation activities. This reclamation is occurred in between 1999 and 2000. In this study we tried to identify the impacts of this reclamation activity on Mahim bay. Figures shows the shoreline changes before and after the reclamation. Before reclamation, 120 m of accretion is observed in the rounded region from 1972 to 1998 (26 years). After the reclamation 35 m of erosion is observed in the same region from 1998 to 2015 (17 years).



Fig. 4.45. Shoreline change observed before and after reclamation for Bandra – Worli sea link construction

Erosion observed in Mahim bay, near Mithi river is found to be triggered by the construction of Bandra- Worli sea link. On high tide, the water tries to enter to the reclaimed region as before the reclamation. Because of the reclaimed land mass, the water distracts towards the Mithi river side and with the presence of the river again the water flow redirects towards the southern side of the Mithi river. This action could be the reason for the erosion observed where accretion was observed before the construction of the sea link. This erosion can be controlled by constructing an artificial bund under the sea water. This can act as a barrier to prevent the sand transportation.

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4.4.23 Sea level rise of 1 m

Sea Level Rise (SLR) of 1 m may inundate 57.21 km^2, in which more than 50% of the areas are mangroves or mudflat regions (Fig. 4.40). It's really serious to know that 9.5 km^2 (17%) of the vulnerable region are falling in built-up land. Most of the vulnerable built-up regions are located in the northern sides near Mira bhayandar.

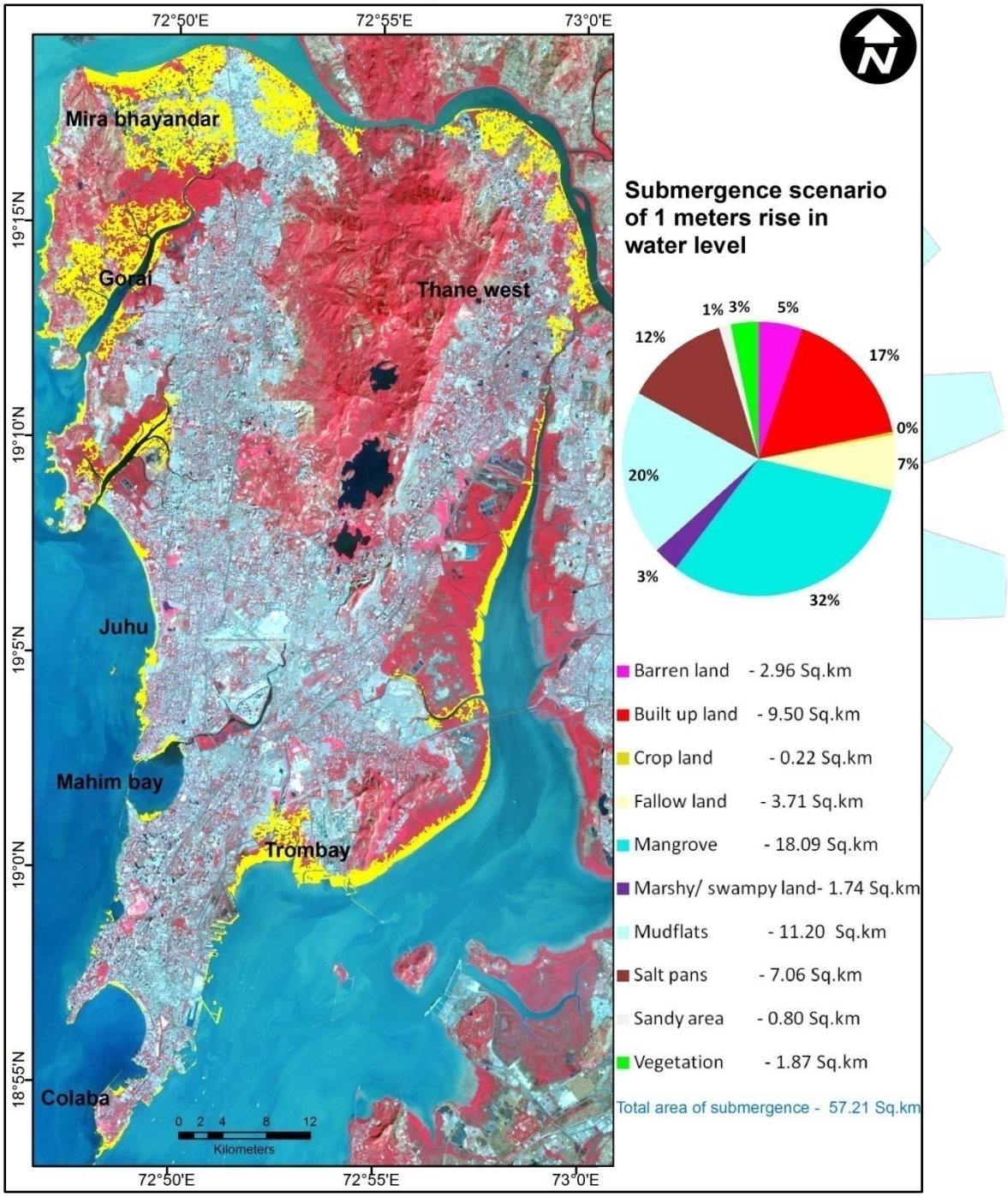


Fig. 4.46. Inundation map of 1 m rise in the sea level

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4.4.24 Sea level rise of 2 m

SLR of 2 m may cause inundation of 91.74 km^2. In which 16.15 km^2 (18%) of built-up land is included. 31.04 km^2 (34%) of the vulnerable region is mangrove covered region (Fig. 4.41). Most of the mangrove covers around the study area are vulnerable to the SLR. This can affect the mangrove forest adversely (R J Nicholls & A Cazenave, 2010).

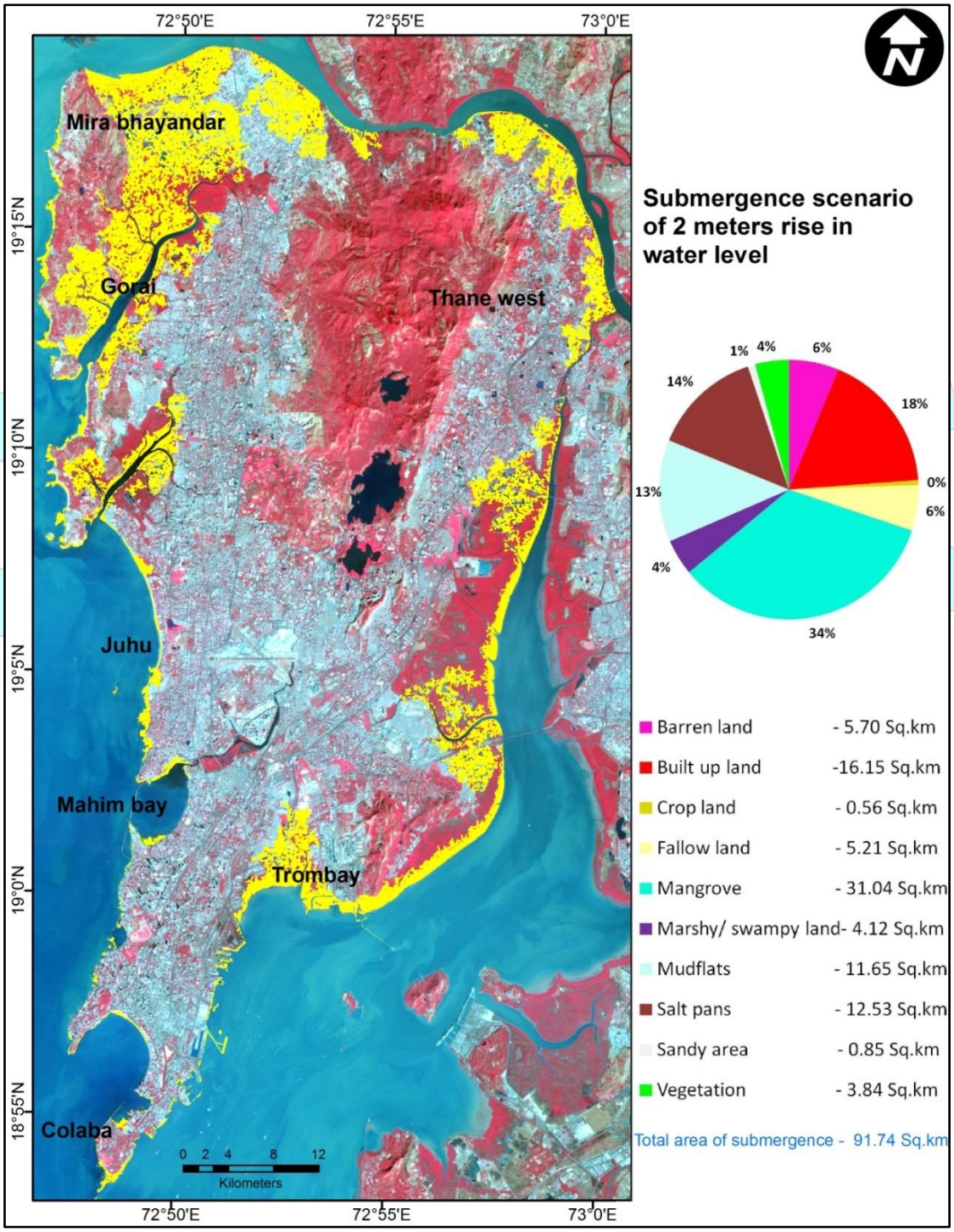


Fig. 4.47. Inundation map of 2 m rise in the sea level

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4.4.25 Sea level rise of 3 m

With extreme situation of 3 m SLR, the probable inundation area is 134.09 km^2 (Fig. 4.42). the percentage of built-up land and mangrove regions covered in the total vulnerable region is increased by 2% and 3% respectively. The region above the Manori creek (NW) is likely to be isolated since the inundation through Mira bhayandar and through Malad creeks is getting interconnected. Mangroves all around the study area are likely to be inundated in this scenario. Mira Bhayandar region is found to be the most vulnerable in this scenario since it has dense built-up areas.

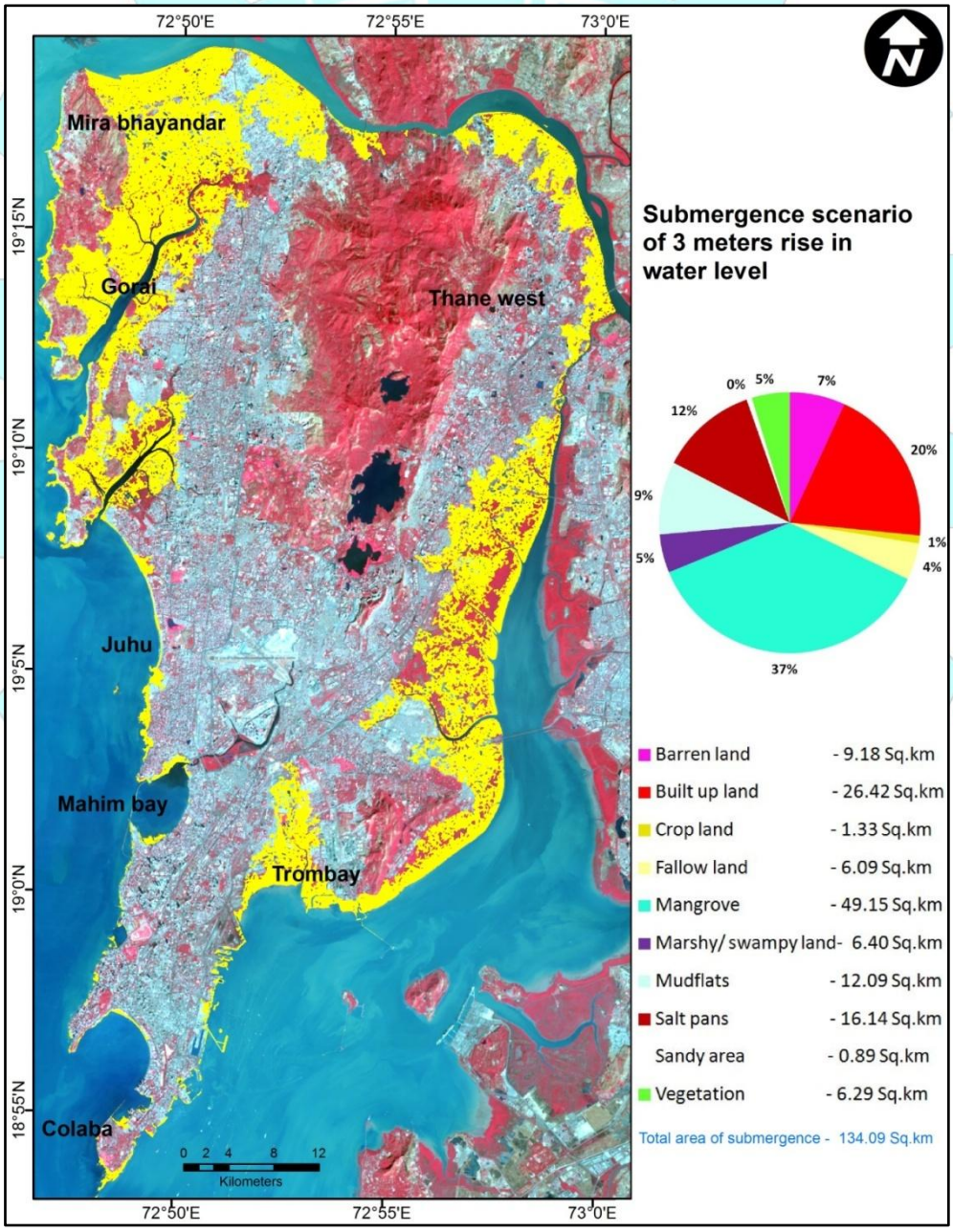


Fig. 4.48. Inundation map of 3 m rise in the sea level

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4.4.26 Possible shoreline changes due to proposed plan in Mahim Bay

Possible shoreline changes which may occur on the implementation of the proposal for creation of sweet water lake by constructing a bund/ dyke at the mouth of the Mithi river, by collecting and storing fresh water during Monsoon is explained here. The bund which is proposed to restrict the tide water would become the man-made shoreline for this region. The shoreline will be shifted towards the sea side along sea-ward side of the bund. The maximum change of more than 2 km in the shoreline is expected in Mahim bay. Present shoreline in Mahim bay will become the landward boundary of freshwater reservoir(Fig. 4.43).

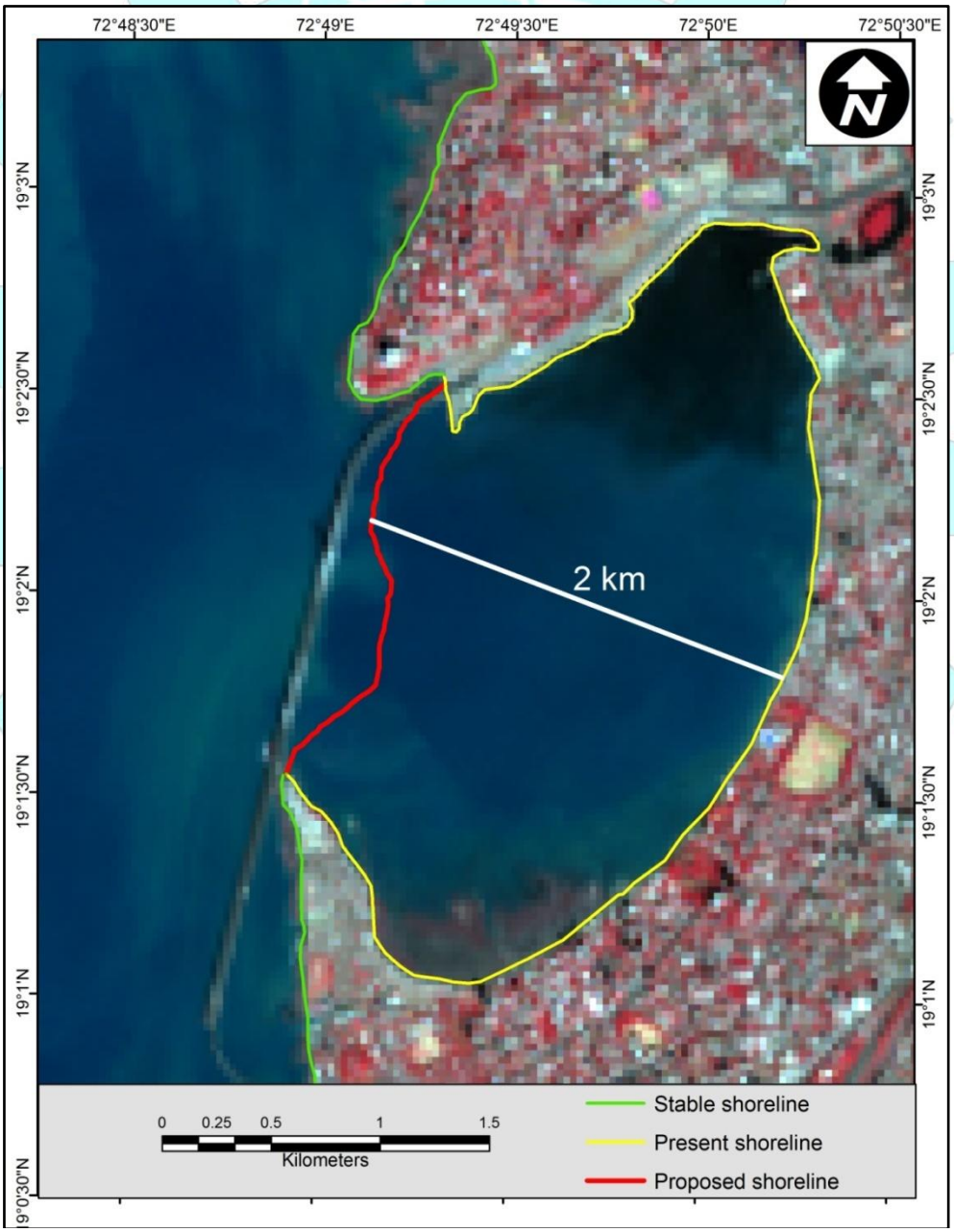


Fig. 4.49. The possible shoreline change on implementation of the plan in Mithi river

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4.4.27 Possible shoreline change due to proposed plan in Cuffe parade

Reclaiming Cuffe parade will certainly alter the present shoreline(Fig. 4.44). The proposed plan is to create more land through reclamation to expand the land mass towards sea. The maximum shoreline change of 350 m is observed in the northern region of the Cuffe parade. Most of the other coastal stretches of this region shows accretion of 100 to 200 m

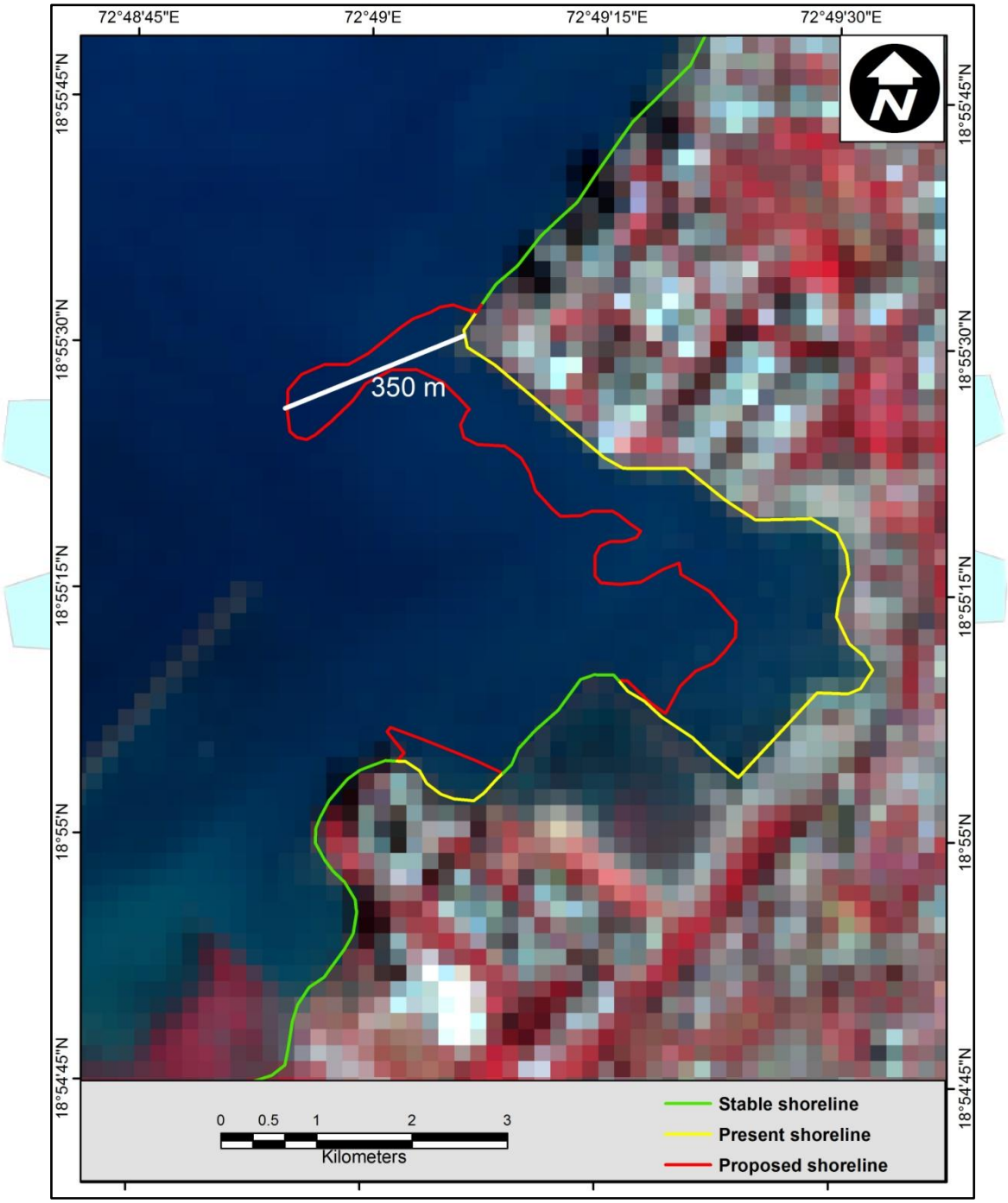


Fig. 4.50. Possible shoreline change on implementation of proposed plan in Cuffe parade

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4.4.28 Possible shoreline change due to proposed plan for coastal road

Coastal road project involves reclamation at few patches based on the alignment given. It will change the shoreline while implementing this plan. Around 1.47 sq.km of land has to be reclamied for the establishment of the coastal road. Which will create 1.93 km of extra shoreline to the current length of shoreline. The maximum change in shoreline is estimated around 440 m on the Juhu beach. Red line represents the shoreline after implementing the proposed plan; yellow representing the present shoreline and Green represents the shoreline which will not be affected on the implementation of the plan for the coastal road.

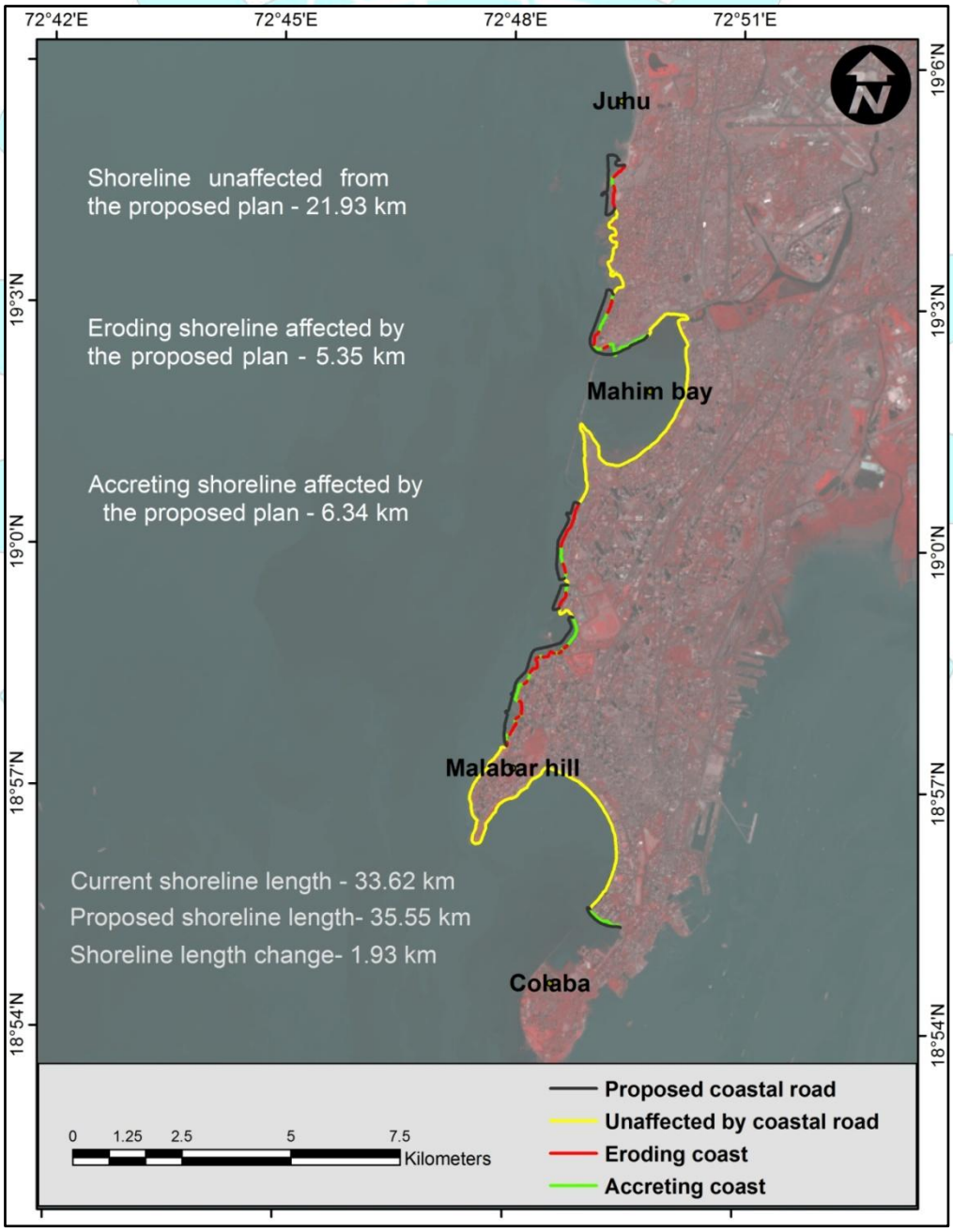


Fig. 4.51. Possible shoreline change in on the implementation of planned coastal road

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4.5 Conclusions

This study states that the coastal area in Mumbai has undergone different levels of erosion and accretion. The major observations from the studies are

- The mangroves located in the eastern parts of the study area, along the Thane creek have increased.
- The mudflat deposition has also increased in the same region where the mangroves have grown.
- Mudflat depletion is observed on most of the regions except south-east. The mudflat depletions are at Mahim bay, Mahul creek and on the south tip of the study area.
- Open coast regions (western side) have mostly eroded.
- The maximum erosion prone region is from Andheri west to Juhu beach.
- The bund built in the south-east region, near Trombay resulted in high accretion.
- Sea Level Rise (SLR) may cause flooding of large tracts of land all around the Mumbai region and the mangroves. Within the vulnerable regions, large amount of built-up lands are at high risk.
- Mira Bhayandar region (NW) is the highest vulnerable region due to SLR.

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Chapter 5

5 MEASUREMENTS

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5.1 Introduction

This chapter comprises of the methodology adopted, instruments used and the results of the measurements carried out to assess the impact of the selected reclamation works on the Mumbai coast. To assess the likely impacts due to proposed changes in the coastline, it is essential to understand the existing conditions of the study region. Therefore, measurements were carried out to ascertain the prevailing physical processes which are critical and which are likely to be affected due to proposed reclamation projects. The physical processes measured are water currents, tidal variation and wave parameters. These parameters were measured using offshore instruments deployed in the study region. The field measurements were carried out at two locations, viz., (a) one inside Backbay region and (b) one location off Mahim bay region. These locations were selected based on the water depths available for deployment of equipment as well as considering the navigational hazards and warnings as provided in the Naval Hydrographic Office (NHO) charts for Mumbai region.

5.1.1 Instruments used

State of the art marine instruments capable of measuring wave height, wave period, wave direction, current speed, current direction and water level variation were deployed at a location offshore of Mahim bay in water depth of 5m and another location inside the Backbay area (Fig. 5.1) in 5m depth.

The marine equipments that were deployed in this study are InterOcean® -S4DW directional wave, tide and current measuring instrument, AquiStar® pressure transducers capable of measuring the water level variations and Aanderaa recording current meters (RCM9/11) capable of measuring the flow speed and flow direction. These marine instruments were deployed with the help of fishing trawlers and watch keeping boats were anchored in the vicinity of these instruments during the study. The data obtained from these measurements were further analysed to ascertain the local hydrodynamics conditions. These measurements were used to validate the hydrodynamic numerical model.

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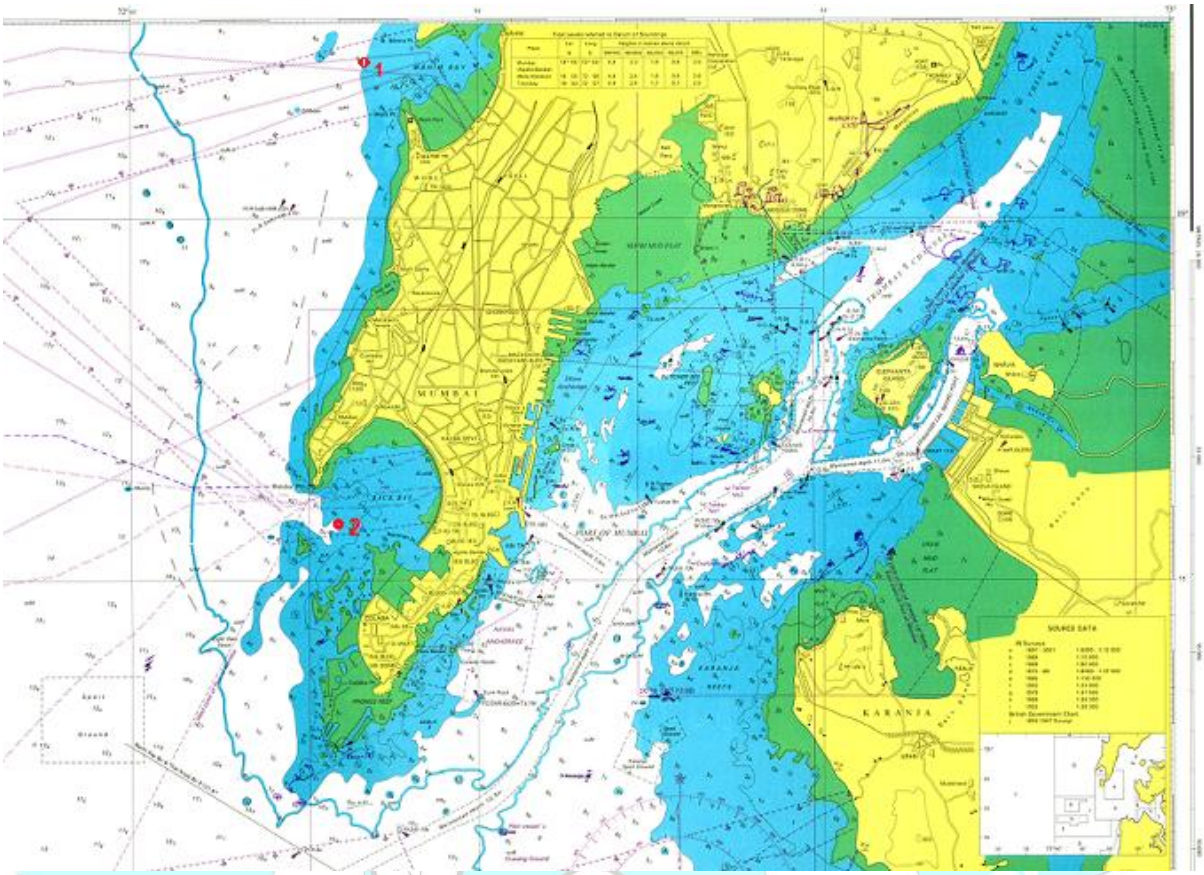


Fig. 5.1. Locations of field measurements overlaid on NHO chart

5.2 Results

The results of the measurements carried out in the study region on waves, tides and currents are presented in this section. The measurements off Mahim were carried during 21st November to 10th December 2014 off Mahim. And the measurements off Colaba were carried out between 25th November 2014 and 17th December 2014. Although, all the instruments were deployed during the same period at each location, useful wave and tide data of about one week only could be obtained off Colaba due to the instruments getting buried in the seabed due to very soft clay seabed. However, the current measurements which are critical in this study were obtained for all the measurement locations.

5.2.1 Waves

The significant wave height off Mahim during the measurement period varied between 0.17m and 1.04m and maximum wave height varied from 0.26 to 1.62m. The variations of significant wave height (H_s), maximum wave height (H_{max}) are presented in Fig. 5.2. The

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mean wave period varied between ~4s and 8s. The mean wave period (T_z) and the wave period corresponding to maximum wave height (T_{max}) are presented in Fig. 5.3. The variation of wave direction off Mahim during the measurement period is shown in Fig. 5.4. The predominant wave direction is observed to be from west for location off Mahim whereas it is observed to be predominantly from south at Colaba, which could be due to the waves refracting at this location. The spectral width parameter is observed to vary between 0.3 and 0.9 (Fig. 5.5).

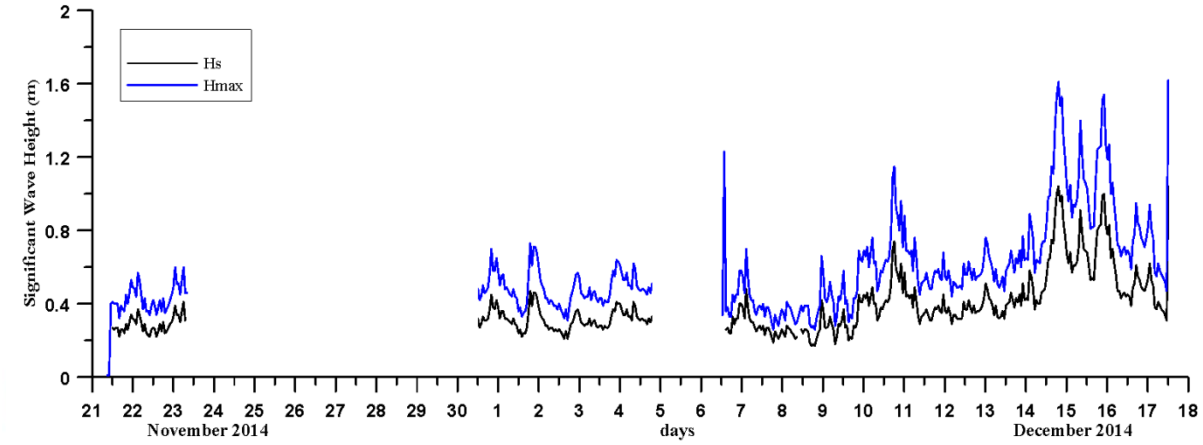


Fig. 5.2. Variation of significant wave height (H_s) and maximum wave height (H_{max}) off Mahim.

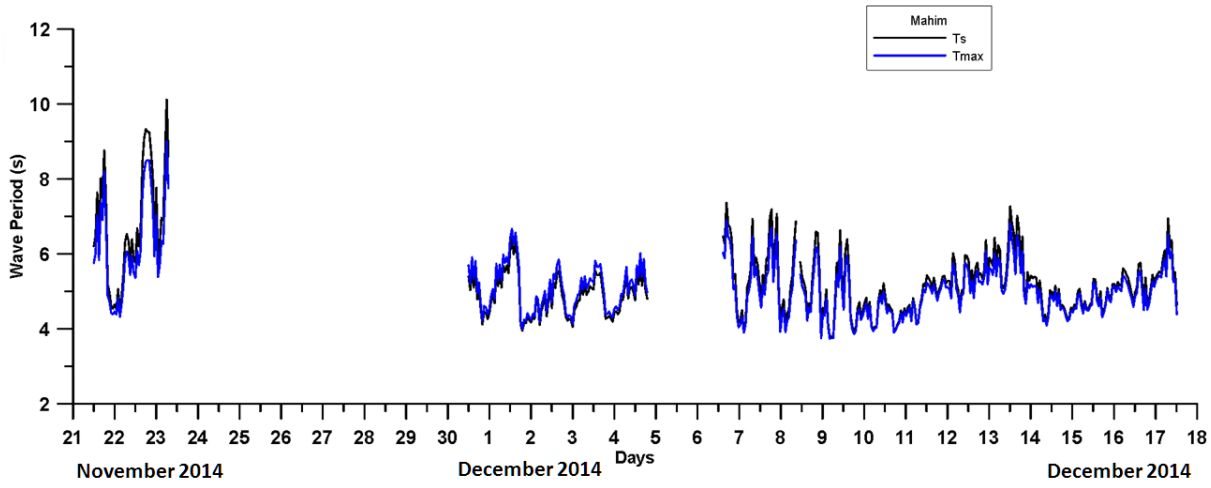


Fig. 5.3. Variation of mean wave period (Tz) and wave period corresponding to maximum wave height (Tmax) off Mahim

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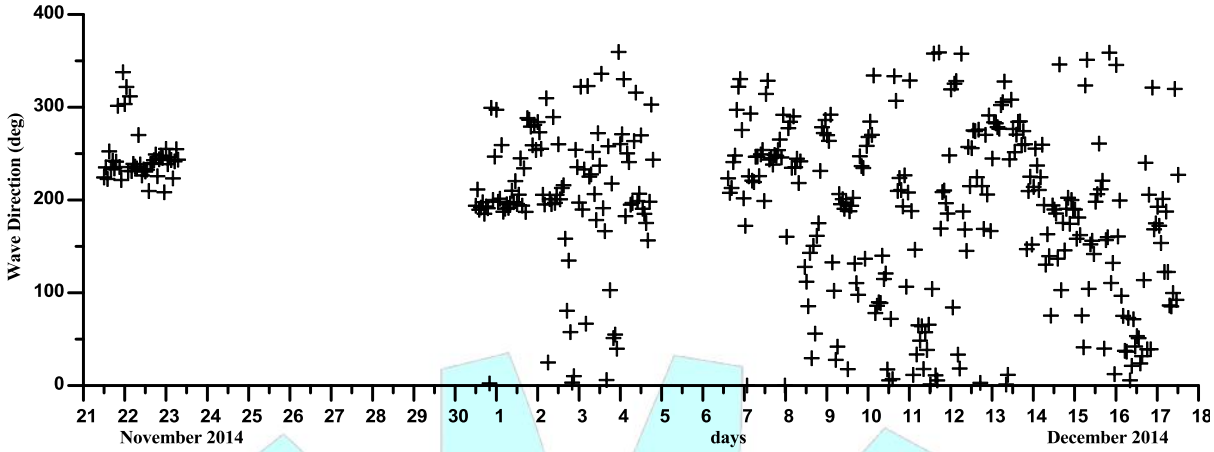


Fig. 5.4. Variation of wave direction off Mahim

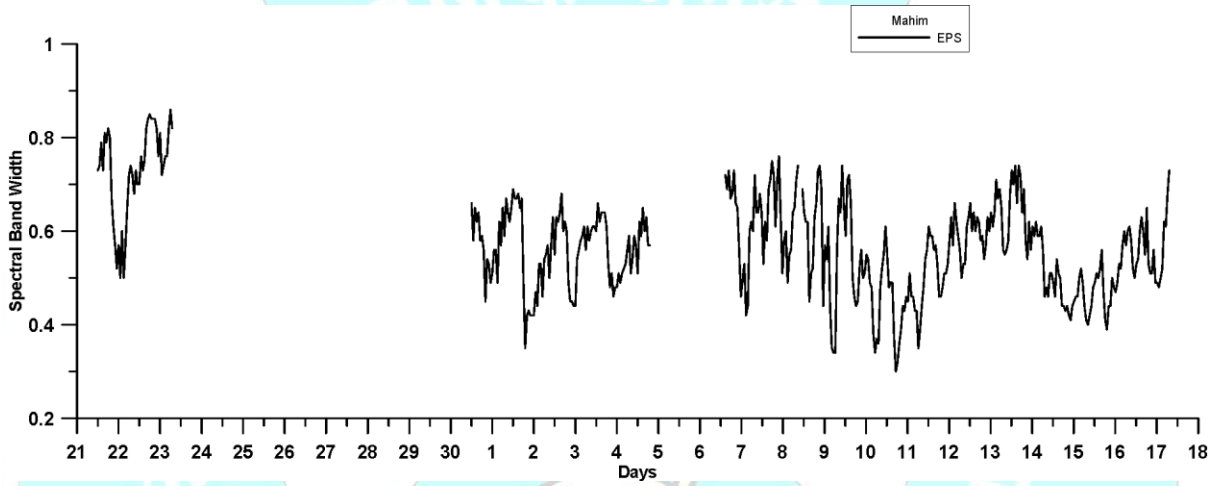


Fig. 5.5. Variation of wave Spectral band width off Mahim

The wave measurements off Colaba showed that the significant wave height varies between 0.07m and 0.8 m and the maximum wave height varies between 0.11m and 1.2m. The variations of significant wave height (H_s) and maximum wave height (H_{max}) are shown in Fig. 5.6. The mean wave period was observed to vary between 3.8 and 6.7s. The variation of mean wave period (Tz) and wave period corresponding to maximum wave height (Tmax) are shown in Fig. 5.7. The spectral width parameter is observed to vary between 0.35 and 0.75 (Fig. 5.9). The wave parameters off Mahim and Colaba are tabulated in Table. 5.1.

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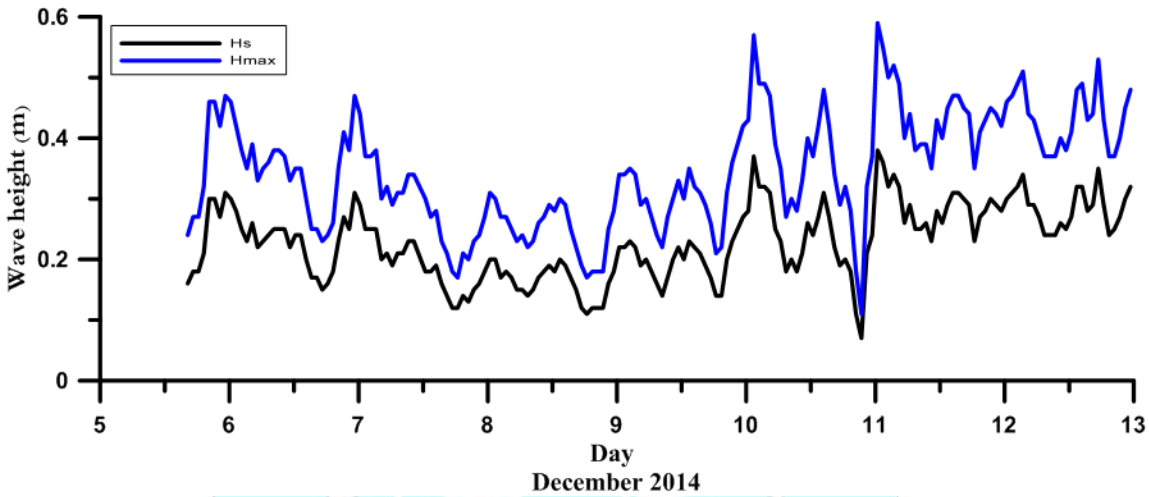


Fig. 5.6. Variation of significant and maximum wave heights off Colaba

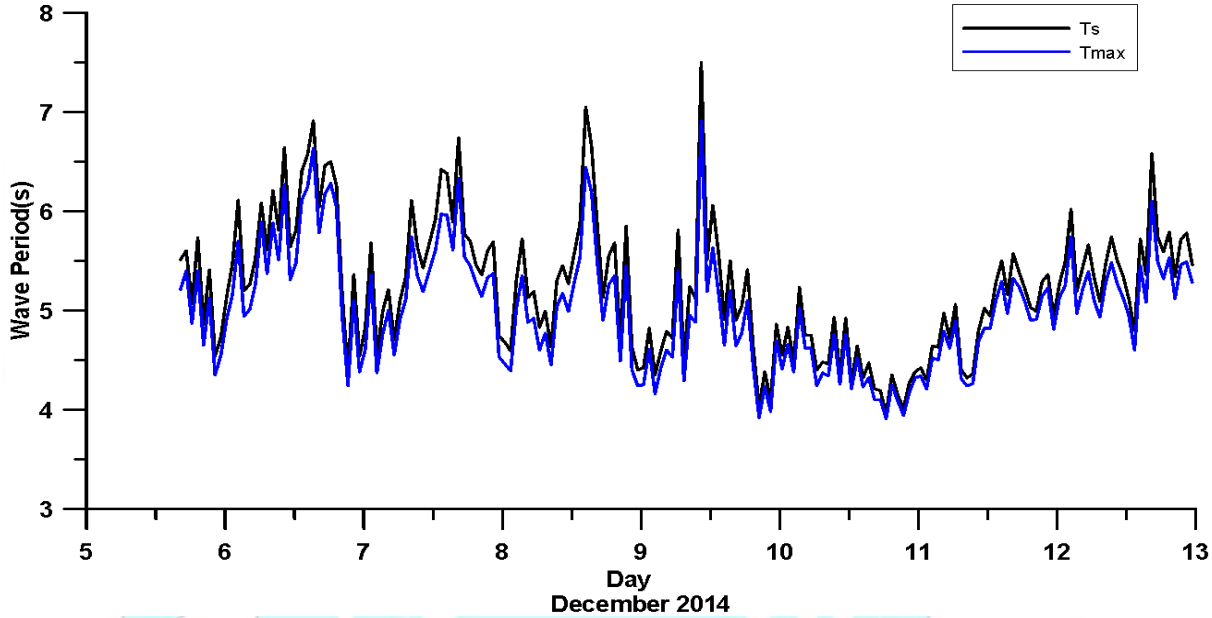


Fig. 5.7. Variation of mean and maximum wave periods off Colaba during December 2014

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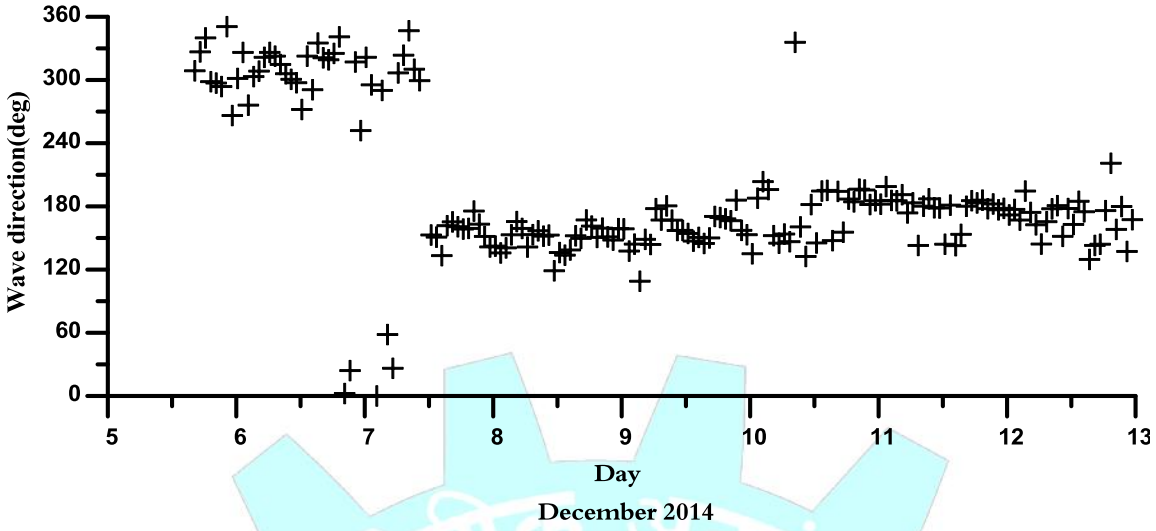


Fig. 5.8. Variation of wave direction off Colaba during December 2014

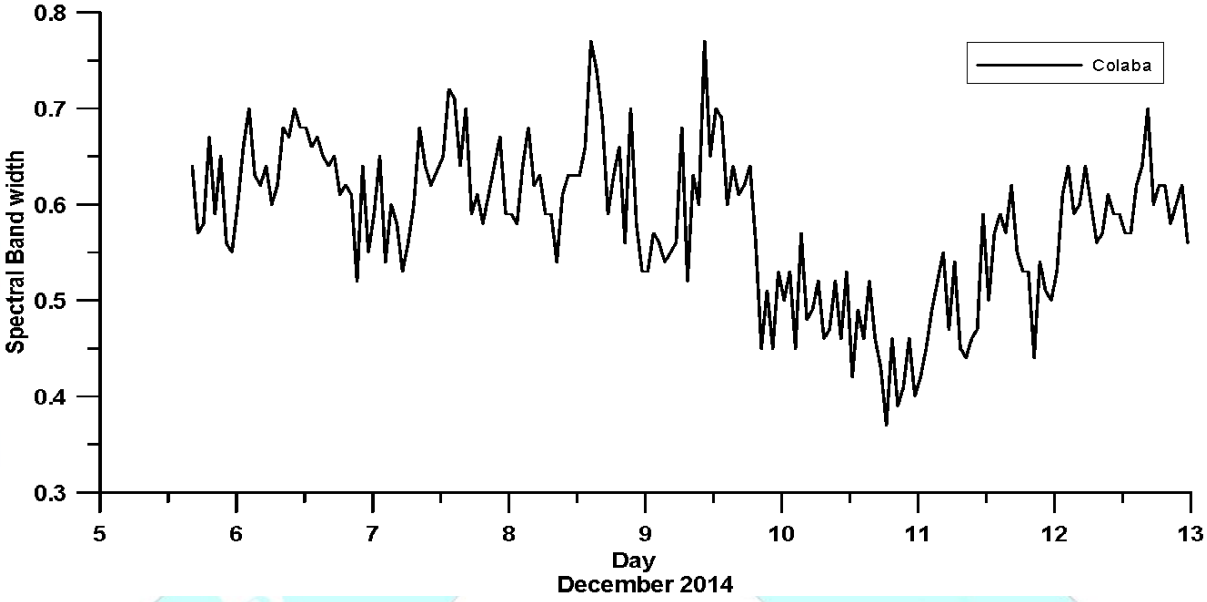


Fig. 5.9. Variation of wave Spectral band width off Colaba during December 2014

Table 5.1 Minimum, maximum and average values of wave parameters off Mahim.

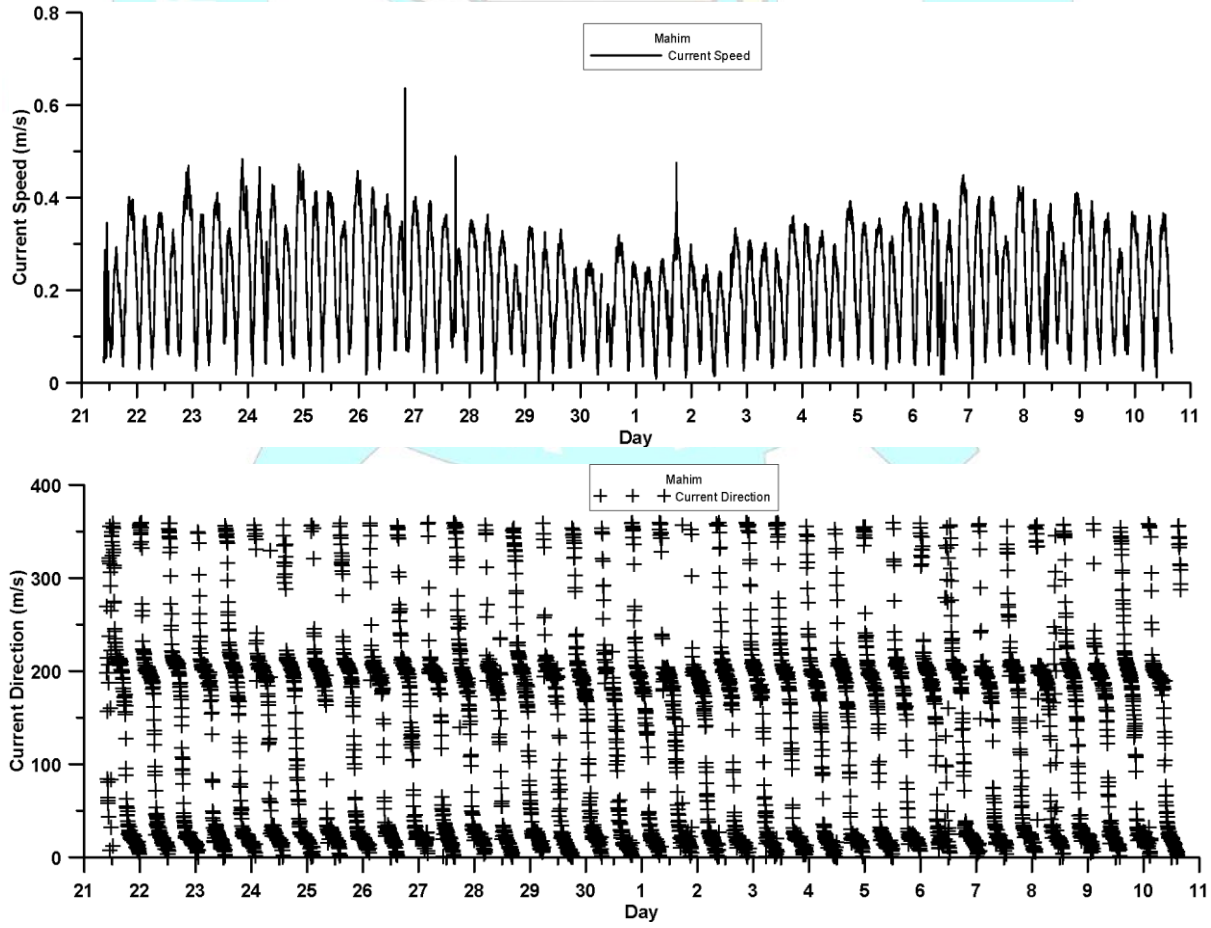
Wave Parameter	**Mahim**			**Colaba**		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Hs (m)	0.17	1.04	0.39	0.07	0.81	0.23
Hmax (m)	0.26	1.62	0.59	0.11	1.20	0.35
Tz(s)	3.63	8.06	4.84	3.84	6.68	5.02
Tmax(s)	3.74	9.00	5.09	3.96	7.45	5.28
Spectral width parameter	0.30	0.90	0.60	0.40	0.80	0.60

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Based on the wave measurements during the November-December 2014 (post monsoon season), the wave climate off the study region in general is ascertained. The wave heights at Colaba are comparatively lower than at Mahim, which is due to the reason that location where measurements off Mahim were carried out is directly exposed to the open sea conditions. Whereas at the Colaba measurement site, the waves tend to get dissipated due to shoaling and dissipation, this is a cause for reduced wave climate at the Colaba measurement location.

5.2.2 Currents

Water currents were measured off Mahim at mid depth in water depth of 8m below Chart Datum (CD). The maximum and average current speed was of the order of 0.63m/s and 0.22m/s respectively. The current speed and direction measured are presented in Fig. 5.10. The currents in this region are tide dominated with the current direction varying with tide. The current rose plot (Fig. 5.11) show clearly that the flow is predominantly tide driven with the flow being NNE - SSW direction.



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Fig. 5.10. Variation of current speed and direction off Mahim

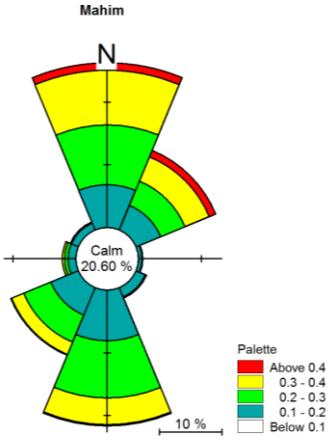


Fig. 5.11. Current rose plot off Mahim

Variation of currents measured at Colaba in water depth of 7m CD is shown in Fig. 5.12. The maximum current speed was of the order of 0.3 m/s and the average current speed was of the order of 0.11 m/s. The currents are tidal driven with the direction changing with tide as can be seen from the current rose plots (Fig. 5.13).

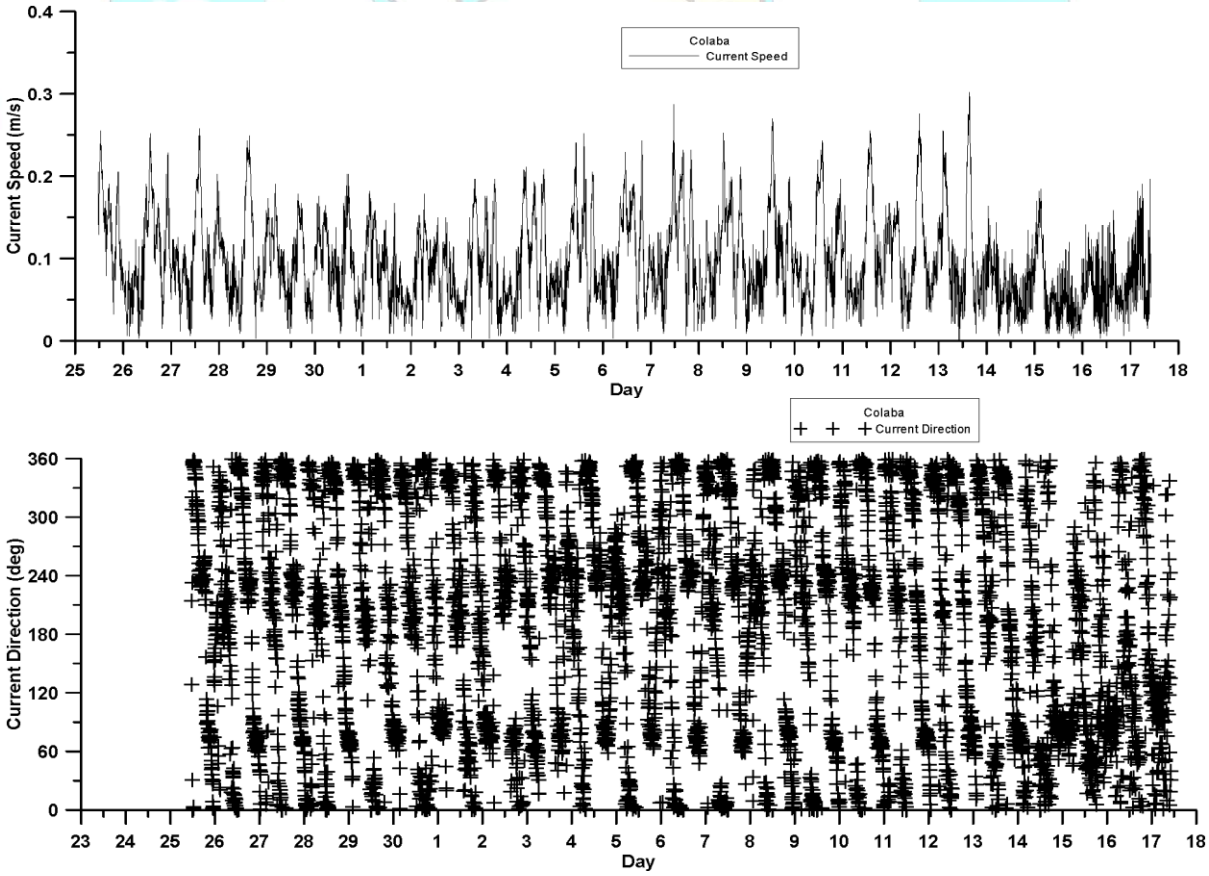


Fig. 5.12. Variation of mid depth current speed and direction off Colaba

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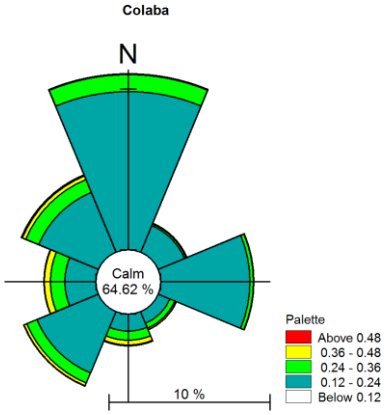


Fig. 5.13. Current rose plot off Colaba

The measured currents were analysed further to ascertain the influence of tidal and non-tidal tidal forces acting on the hydrodynamic conditions of the study area. The measured currents off Mahim were resolved into east and north components (Fig. 5.14) and were subjected to tidal analysis and the tide induced currents are shown in Fig. 5.15 and the non-tidal currents are shown in Fig. 5.16. Similarly the measured currents off Colaba were resolved into the north and east components (Fig. 5.17) and were subjected to tidal analysis of currents to obtain the tidal current components (Fig. 5.18) and non-tidal current components (Fig. 5.19).

The tidal current components off Mahim, especially the dominant north components were of the order of ± 0.4m/s whereas the non-tidal components were of the order of ± 0.125m/s, whereas at Colaba the north tidal current components were of the order of ± 0.2m/s and the non-tidal components were of the order of ± 0.05m/s. Based on the analysis of measured currents off Mahim and Colaba, it is observed that the flow in the study region is primarily influenced by tides as the tidal components are larger than the non-tidal components.

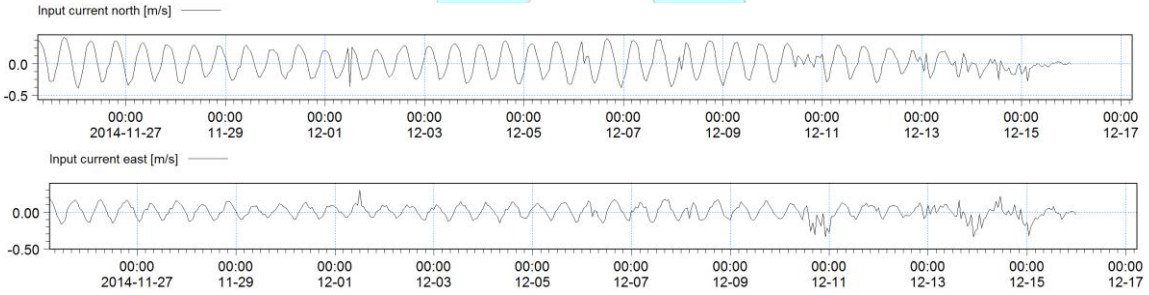


Fig. 5.14. North and east components of measured currents off Mahim

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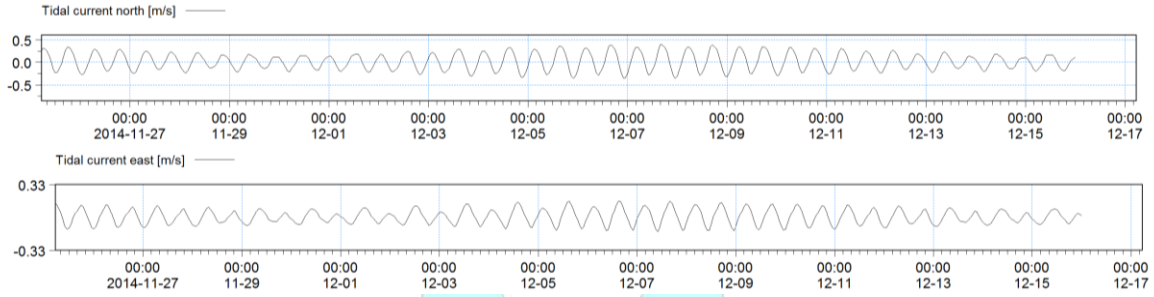


Fig. 5.15. Tidal component of measured currents off Mahim

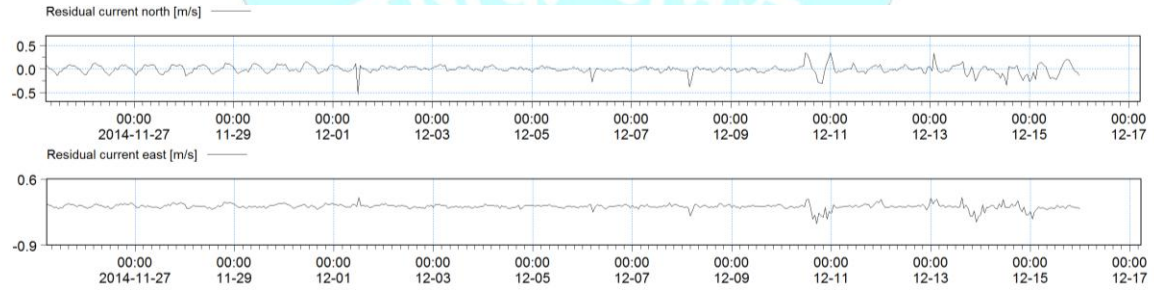


Fig. 5.16. Residual currents (non-tidal component) off Mahim

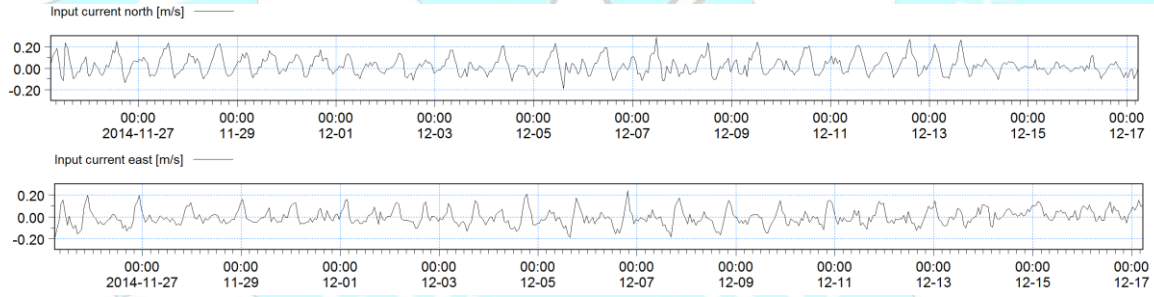


Fig. 5.17. North and east components of measured currents off Colaba

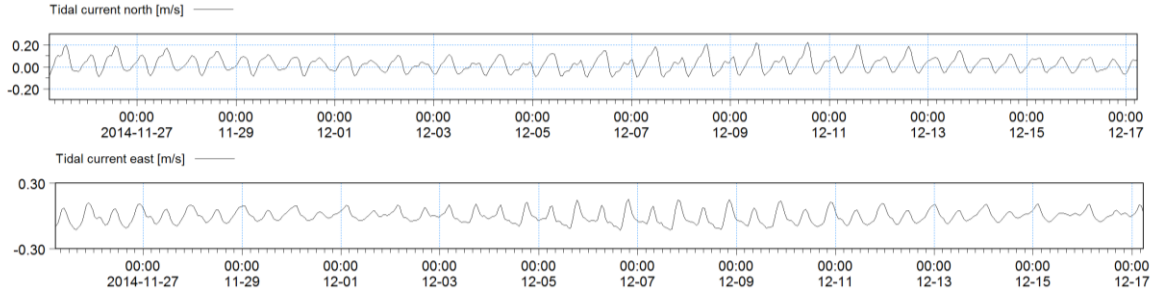


Fig. 5.18. Tidal component of measured currents off Colaba

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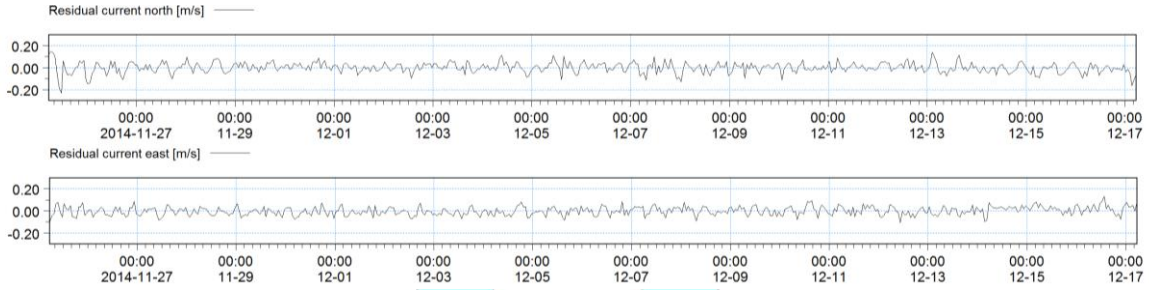


Fig. 5.19. Residual currents (non-tidal component) off Colaba

5.2.3 Tides

The variation in measured water levels off Mahim and Colaba are presented in Fig. 5.20 and Fig. 5.21 respectively. The tides are semi-diurnal in nature. The spring tide range from the measured data is found to be 4.13 m and the neap tide range is about 1.01 m. The tidal elevations at Mahim and Colaba were of the same order of magnitude.

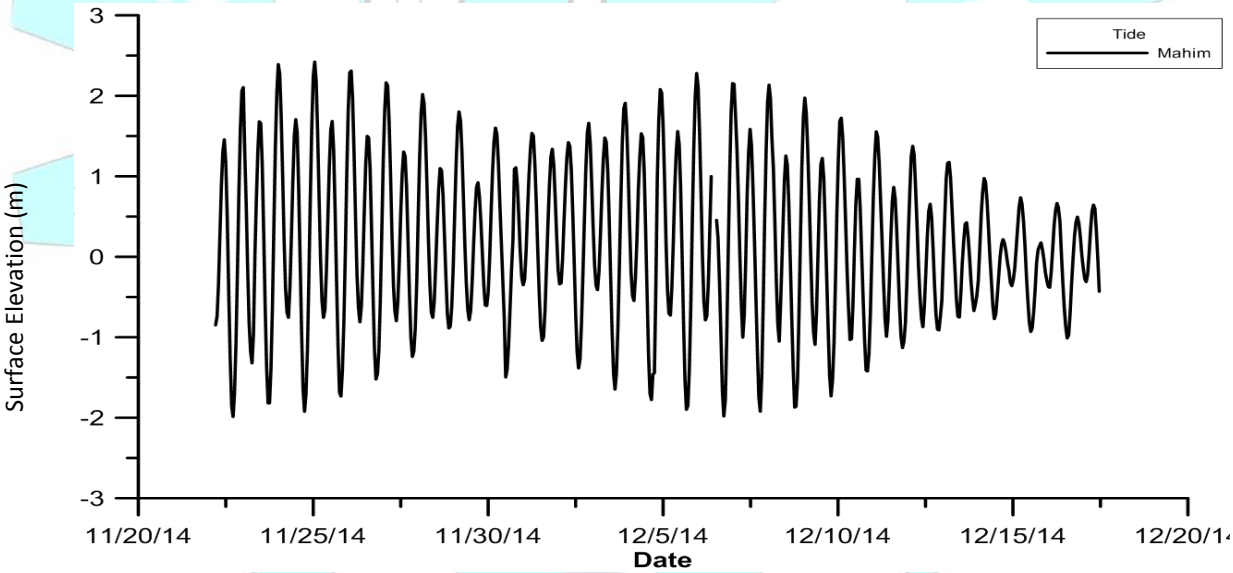


Fig. 5.20. Variation of Tide off Mahim

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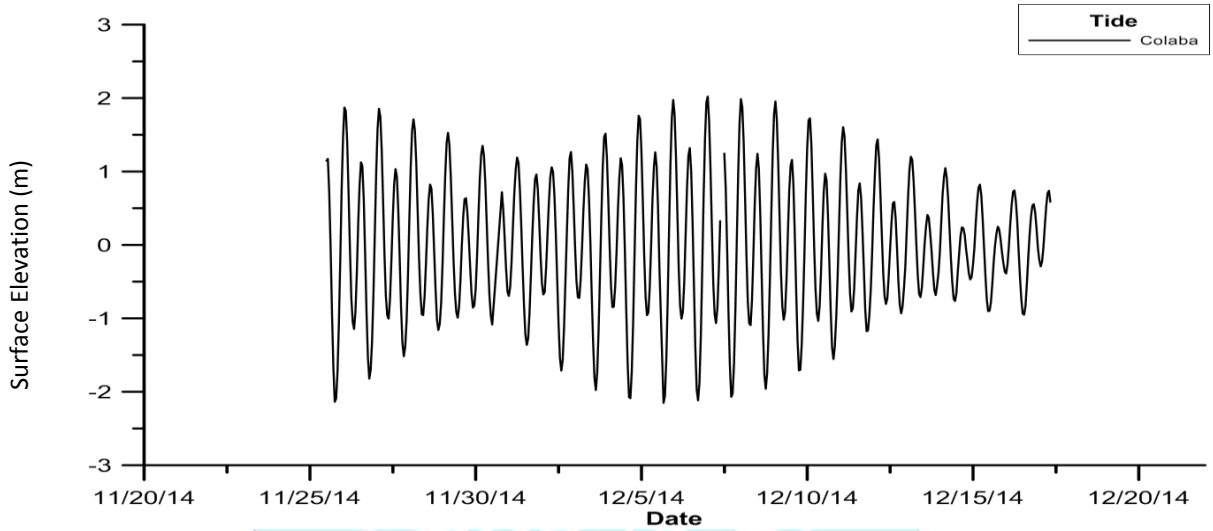


Fig. 5.21. Variation of Tide off Colaba

5.2.4 Winds

Winds were measured at 8 m water depth on board the watch keeping boat. The variation of wind speed and direction during the measurement period is shown in Fig. 5.22. An average wind speed of 2.55 m/s and a maximum wind speed of 9.4 m/s averaged over 1 minute are observed during the measurements. The wind direction was in the sector between east-north and north-northwest with the high winds coming along the shore about 250°N (Fig. 5.23). Negligible winds were seen coming from south, southeast or southwest sectors.

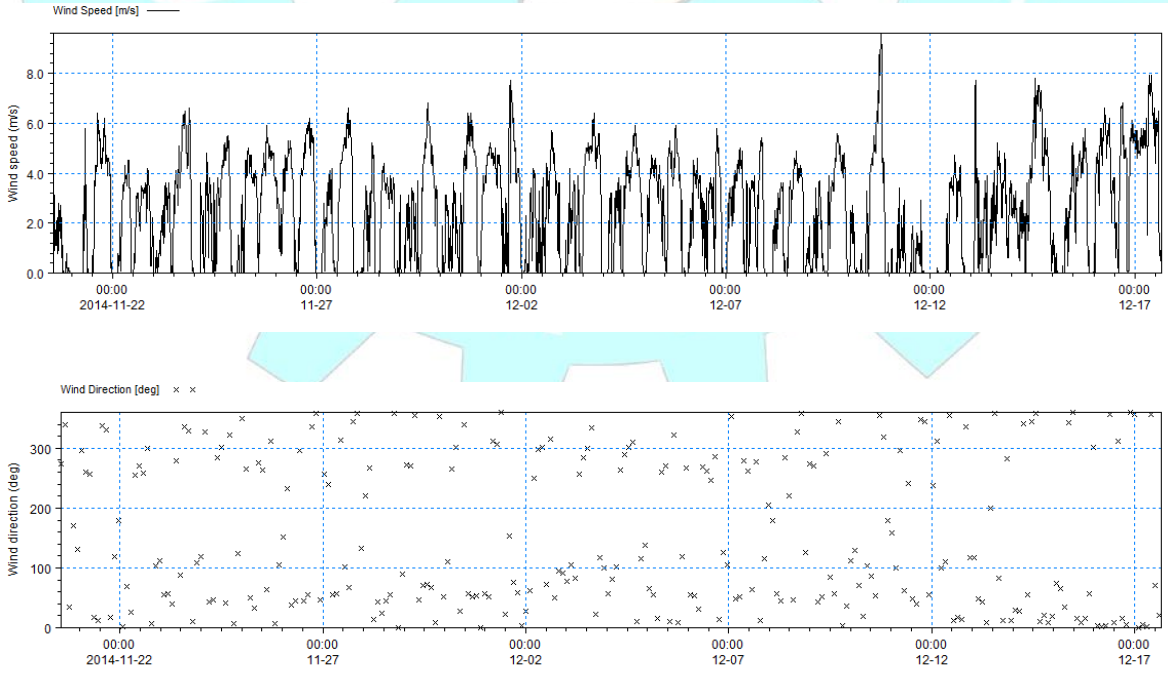


Fig. 5.22. Variation of wind speed and direction in the study region

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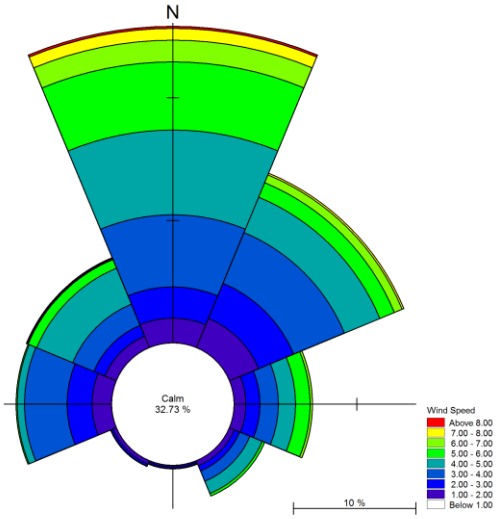


Fig. 5.23. Wind rose plot

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5.3 Conclusions

- Measurements on tides, currents and waves were carried out for a period covering two weeks at two locations in the study region to ascertain the hydrodynamics of the region. The locations considered were off Colaba and off Mahim Bay in water depths about 8m. The measurements were carried out during post-monsoon period. However, during monsoon periods the waves and currents would be of higher magnitude than that reported here.
- Tides measured at two locations in the study region are semi-diurnal in nature with the spring tide range being 4.13m and the neap tide range about 1.01m for the measurement duration. The tides off Mahim Bay and off Colaba were found to be of similar magnitude and phase indicating that the region of study has similar tidal conditions.
- The waves measured off Mahim during the measurement period observed a maximum wave height of about 1.6 m off Mahim and about 0.6m off Colaba. The waves off Mahim are higher due to direct exposure to open sea whereas the waves off Colaba region are lower due to the dissipation of waves before they reached the measurement location.
- Currents measured at the two locations showed diurnal variation influenced by the tides. Analysis of currents showed tidal dominance and to a lesser extent influence from non-tidal factors. Current direction off Mahim showed predominant north-south direction along with NE-SW component whereas off Colaba it was in all directions indicating eddy type currents.
- Winds were measured off Mahim and the average winds were about 2.5m/s and a peak of 9.4m/s was observed during measurements. The predominant direction of wind was from north-northeast direction.
- Some of these measurements were used as input further in the numerical models used in the study to assess the impact of reclamation and the numerical model results were validated with the measurements and further used to study the impact assessment.

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