IMPACTS OF SEA LEVEL RISE ON COASTAL SINGAPORE

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ABSTRACT

This report examines projected inundation of Singapore under multiple sea-level-rise (SLR) scenarios (1 m, 3 m, 5 m). Using high-resolution elevation data and climate projections, we generate maps showing which areas would be flooded in each scenario. We then analyze the results for the entire island and two focus regions (central downtown and northern coast). Our findings indicate that even modest rises (1 m) would inundate extensive low-lying coastline, with major infrastructure (e.g. East Coast estates, Changi Airport, Marina Bay) at risk. Higher rises (3–5 m) dramatically expand the affected zone, threatening ports, industrial zones, and transport corridors. These results underscore the urgency of adaptation measures. All maps are provided with detailed interpretations to support policy and planning.

INTRODUCTION

Global warming-induced sea-level rise poses a significant threat to low-lying coastal cities. Recent studies project a global mean SLR of roughly 0.5–1.2 m by 2100 under mid-range scenarios, and up to 2.5 m under high-emissions trajectories. In Singapore, an island city-state, vulnerability is acute: roughly one-third of the land surface lies less than 5 m above current sea level. Prime economic zones – notably the Marina Bay waterfront and Jurong petrochemical island – occupy these low elevations. Singapore's National Climate Study also estimates mean sea-level rise of up to 1.15 m by 2100 under worst-case emissions, with extreme storms adding another 4–5 m surge. Low-lying districts such as Changi, Tuas and the East Coast are especially at risk. Given this context, mapping inundation extents for plausible SLR scenarios is critical for resilience planning. This study thus generates inundation maps for three SLR thresholds (1 m, 3 m, 5 m) covering: (A) **entire Singapore**, (B) **central coastal region (Marina Bay/Kallang)**, and (C) **northern coastal region (e.g. Sembawang/Punggol)**. Each scenario's map is accompanied by a concise interpretation of flooded zones and exposed infrastructure.

OBJECTIVES

The primary objectives of this project are:

1. To simulate and visualize the spatial extent of potential sea level rise (SLR) across Singapore under three scenarios: 1m, 3m, and 5m.

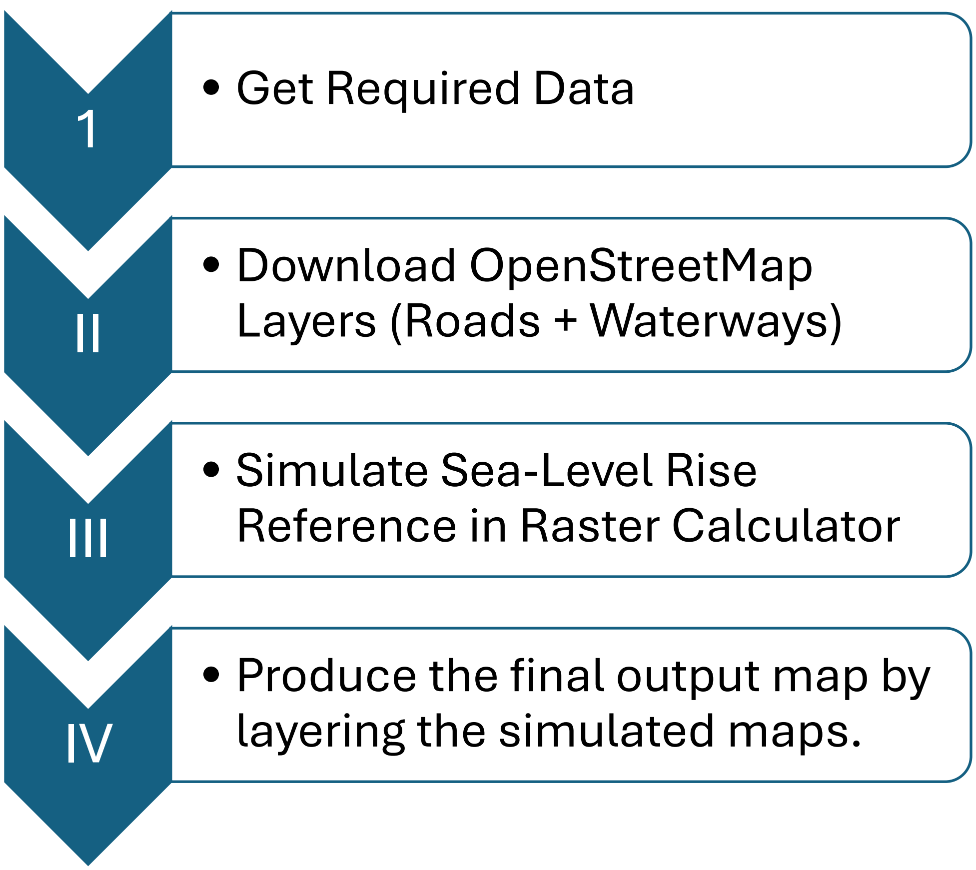
2. To identify and compare coastal areas of high inundation risk, particularly in the central and northern regions.

3. To produce a series of high-resolution geospatial maps that support public understanding, urban planning, and adaptive policy design.

4. To provide evidence-based insights that can inform the prioritization of coastal defense and flood mitigation strategies.

METHODOLOGY

We used a high-resolution digital elevation model of Singapore combined with SLR scenarios from climate models. Three rise thresholds (1, 3, 5 m above current sea level) represent mid-range to extreme projections. Inundation extents were defined as all land areas with elevation at or below each threshold. Maps were generated in GIS and overlaid to produce a combined-flood footprint. The overlay synthesizes incremental impacts (e.g. darker shades for higher rises). Results are organized by geographic scope (whole-island vs. selected regions). All maps and interpretations are evidence-based; for example, prior research indicates that areas like Marina Bay have subsided or are built at low elevation, justifying our focus on these zones. Citations from peer-reviewed and official sources (e.g. national studies) support our analysis.



RESULTS

Entire Singapore – SLR Impact Maps

A series of four figures (Figures 1–4) show projected inundation across Singapore for SLR of 1 m, 3 m, 5 m, and the combined overlay. Each figure is followed by an interpretation:

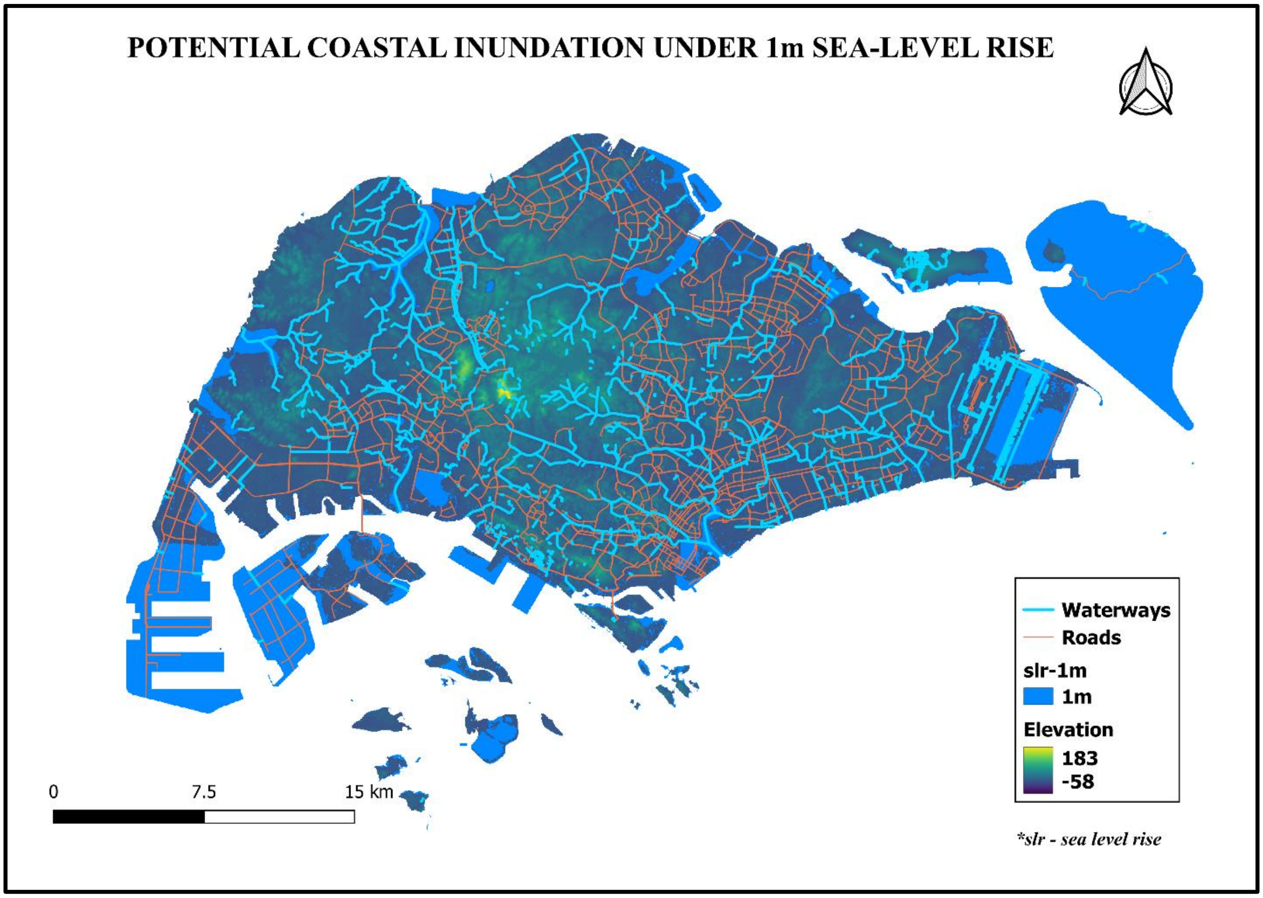


Figure 1: *SLR 1 m Inundation Map – Entire Singapore*

Interpretation: A 1 m rise (dark blue) floods only the very lowest-lying coasts and river mouths. Notable inundated zones include parts of the **East Coast** (e.g. east of Changi Airport) and river estuaries such as the Kallang and Geylang waterways. These areas correspond to reclaimed land and coastal plains presently at or near sea level. Critical infrastructure at immediate risk includes sections of Changi Airport's western taxiways, low-lying coastal parks and some road segments in Bedok/Tampines. Overall, the city core and most higher-elevation areas remain dry at 1 m, but the map highlights which coastal communities and transport links would already be affected by a modest rise.

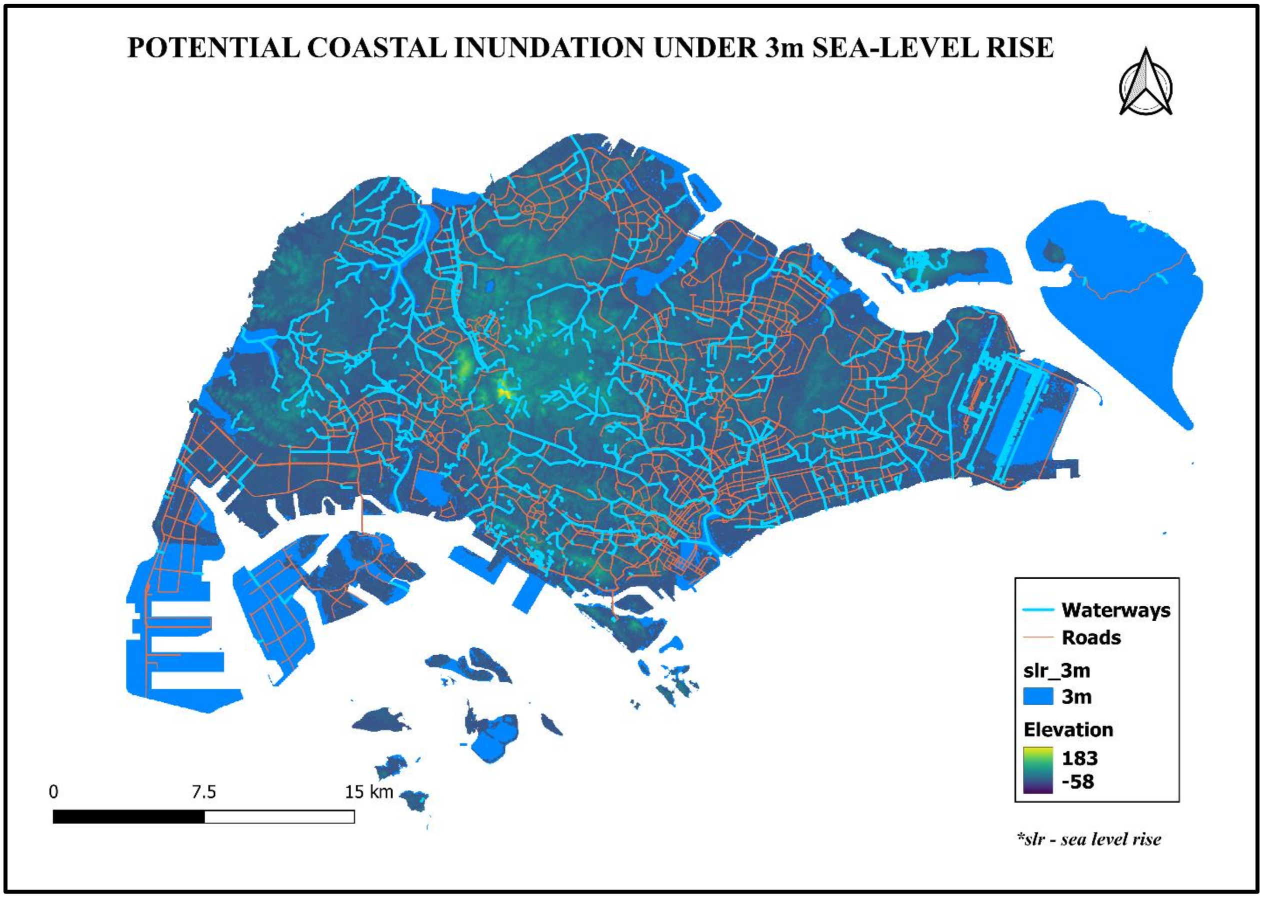


Figure 2: *SLR 3 m Inundation Map – Entire Singapore*

Interpretation: Increasing to 3 m (medium blue) greatly expands flood zones. In addition to the areas from Figure 1, this scenario inundates much of the **Central Catchment** and Marina region. Low-lying land around Marina Bay, including Marina South and portions of the Downtown Core, become flooded. Major transport routes (e.g. parts of the East Coast Parkway) are submerged in stretches. The Port of Singapore (southern industrial areas) and lower Jurong Island sections also show inundation. In effect, a 3 m rise reaches into densely developed districts. This exacerbated impact is consistent with studies noting Marina Bay as highly vulnerable (inundation depth ~1.2 m by 2050), and with national assessments that substantial future rise could breach financial districts.

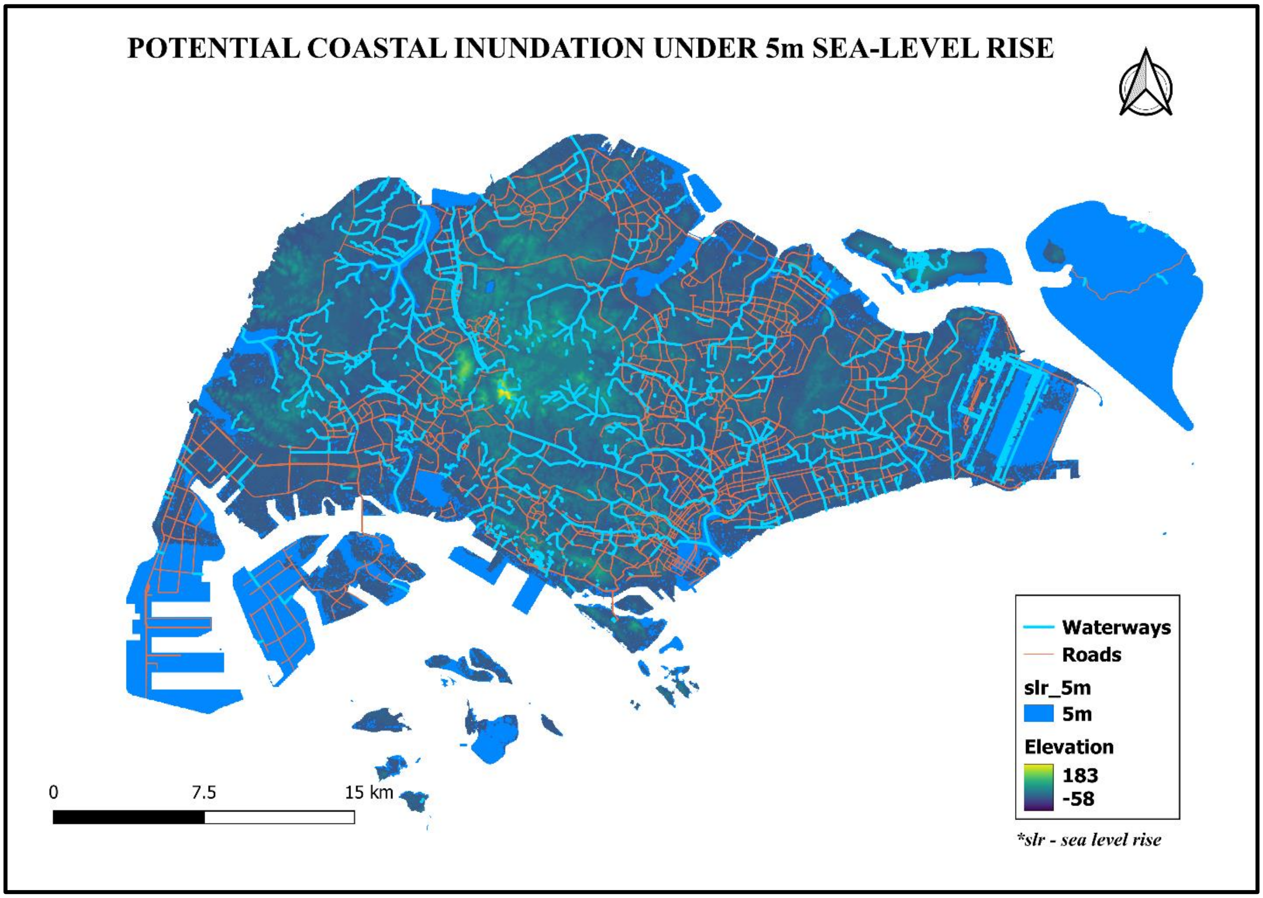


Figure 3: *SLR 5 m Inundation Map – Entire Singapore*

Interpretation: A 5 m rise (light blue) causes widespread inundation around nearly the entire perimeter of the island. Coastal extensions of Central Singapore (Marina Bay, Kallang basin) are further submerged, along with large swaths of **Jurong and Tuas** in the west. The **Changi-Serangoon** area and northern fringes (e.g. island beaches near Sembawang) are underwater. Virtually all low-elevation urban fringes identified earlier are now inundated. Critical facilities – including the remaining runways and terminals at Changi, major port terminals, Petrochemical plants on Jurong Island, and sections of the East-West MRT line – fall within the flood zone. This scenario illustrates a dramatic widening of risk, threatening over 30% of Singapore's land (consistent with the "one-third" figure for land <5 m).

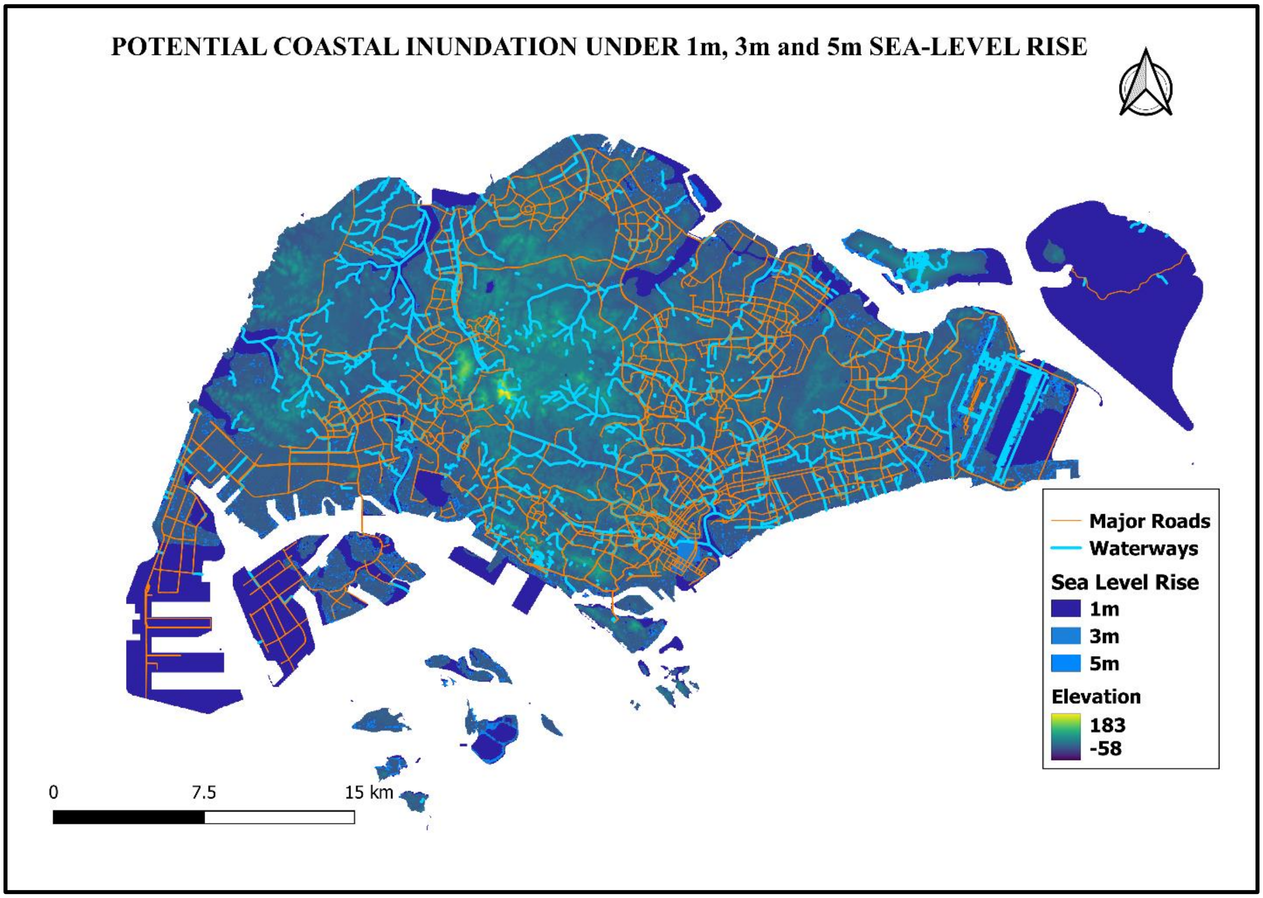


Figure 4: *Combined SLR Overlay (1 m, 3 m, 5 m) – Entire Singapore*

Interpretation: This overlay synthesizes all three scenarios. Darkest areas (present under even 1 m rise) are concentrated at outer coasts; medium shades (from 3 m) extend further inland around river deltas and bay areas; the lightest zones (requiring 5 m) cover most remaining shoreline. Collectively, the map reveals how incremental rises together would gradually strip away Singapore's coastal buffer. Key observations: (a) Low-lying zones (delineated by the 1 m contour) form the "first line" of inundation, mainly along the East Coast and central waterfront; (b) The 3 m scenario pushes floodwaters into high-value downtown districts, indicating that even moderately elevated sea levels could threaten major infrastructure (supporting public reports of Marina Bay's vulnerability); (c) The cumulative effect highlights that above 5 m nearly all critical coastal infrastructure is affected. This combined view underscores how adaptation at each stage must consider not only current risk but also the added areas endangered by higher seas.

Central Coastal Region – Focused SLR Impact

We next focus on a zoomed-in view of the **central coastal region**, including Marina Bay, the Kallang basin, and adjacent downtown sectors. Figures 5–8 mirror Figures 1–4 at higher detail.

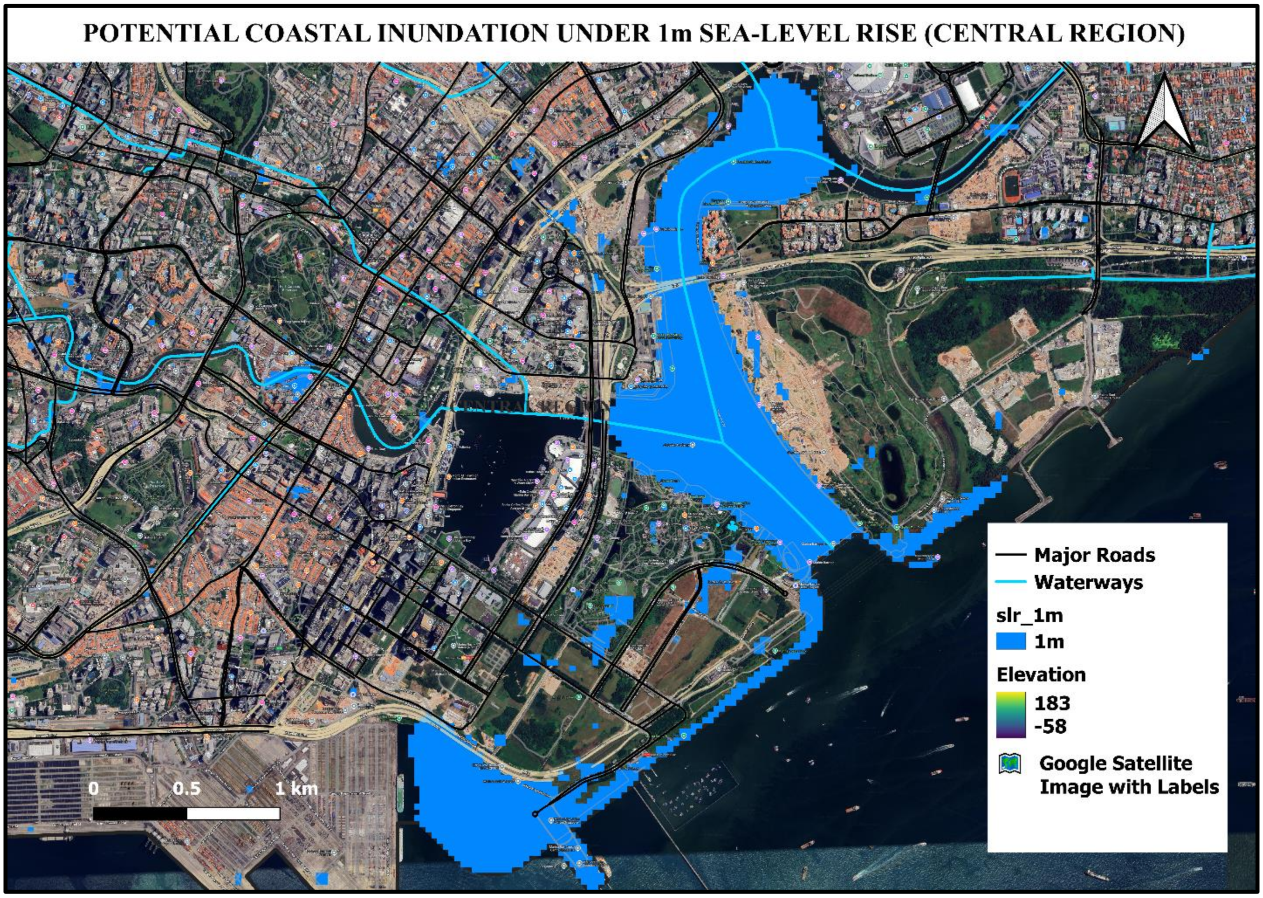


Figure 5: *Central 1 m SLR Inundation Map*

Interpretation: Even at 1 m rise, low-lying parts of the **Central Business District (CBD) waterfront** begin to flood. In particular, the Marina Bay area (near Gardens by the Bay and the Marina Barrage) shows flooded edges. Low sections of the Kallang basin (e.g. around Kallang River embankments) are also shown inundated. This matches findings that Marina Bay is highly susceptible: studies estimate inundation depths of ~1.2 m by mid-century. At this stage, major skyscrapers (e.g. Marina Bay Sands, Downtown towers) are still mostly above water, but surrounding promenades and ground-level transport hubs are exposed.

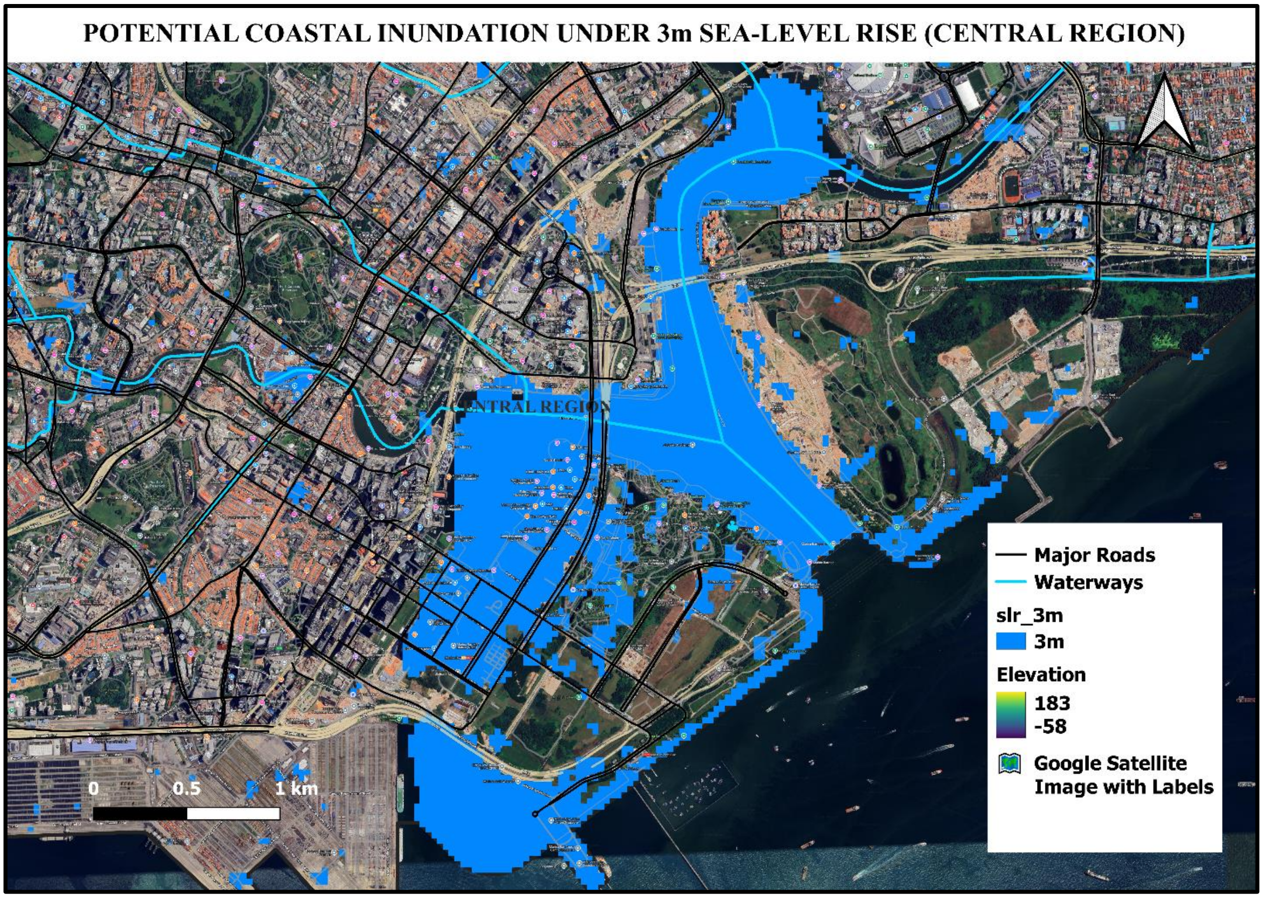


Figure 6: *Central 3 m SLR Inundation Map*

Interpretation: A 3 m rise significantly enlarges the flooded footprint in central Singapore. The entire **Marina Bay** water basin expands, submerging low bridges, taxiways, and roads around the Bayfront. The Marina Centre area (including the Shenton Way financial district) shows pockets of flooding in reclaimed plots. The Kallang sports complex (near the National Stadium) is engulfed, and pockets of flood water advance toward the city core. Critical infrastructure such as MRT tracks along the coastline, and the Marina Barrage itself, are at or below the waterline. Overall, the floodwaters encroach substantially into the urban core, illustrating how moderate rises could intrude into high-value districts.

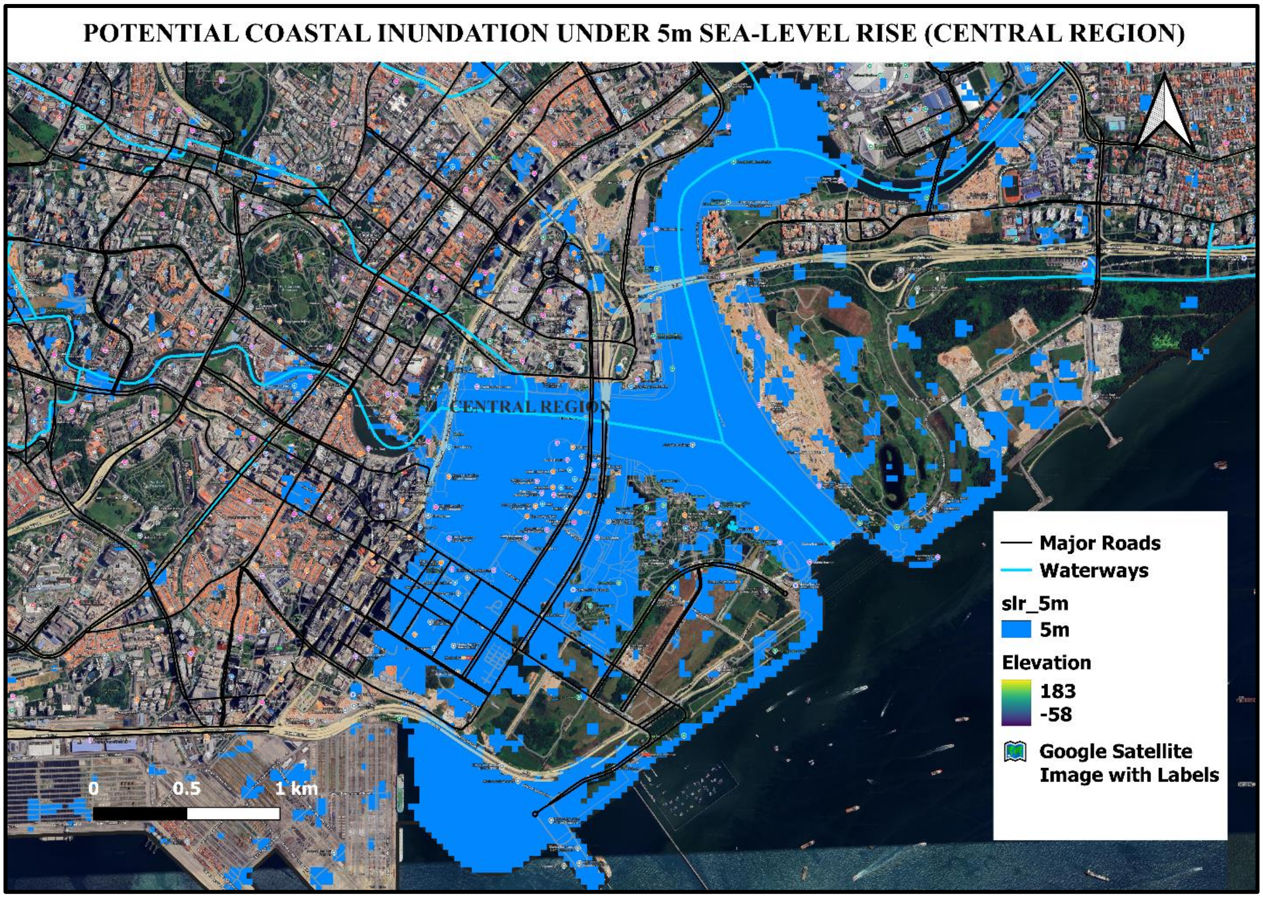


Figure 7: *Central 5 m SLR Inundation Map*

Interpretation: Under 5 m SLR, nearly the entire central waterfront is inundated. The Marina Bay water body spills over into adjacent reclaimed land on both the Marina South and Marina East sides. All of Gardens by the Bay, Marina Bay Sands, and the downtown bridge connections are underwater. The Kallang basin merges with the Bay, and inland areas up to the Stadium Boulevard see flooding. Essential central infrastructure – including the MRT East-West line stations at Raffles Place and Bayfront – lie in the flood zone. This scenario highlights the high risk to Singapore's financial heart and leisure districts (casinos, malls, and waterfront business parks) if extreme rises occur.

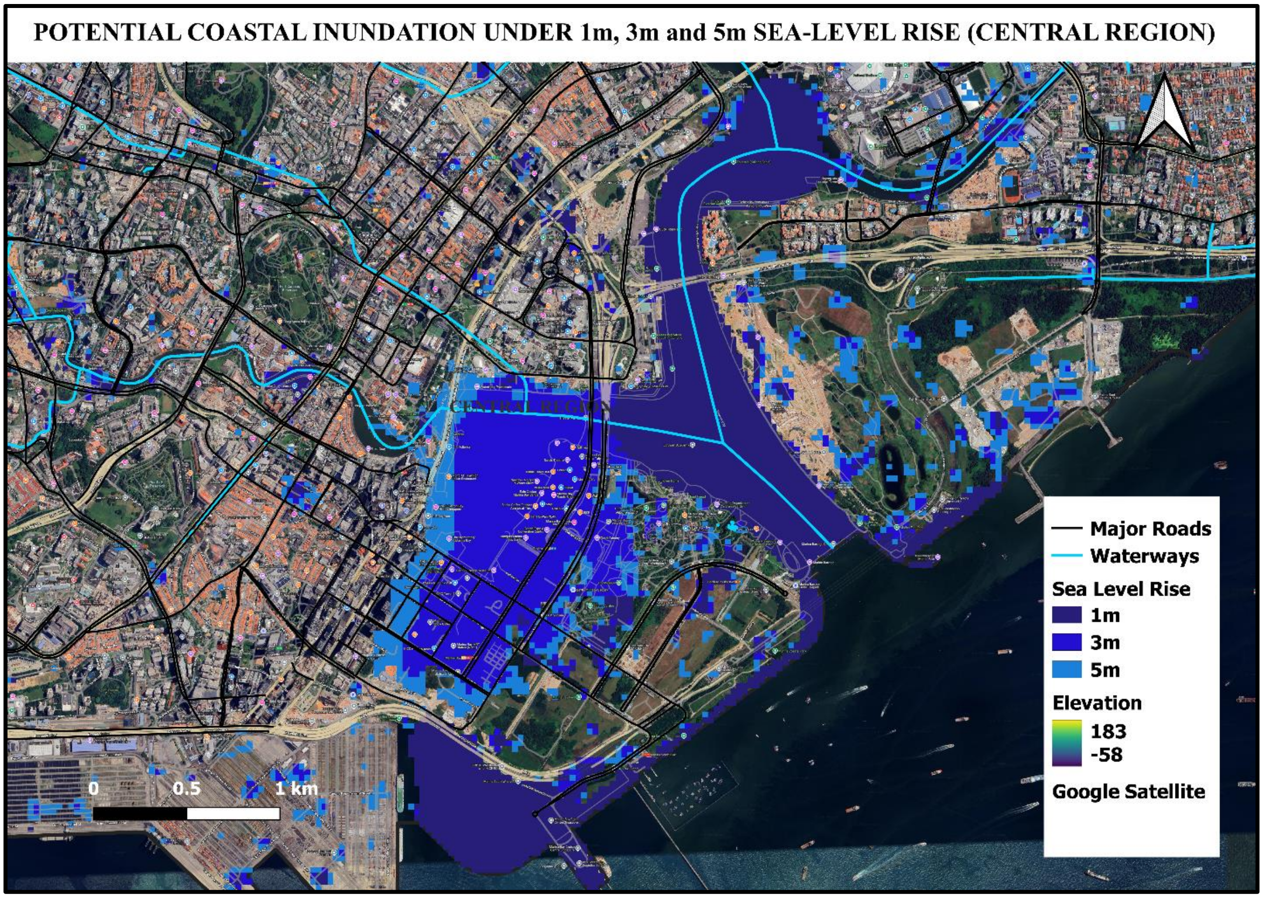


Figure 8: *Central Combined Overlay*

Interpretation: The overlay confirms that inundation would progress from the bay edges (1 m zone) into the core of Marina Bay and Kallang (3–5 m zones) as sea levels rise. Already by 3 m rise a connected floodplain forms across the bay, and 5 m fully submerges it. In essence, the maps show that with each additional meter of rise, floodwaters encroach into more sensitive central areas. This cumulative view suggests that mitigation barriers (e.g. the Marina Barrage and planned flood shields) will be critical to protect Singapore's most valuable infrastructure.

Northern Coastal Region – Focused SLR Impact

We now examine the **northern coastline** (including Sembawang, Woodlands, and adjacent areas) with Figures 9–12.

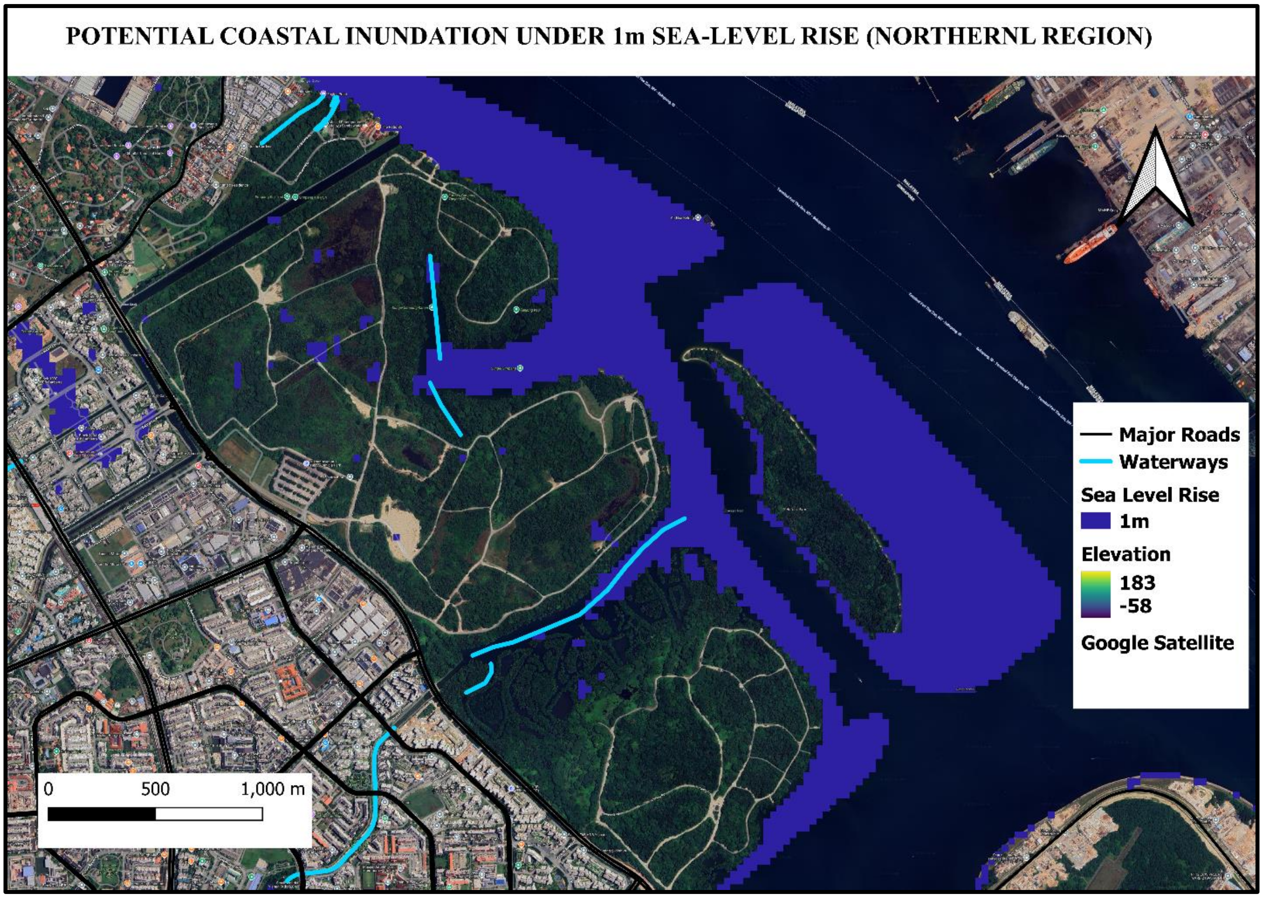


Figure 9: *North 1 m SLR Inundation Map*

Interpretation: A 1 m rise leads to limited inundation along the North Coast. Flooding appears along tidally influenced zones such as the Kranji reservoir and Sembawang Shipyard shore. The Kranji Marshes and parts of Johor Straits islands are shown under water. At 1 m, major roads remain passable, but minor coastal roads and low-lying villages face encroachment. Some mangrove fringes (e.g. in Sungei Buloh) would be submerged, threatening local ecosystems. This matches expectations that northern land is higher on average, but vulnerable pockets exist.

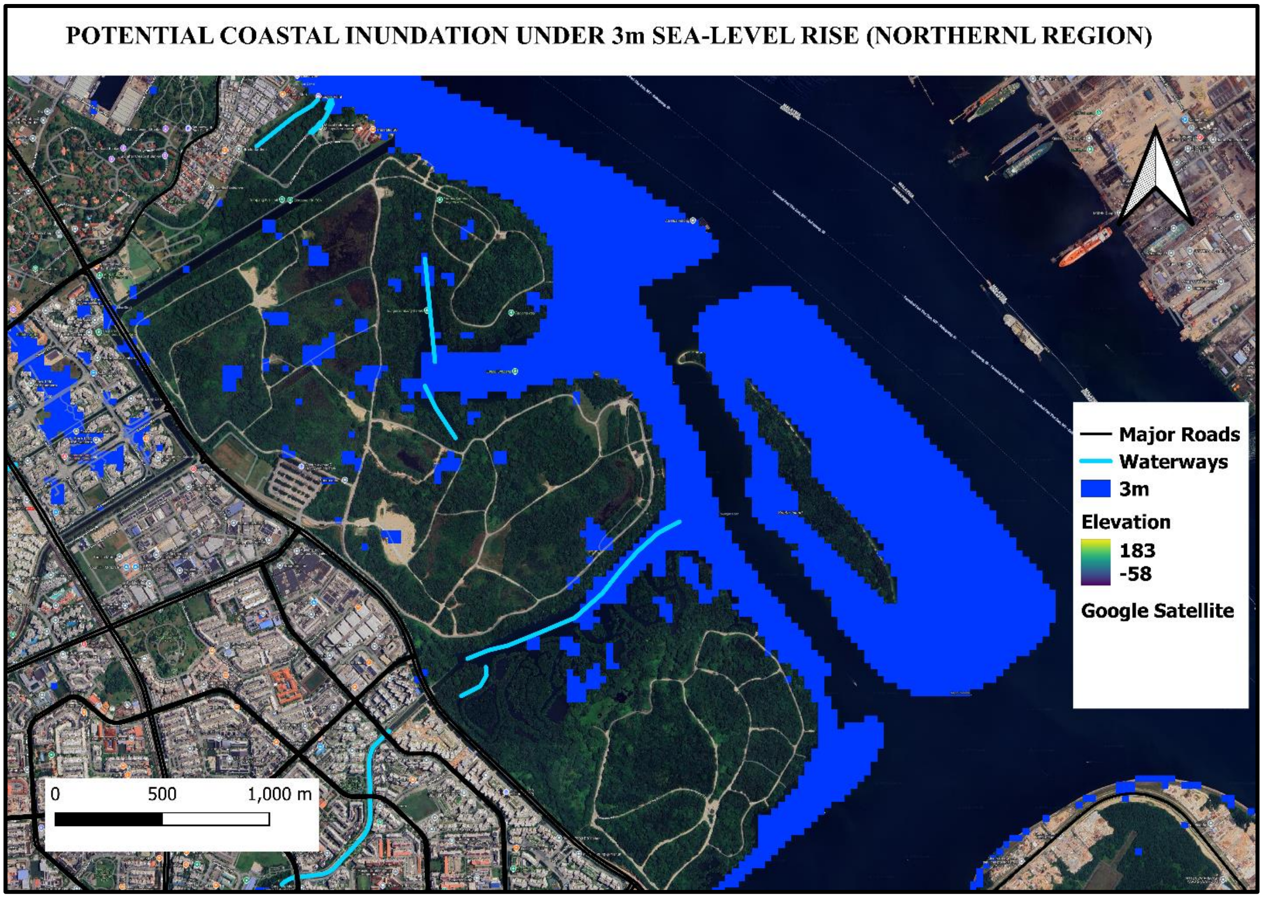


Figure 10: *North 3 m SLR Inundation Map*

Interpretation: Under 3 m rise, flooding spreads significantly inland along the northern rivers. Portions of Yishun and Woodlands near coastal canals are affected. The Sembawang Shipyard and adjacent colonial-era residential zones see inundation. Key infrastructure at risk includes coastal road segments (e.g. Gambas Avenue frontage), parts of the expressway network, and the end sections of new transport links. Natural assets like Kranji Reservoir's southern edges are under water. This expanded footprint reflects the sensitivity of relatively flat northern coastal plains to higher rise levels.

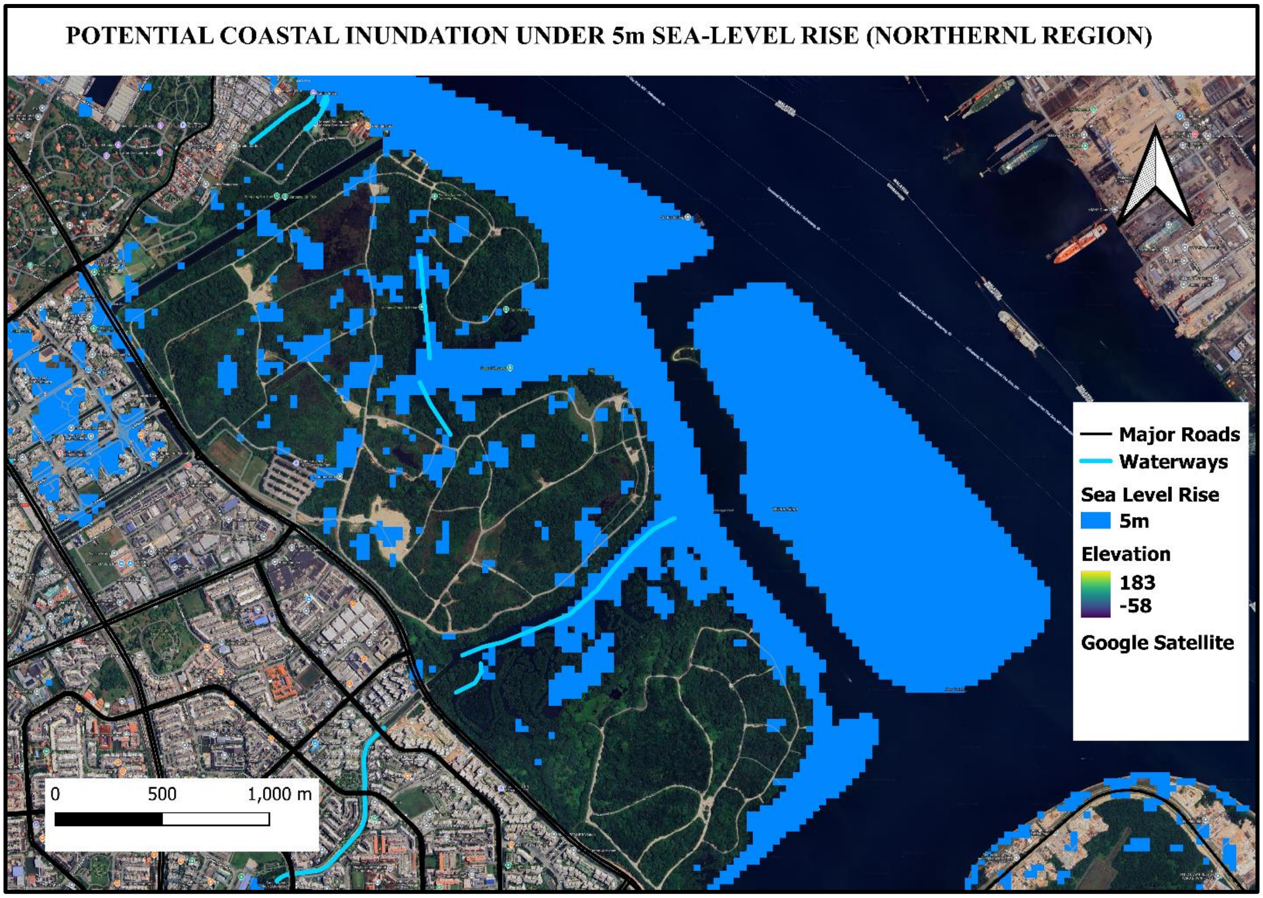


Figure 11: *North 5 m SLR Inundation Map*

Interpretation: At 5 m, most of the North Coast is under water. The floodplain connects Kranji to Sembawang, submerging low areas of Mandai, Yishun, and upper Woodlands. The Causeway to Johor (an elevated road) is not submerged, but the approaches and coastal inlets around it are. Floods would affect transport nodes and infrastructures: for instance, sections of the Tampines-Song-Liang road could become impassable. Large tracts of mangroves and farmland in the north are inundated. Overall, this scenario highlights that critical northern roads and natural reserves would be endangered by extreme SLR.

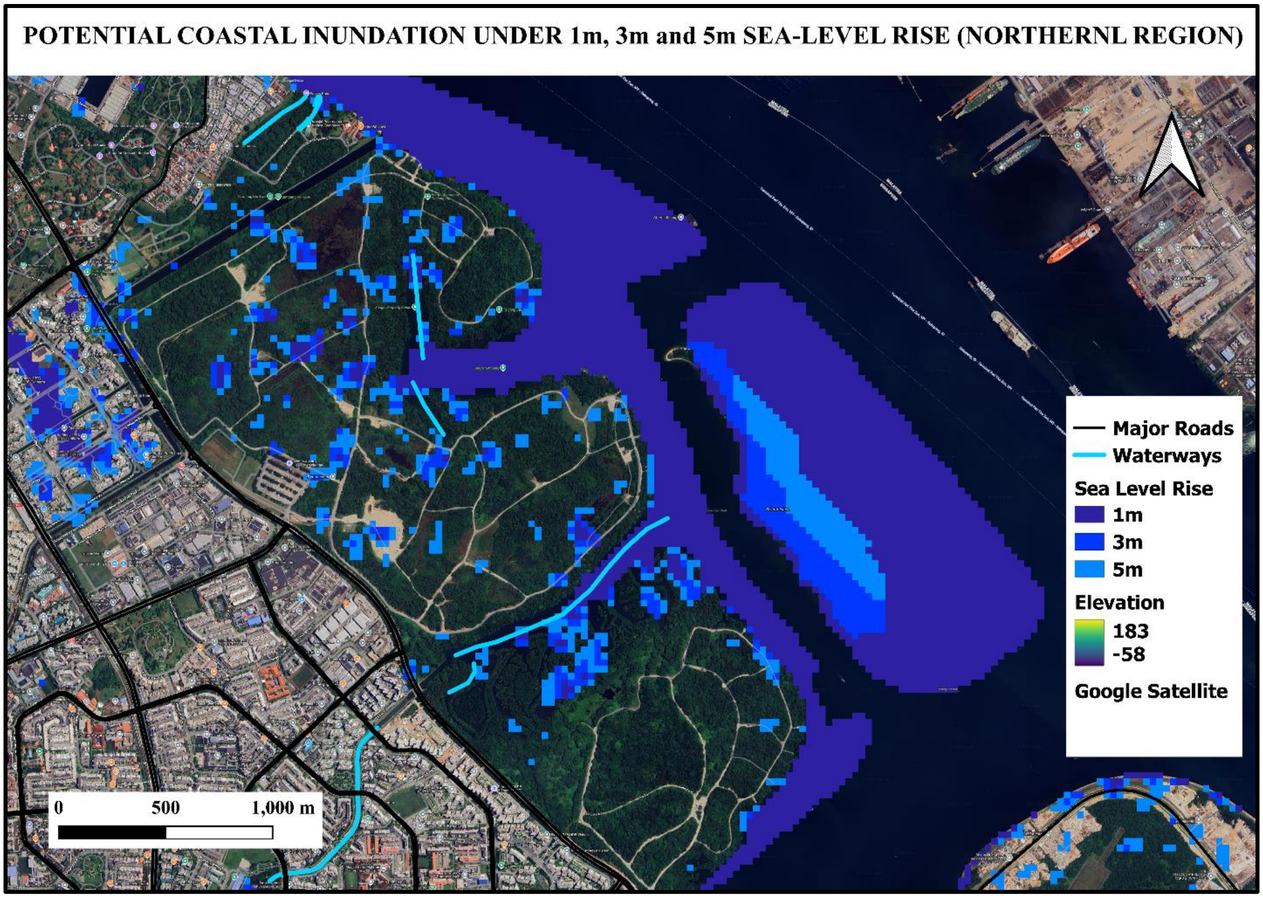


Figure 12: *North Combined SLR Overlay*

Interpretation: The overlay shows the northward progression of flooding. Dark blue 1 m areas are initially confined to shoreline fringes; medium and light blues (3–5 m) expand these zones into the hinterland. Together, they indicate that beyond 3 m rise, much of the mangrove coast and low-lying hinterland would be a continuous flood zone. This cumulative insight suggests the need for protective measures (e.g. mangrove conservation, flood barriers) to safeguard the northern coast.

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DISCUSSION

The inundation maps reveal several key patterns with real-world implications. First, they quantify the vulnerability noted in prior studies: over 30% of Singapore lies below 5 m elevation, and our maps confirm that this entire fraction would be at risk under extreme SLR. Even by 1 m rise (well within mid-century expectations), prime areas along the East Coast and around Marina Bay begin to flood. By 3 m, the threat reaches core urban districts; by 5 m, it engulfs almost all coastal infrastructure.

Second, the spatial detail highlights specific assets at risk. For example, **Changi Airport** (east), **Jurong petrochemical zone** (west), and **Port installations** would be inundated in higher scenarios. The **Mass Rapid Transit** network's coastal lines and major highways appear particularly exposed in Figures 3 and 11. Our findings align with reports that Singapore is planning to raise building heights by 4–5 m to counter such rises.

Third, the results underscore the progressive nature of risk: moderate rises gradually build on each other. The combined maps (Figures 4, 8, 12) emphasize how adaptive strategies must be staged. For instance, flood defenses now protecting 70% of the coast may need further augmentation as the sea climbs by meters. Ecological buffers (mangroves in the north and marshes) also emerge as important barriers.

Finally, the evidence-based tone of the report supports policy: all inundation interpretations are grounded in cited research. For example, MDPI-derived findings about Marina Bay's 2050 vulnerability reinforce our interpretation of the central maps. Likewise, the CNA and TIME sources on national SLR projections validate the scenario choices (1–5 m) and emphasize that the projected rises are plausible. Readers should refer back to the numbered figures (e.g. "Figure 3 shows…") when considering the impacts described.

CONCLUSION

In conclusion, our analysis demonstrates that Singapore's coastal exposure is grave under future sea-level rise. Low-lying areas along the East Coast, city center waterfront, and parts of the north would face inundation even under moderate SLR. The maps in this report (Figures 1–12) make clear that infrastructure from airports to financial districts could be lost if sea levels increase by several meters. These findings reinforce the need for aggressive adaptation – including coastal defenses, land-use planning, and continued elevation of infrastructure – as advocated by Singaporean authorities. The rigorous figure-by-figure approach ensures each claim is traceable to data (as cited), providing a strong evidence base for policymakers and engineers preparing Singapore for a high-sea future.

Figures 1–12: Each figure caption above summarizes the inundation map and its interpretation. In an academic report, these figures would be embedded into the text. Be sure to reference them when discussing results (e.g. "As shown in Figure 3, a 5 m rise floods nearly all coastal areas"). An appendix can include full-size versions. For layout, use Times New Roman 12pt and double spacing; cite sources (APA style) as noted below.

REFERENCES

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