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ANNEX III: KEY IMPACT PROFILES FOR YEMEN

ANTICIPATORY ACTION

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EXECUTIVE SUMMARY

Flooding poses a significant and escalating threat to the southern governorates of Marib and Hadhramaut, causing recurring loss of life, mass displacement, and widespread damage to infrastructure, homes, and livelihoods. Over the last 40 years, Yemen has experienced over 90 major flood events, resulting in more than 1,400 deaths and affecting approximately 1.45 million people. Marib and Hadhramaut are consistently among the most affected, with landmark disasters such as the 2008 Wadi Hadhramaut floods (which displaced 25,000 people and caused an estimated US$1.6 billion in damage), the 2020 nationwide monsoon floods, and more recently, Cyclone Tej in 2023, which brought destructive winds and coastal inundation. Marib, in particular, has seen its flood risk amplified by demographic shifts—its population has surged due to conflict-driven displacement, with around 1.5 million IDPs now residing in the governorate. These displaced populations, many of whom live in makeshift shelters in flood-prone zones, have been repeatedly affected by flash floods, especially during the 2020–2021 seasons.

Compounding this physical risk is the worsening impact of climate change. Rainfall patterns across Yemen have become more erratic and intense, while the Arabian Sea has seen a marked rise in cyclonic activity—cyclone frequency and duration have increased by over 50% and 80%, respectively, in the past two decades. Climate projections under both RCP 2.6 and RCP 8.5 scenarios show a high likelihood of increased extreme precipitation, with the high-emissions pathway predicting significantly more intense storms and floods. Coastal areas like Mukalla are becoming increasingly vulnerable to storm surge and sea level rise, while inland wadis face growing threats from flash floods. These trends threaten to worsen Yemen's already fragile humanitarian situation, with the country ranked among the top three most climate-vulnerable globally.

In response, this report presents a detailed impact profile of flood risk in Marib and Hadhramaut, aimed at informing anticipatory action planning. It draws on four decades of disaster data, remote sensing, spatial flood mapping, community vulnerability assessments, and climate modeling to assess exposure across sectors—population, housing, agriculture, and infrastructure. The report synthesizes historical impacts with future risk outlooks and presents targeted recommendations to reduce hazard exposure and build resilience. These include strengthening early warning systems, upgrading drainage and protective infrastructure, implementing land-use controls in floodplains, and delivering community-level preparedness and risk reduction initiatives. The evidence presented underscores the urgent need for pre-emptive, coordinated action to protect lives and livelihoods as flood risks continue to intensify.

1. INTRODUCTION AND PROJECT CONTEXT

Flood hazards present a growing and severe threat to Yemen's southern governorates of Marib and Hadhramaut, repeatedly causing fatalities, large-scale displacement, and destruction of infrastructure, farmland, and housing. Over the past four decades, Yemen has experienced more than 90 flood events, resulting in over 1,400 deaths and affecting 1.45 million people. Marib and Hadhramaut stand out as among the most impacted areas, with major events such as the 2008 Hadhramaut floods, the 2020 monsoon floods, and Cyclone Tej in 2023 causing substantial human and economic losses. Marib, now hosting the country's largest internally displaced population, is especially vulnerable, with informal camps frequently inundated during seasonal rains.

Emerging climate trends are compounding the hazard. Rainfall patterns have become more erratic, and sea surface warming has led to stronger, more frequent cyclones—projected to worsen under both moderate (RCP 2.6) and high (RCP 8.5) emissions scenarios. If current trends continue unchecked, Yemen could face more intense flash floods and coastal inundation, placing additional strain on already fragile humanitarian systems. Yemen ranks among the world's most climate-vulnerable countries, with low adaptive capacity.

This report provides an evidence-based flood impact profile to support anticipatory action planning in Marib and Hadhramaut. It combines historical analysis, exposure and vulnerability mapping, and future climate scenarios to identify risks to key sectors—population, housing, agriculture, and infrastructure. The findings highlight the urgency of scaling up early warning systems, flood-resilient infrastructure, and community preparedness to protect the most at-risk populations and mitigate the escalating impacts of climate-driven floods.

GEOGRAPHIC AND HUMANITARIAN CONTEXT:

Marib and Hadhramaut, located in the southern half of Yemen (with Marib in the inland northeast and Hadhramaut spanning from the interior plateau to the Arabian Sea coast), face a confluence of natural hazard exposure and humanitarian vulnerabilities. Both governorates have arid to semi-arid climates with seasonal rainfall that can trigger flash floods in the dry river valleys (*wadis*). Hadhramaut is Yemen's largest governorate by area, characterized by rugged highlands and the long Wadi Hadhramaut system, as well as a populous coastal strip (including the provincial capital Mukalla). Marib, historically sparsely populated, has in recent years become an epicenter of internal displacement due to Yemen's

protracted conflict. As of 2023, Marib hosts an estimated 1.5 million internally displaced persons (IDPs) – roughly 90% of Marib's total population – making it the governorate with the largest IDP concentration in Yemen (NRC, 2024). These displaced families often live in overcrowded camps or informal settlements, many situated in low-lying plains that are naturally flood-prone. The humanitarian crisis (ongoing conflict, economic collapse, and limited governance) has severely strained local capacity to manage disasters, leaving communities highly vulnerable to natural shocks.

Flood Hazard in Southern Yemen: Floods are among the most recurrent and damaging natural hazards in Yemen. Seasonal torrential rains (driven by the convergence of monsoon systems) and occasional tropical cyclones result in flash floods along dry riverbeds and extensive surface flooding in basins. Marib Governorate, with its many ephemeral wadis and the Marib Dam reservoir, and Hadhramaut Governorate, with its large watershed and coastal exposure, are notably susceptible to flooding. Marib is described as "one of the regions most severely impacted by recurring floods". In Hadhramaut, historical records show periodic catastrophic floods (e.g. 1989, 1996, 2008) affecting both rural oasis towns and coastal cities. The convergence of climatic risks with the vulnerability of communities (especially displaced and rural populations) underpins the need for anticipatory action. Flood emergencies in recent years have repeatedly overwhelmed local response capacity – for instance, floods in 2020 struck while Yemen was coping with conflict and disease outbreaks, compounding humanitarian needs.

Anticipatory Action Project:

In this challenging context, the Anticipatory Action Project in Southern Yemen aims to reduce flood disaster impacts through proactive risk analysis and early interventions. This report serves as an impact profile to guide that effort, targeting Marib and Hadhramaut. It provides stakeholders – including donors, government authorities, and humanitarian agencies – with an evidence base on flood hazard patterns, exposed populations and assets, and the likely future risk trajectory under climate change. The goal is to inform timely, pre-emptive actions (such as early warning dissemination, activation of cash assistance, pre-positioning of relief supplies, and community preparedness measures) that can save lives and protect livelihoods ahead of forecasted floods.

2. HAZARD IDENTIFICATION AND COMMUNITY EXPOSURE

Among the range of natural hazards facing communities in Marib and Hadhramaut, flooding—driven by intense rainfall and thunderstorms—emerged as the most pressing and recurrent threat. This is reinforced by both field-level insights and spatial hazard mapping.

Recent community surveys revealed that nearly all respondents identified heavy rains and associated storms as the most frequent and damaging hazard they experience. These rainfall events often lead to flash floods, particularly along wadi systems and low-lying areas, where poor drainage, proximity to riverbeds, and informal settlements increase exposure.

While other hazards such as droughts, earthquakes, and landslides are present, they are either less frequent or have a more localized impact. Flooding, by contrast, consistently affects both urban infrastructure and rural agricultural livelihoods, leading to widespread disruption, displacement, and long-term economic losses. In urban areas, stormwater inundation compromises roads, shelters, and critical services, while in rural zones, floods destroy crops, wash away topsoil, and damage irrigation systems—undermining already fragile food systems.

Given its high frequency, geographic spread, and cross-sectoral impact, flooding was prioritized as the primary hazard for this impact profiling exercise. Its selection is also supported by existing multi-hazard assessments, DesInventar data, and humanitarian reports identifying floods as the leading cause of displacement and asset loss in both governorates in recent years.

To assess the scope of flood risk and its implications for anticipatory action, the following methodology was adopted.

METHODOLOGY

This report uses a mixed-methods approach to profile flood hazards and impacts in Marib and Hadhramaut, integrating historical data analysis, spatial modeling, climate projections, and qualitative field insights.

- Historical Data and Secondary Sources: The analysis draws on over four decades of historical disaster data from established databases such as DesInventar (1981–2022) and EM-DAT, to identify flood frequencies, severity, and their associated impacts. These sources were cross-referenced with national reports, post-disaster needs assessments, and humanitarian situation updates (e.g., Red Crescent/OCHA flood briefs from 2020–2023). These references were critical in establishing a timeline of flood-related damage, including displacement, shelter loss, and infrastructure disruption.
- Remote Sensing and GIS-Based Hazard Mapping: Spatial analysis was conducted using satellite imagery and digital elevation models to assess topography, wadi systems, and areas prone to water accumulation. Flood susceptibility maps were produced using hydrological modeling and incorporated layers from recent multi-

hazard risk assessments. These maps allowed for a regional-level visualization of flood-prone areas across Marib and Hadhramaut, particularly focusing on riverine systems, wadis, and coastal lowlands without emphasizing administrative boundaries.

- Use of Field-Based Knowledge and Surveys: Though no primary field assessments were conducted as part of this report, existing findings from knowledge, attitudes and practices (KAP) surveys, community-based observations, and previous humanitarian assessments were integrated. These insights, gathered through focus groups, AA workshops, and IDP site reports, helped contextualize exposure, vulnerability, and early warning gaps. Community perceptions of rainfall variability, alert effectiveness, and preparedness levels informed the qualitative aspects of the vulnerability analysis.
- Climate Change and Scenario Modeling: The report incorporates climate projections under Representative Concentration Pathways (RCP) 2.6 and 8.5 using datasets from the IPCC and World Bank Climate Knowledge Portal. Regional projections for Yemen were reviewed to assess shifts in rainfall intensity, storm frequency, and seasonal variability. These projections informed forward-looking flood scenarios and implications for anticipatory action planning over mid- and long-term horizons.
- Impact Characterization by Sector: While no new sector assessments were conducted, sectoral impacts (population displacement, agricultural loss, infrastructure damage) were inferred from previously published post-flood reports and cluster updates (Shelter, WASH, Food Security). DesInventar data and humanitarian response documents were used to compile governorate-level figures were available. These were supplemented with qualitative descriptions from field reports and narrative summaries to reflect the socio-economic impacts of flooding.

3. HAZARD PROFILE: FLOODING IN MARIB AND HADHRAMAUT

1. HISTORICAL FLOOD OCCURRENCE AND KEY EVENTS

Flooding in Yemen is a recurring hazard with a **seasonal pattern** and occasional extreme events. The country typically has two rainy periods (spring and summer), during which intense cloudbursts can trigger flash floods in the highlands and interior basins, while tropical cyclones from the Arabian Sea pose an episodic threat to eastern coastal areas. According to disaster records, **over 93 flood events** (classified as general floods or flash floods) have been recorded in Yemen since 1986. These events are distributed across 17 governorates, indicating that flood risk is widespread. However, Marib and Hadhramaut stand out for both the frequency and severity of floods affecting them:

Marib Governorate:

Historically an arid region, Marib experienced infrequent floods in past decades, but the frequency has risen with climate variability and the greatly increased population exposure. Notably, Marib Dam, rebuilt in 1986, regulates flow in the Marib valley – yet in August 2020, exceptionally heavy rains caused the Marib Dam to overflow for the first time since its reconstruction, sending torrents downriver. The overflow persisted for six days, inundating nearby areas. Officials reported that floodwaters from this event affected over 1,300 displaced families sheltering in the downstream Sarwah district. This 2020 flooding in Marib was part of a nationwide flood crisis: across Yemen, an estimated 223,000 people were displaced by floods in 2020, with Marib among the worst-hit as informal IDP camps were swamped. Earlier in April 2020, flash floods had already hit southern governorates (including Abyan, Aden, and Hadhramaut), killing at least 2 and affecting over 23,000 people.

Hadramaut Governorate:

Hadhramaut has a long history of devastating floods, especially in the interior Wadi Hadramaut area. The most catastrophic on record was the October 2008 flood, caused by a tropical storm that poured ~91 mm of rain in 30 hours (far above the 5–6 mm normally seen). This led to 10-meter-high flash floods in valleys. The 2008 disaster is considered *"one of the worst natural disasters to hit Yemen in decades"*, prompting disaster area declarations in Hadhramaut and Al-Mahrah. It killed 73 people and left 25,000 people displaced; roughly 650,000 residents were affected in total. Damage was extreme: entire villages in Wadi Hadhramaut were washed away, and infrastructure was demolished (bridges, roads, power and water lines). The joint damage and loss assessment estimated US$1.638 billion in damages and losses, including destruction of thousands of homes and farms (over 22,900 acres of cropland were damaged (GFDRR, 2023). More recently, Hadramout's coastal areas have been struck by cyclonic storms: in November 2015, Cyclone Chapala made landfall on the Hadhramaut/Shabwah coast – it drove a 10 m storm surge ashore and dumped several years' worth of rainfall in days, causing widespread flooding in Mukalla and nearby districts. In October 2021, the remnants of Cyclone Shaheen brought heavy rains to Mukalla and Ash Shihr; while less severe, it still damaged over 23 houses, swept away dozens of vehicles, and flooded neighborhoods in coastal Hadhramaut. Most recently, in October 2023, Cyclone *Tej* (a Category 3 tropical cyclone) struck the Al-Mahrah–Hadhramaut coast. *Tej* caused torrential rains and strong winds (160 km/h gusts) across eastern Yemen. In Hadramout's Al Raydah and Qusayar districts, the cyclone displaced 305 families and inflicted heavy infrastructure damage (power lines, roads, and buildings). Fortunately, casualties from *Tej* were minimal, but needs assessments found nearly 2,901 families requiring basic relief items after the storm.

Nationwide Flood Trends:

Yemen has witnessed a notable increase in flood disasters in the last decade. In 2010, severe flash floods in the western highlands (outside our focus area) caused dozens of deaths in Hodeidah and Sana'a, showing that even traditionally drier or urban areas are at risk. Since 2016, large-scale floods have occurred almost yearly, often overlapping with the ongoing conflict. In 2020, as noted, two major flood waves occurred (spring and summer) affecting nearly 150,000 people across 13 governorates. In 2021, heavy rains in July–August hit northern and central areas; one flood event in July 2021 impacted *13,596 families nationwide*, with Marib among the hardest-hit (it accounted for a significant share of the 13 flood-related deaths reported that year). 2022 brought extraordinary rains (~300% above average) that made it the wettest season in 40 years; floods and flash floods impacted 80% of Yemen's territory, with 74,000 households affected in 18 governorates. Marib, Hajjah, and Hodeidah governorates together had about 50,000 households affected (primarily in IDP sites). By early May 2023, after an early start to the rains, humanitarian trackers had already counted 19 flood fatalities and 33,000 affected households across Yemen (with further floods continuing through that summer). These figures underscore an escalating pattern of flood impacts.

Event (Year)	**Location & Description**	**Fatalities**	**Displaced / Affected**	**Property/Asset Damage**
Hadhramaut Floods (Oct 2008)	Tropical storm caused Wadi Hadhramaut flash floods; Hadhramaut & Al-Mahrah declared disaster areas.	73 deaths	25,000 displaced; ~650,000 affected	1,370 homes destroyed; 6,000+ homes damaged; 22,902 acres of cropland ruined; infrastructure losses ≈$1.6 billion.
Cyclone Chapala (Nov 2015)	Category 4 cyclone hit Hadhramaut coast (Mukalla).	8 deaths (est.)(nationwide)	~18,000 displaced (coastal Hadhramaut/Shabwah)	Severe flooding in Mukalla (10 m storm surge); port and road infrastructure damaged (multi-million $ losses).

Cyclone Shaheen (Oct 2021)	Remnant cyclone hit Hadhramaut coast (Mukalla, Ash Shihr).	0 deaths	Dozens displaced temporarily	23 houses damaged; dozens of vehicles washed away; clinic and roads flooded.
Cyclone Tej (Oct 2023)	Cat. 3 cyclone struck Al-Masila coast (Hadhramaut) and Al-Mahrah.	0 deaths	305 families displaced (Al Raydah & Qusayar)	Widespread flood damage to homes and infrastructure; 2,900 families in Hadhramaut needed relief aid.
Marib Flash Floods (Apr 2020)	Torrential rain in Marib and Sanaa regions; IDP camps flooded.	2 deaths	~23,000 affected (south Yemen); *~4,000 IDP families affected in Marib* (est.)	Hundreds of tents/shelters swept away in Marib IDP sites; Marib Dam close to capacity.
Marib Dam Overflow (Aug 2020)	Prolonged heavy rain caused Marib Dam spillover.	0 direct deaths	1,300+ families displaced/threatened downstream	Floodwaters inundated IDP camps in Sarwah; agricultural fields along wadi flooded.
Nationwide Floods (Jul 2021)	Widespread floods (Marib, Hajjah, etc.).	13 deaths	13,596 families affected (countrywide); *3,500+ families in Marib affected* (cluster est.)	2,500+ IDP shelters destroyed in Marib camps; roads in Marib city submerged; Marib–Seiyun highway cut.

Hadhramaut Floods (Aug 2022)	Monsoon rains caused flash floods in Interior Hadhramaut.	0 deaths	~5,000 affected (incl. 1,300 in Tarim/Shibam)	Damage to 200+ houses; date palm groves flooded; rural roads washed out.

Figure 1:Table 1: Major flood events in Marib and Hadhramaut (2008–2023) with their impacts. (Data compiled from DesInventar, EM-DAT, PDNA 2008, and humanitarian reports)

Flood Frequency and Seasonality:

On average, at least one significant flood disaster has struck Yemen each year in the past two decades (many years seeing multiple localized flood events). Most floods occur in the April–May or July–August rainy peaks, but cyclones (June–October) add to risk in eastern Yemen. Marib tends to see flash floods at the tail end of summer storms when grounds are parched and unable to absorb sudden downpours. Hadhramaut faces both spring flash floods in the highlands and autumn cyclonic storms on the coast. Climate data indicate an increase in *extreme precipitation days*, meaning the most intense rainfall events are becoming more common, which correlates with the observed uptick in flash flood incidents.

FLOOD HAZARD DRIVERS AND PATTERNS

The severity of floods in Marib and Hadhramaut is driven by environmental factors and climate phenomena:

- **Topography and Drainage:** Both governorates have terrain that exacerbates flash flooding. Marib's landscape is a mix of highlands (Jabal Murad area) and open desert. Sudden heavy rainfall in the highlands produces high-velocity runoff down seasonal riverbeds (*wadis*) that traverse populated areas. Because Marib's soils are dry and impervious for much of the year, intense rain quickly becomes runoff. The presence of the Marib Dam provides some flood regulation for the Marib valley, but as 2020 showed, extreme inflows can overwhelm it. Downstream of the dam, the floodplain is relatively flat and heavily settled with farms and IDP camps, which are at risk when the dam overtops or when tributary wadis flood. Hadramout's terrain is rugged in the interior (high plateaus and steep valleys), funneling water into the long east–west Wadi Hadhramaut. Flash floods there gain force as they collect from side valleys, causing torrents that can destroy anything in their path. The coastal plain of Hadhramaut is narrow and backed by mountains; water from those mountains drains

rapidly to the sea, often through towns like Mukalla that straddle wadi deltas. Thus, mountainous terrain and narrow wadis lead to *rapid-onset floods* in both regions.

- **Climate Change and Rainfall Extremes:** Shifting climate patterns have already led to more intense and erratic rainfall in Yemen. Residents report that rains, while still infrequent, now tend to come in short, heavy bursts. This is supported by climate analysis: since 1980, there is evidence of increased inter-annual variability and heavier downpours during rainy seasons, partly linked to phenomena like the Indian Ocean Dipole. In Hadramaut, specifically, rainfall events that previously might cause minor flooding now result in larger inundations due to their intensity. The frequency of cyclones impacting the region has also risen – e.g., from 1982–2000 to 2001–2019 the number of cyclonic storms in the Arabian Sea jumped by 52%, a trend attributed to warmer sea surface temperatures. Climate change has *"led to an increase in the intensity and frequency of heavy rains"* in Hadramaut, according to local assessments, thereby heightening flood risk.
- **Land Use and Environmental Degradation:** Human factors have aggravated flood hazard. Loss of vegetation cover in catchment areas is notable in both governorates – overgrazing and tree-cutting have reduced natural absorption, leading to faster runoff and soil erosion. For instance, upland forests and shrubs in Hadramaut's mountains have thinned, so rain that once soaked into soils now runs off swiftly, carrying sediment that can choke channels. In Marib, the rapid expansion of informal settlements and cultivated lands in floodplains (often without adequate drainage planning) means water has fewer places to safely dissipate. The formation of new torrential channels (spates) has been observed where wadis overflow their banks and carve new paths, sometimes through populated areas – a process accelerated by erosion due to vegetation loss.
- **Infrastructure and Drainage Deficits:** Weak flood control infrastructure significantly contributes to hazard. Marib and Hadhramaut both lack extensive flood protection works beyond a few dams and dikes. Urban drainage systems are underdeveloped; for example, in Marib city and IDP camps, there are minimal stormwater networks, causing even moderate rain to pond and create flash floods in streets and shelters. Hadramout's cities (like Mukalla) have old drainage channels that are often blocked or insufficient for extreme rains. Sewage canals, culverts, and small earth dams in many areas are either poorly maintained or of inadequate capacity. The result is frequent breaches and overflows. In Marib's IDP sites, humanitarian assessments note that many camps are located in natural bowl-like depressions or alongside wadis; without engineered drainage, these sites flood regularly. In Al-

Jawbah and Harib districts of Marib, which lie along major wadis, the exposure is especially high – these areas are consistently identified as flood hotspots where even minor wadis can swell to dangerous torrents. Sarwah district (Marib) similarly sees recurring flooding as it is downstream of the dam and receives flows from multiple catchments.

CURRENT CLIMATE TRENDS

Yemen's climate is already exhibiting changes that aggravate flood hazards. Rising Temperatures (about +1.8 °C since the 1960s) have been observed, which can increase atmospheric moisture and the potential for heavy rainfall events. More directly relevant, rainfall patterns have become more erratic and extreme. The rainy seasons are shifting and sometimes merging: for instance, in parts of Hadramawt and Al-Mahrah, the spring rains peak earlier (April) and the overall distribution is becoming more *unimodal*, concentrating precipitation in intense bursts. This means long dry spells punctuated by short, heavy rain episodes – a recipe for flash floods. Records indicate an increase in the frequency of years with exceptionally high rainfall in short periods. In 2022, Yemen experienced nearly 300% above-average rainfall in the late summer, as noted, which is far outside the norm (IFRC, 2024a). Such anomalies used to be rare (perhaps once in several decades) but are becoming more common.

Crucially, tropical cyclone activity in the Arabian Sea is on an upward trend, bringing new flood risks to areas like Hadhramaut that historically did not face frequent cyclones. Studies show that from the 1980s to the 2010s, the number of cyclones, as well as their duration and intensity, increased markedly. Warmer ocean temperatures contribute to this, enabling stronger storms (*Tej* in 2023 was the strongest cyclone on record in the Arabian Sea for the month of October). The country saw unprecedented cyclones in 2008 (the storm that caused the Hadhramaut floods) and back-to-back cyclones in 2015 (Chapala and Megh) – events outside the previous range of experience.

Another trend is the high variability due to global teleconnections like El Niño/La Niña and the Indian Ocean Dipole. Certain years (especially with a positive IOD) bring excessive rain to Yemen's Red Sea and Gulf of Aden coasts. This partially explains years like 2020 and 2022 with exceptional flood activity. However, even in intervening "normal" years, localized heavy storms have continued to cause floods, indicating a baseline rise in risk.

Yemen's climate has become more hazard-prone, with floods now striking in successive years. The UN ranks Yemen among the top 3 most climate-vulnerable countries (high risk,

low readiness). Notably, this increasing flood threat exists alongside Yemen's chronic water scarcity and periodic drought – a paradox of both too little and too much water. The country remains one of the most water-stressed in the world, yet must also contend with destructive floods, illustrating the extreme variability of its climate regime.

Future projections indicate that without significant climate change mitigation, Yemen (and by extension Marib and Hadhramaut) will experience worsening flood hazards by mid to late 21st century. Below we contrast a low-emissions scenario (RCP 2.6, which assumes global warming is limited to ~1.5–2 °C) and a high-emissions scenario (RCP 8.5, a "business-as-usual" path with 4+ °C warming by 2100)

It is worth noting that Yemen's capacity for climate adaptation is currently limited due to conflict and economic constraints. Thus, anticipatory action planning must incorporate these climate projections to ensure that today's interventions remain effective under tomorrow's conditions. In practical terms, infrastructure designs (e.g. dams, drainage) should account for, say, 20–30% larger flood volumes (as might occur under RCP 8.5), and early warning systems must prepare for cyclone events that could be more frequent than historical experience.

3. EXPOSURE AND VULNERABILITY ANALYSIS

2. EXPOSURE ANALYSIS

Population and Community Exposure

Population Exposed: The population at risk of flooding in Marib and Hadhramaut is substantial and growing. In Marib, the huge influx of IDPs over 2015–2023 has led to the establishment of over 190 IDP sites across the governorate (UNHCR, 2023). Many of these sites were set up in low-lying areas near wadis or on flat desert land without proper elevation or drainage. Reports indicate that 61 districts across Yemen are exposed to severe flooding, several of them in Marib and Hadhramaut. Within those, the CCCM Cluster warned that one-quarter of all IDP sites countrywide are threatened by floods requiring urgent mitigation or relocation (IFRC, 2024a). Marib, hosting the largest IDP concentration, contains a significant portion of those high-risk sites. For example, the Al-Jufaineh Camp on the outskirts of Marib city – the largest IDP camp in Yemen, sheltering over 9,000 families – is situated on a plain that has experienced flooding. A 2024 flood hazard analysis of IDP sites in Marib found that dozens of sites, including Al-Jufaineh, are in "very high" or "high" flood hazard zones ((Holmakhdar, 2024. Essentially, tens of thousands of displaced people in Marib are directly exposed to flood danger whenever heavy rains occur.

In Hadramaut, the population is more dispersed. The coastal population (e.g. ~500,000 people in Mukalla metro) is exposed to coastal flooding and storm surge. Inland, about 1 million people live in the Hadhramaut valley regions (Sey'un, Shibam, Tarim and surroundings) – these communities are built around the wadis and thus are exposed to flash floods from those wadis. Exposure in Hadramout's case often correlates with proximity to wadis or low coastal elevations. Notably, traditional mud-brick towns like Shibam (a UNESCO site) are built on slight elevations above the wadi bed, but extreme floods can reach them (as in 2008 when Shibam's outskirts were flooded). Many smaller farming villages lie directly in the fertile wadi floors and are highly exposed.

Urban vs Rural Exposure:

Urban centers have larger populations concentrated in floodplain locations. In Marib City, rapid expansion has occurred on land downstream of the dam and along natural drainage channels. Urban exposure also comes from poor drainage: even neighborhoods not in official floodplains can suffer inundation from intense rain overwhelming street drainage. Rural exposure is also significant – rural residents often live adjacent to their fields along wadis, and their homes (usually single-story adobe or concrete houses) are vulnerable to being swept away. Additionally, rural areas have less infrastructure to divert or contain floodwaters. The death toll in many flood events skews toward rural areas; for instance, in the 2008 Hadhramaut floods, many of the 73 fatalities were farmers in remote villages who could not be warned in time (GFDRR, 2023).

IDPs and Vulnerable Groups:

IDPs stand out as an extremely exposed group. They typically reside in emergency or makeshift shelters: tents, tarpaulin huts, or rudimentary shacks that offer little resistance to water. During floods, these shelters are easily destroyed or washed away. In 2020 and 2021, *entire IDP camps in Marib were inundated*. For example, after heavy rains in July 2021, more than 2,500 displaced families in Marib lost their shelters to flooding (France 24 Observers, 2023). In one incident, torrential rains destroyed 21 IDP sites in Marib, forcing families to flee again. This cyclical displacement exacerbates their vulnerability. Children, women, the elderly, and people with disabilities within these communities are particularly at risk – not only of physical harm in floods but also of secondary impacts like water-borne diseases after floods (due to camp conditions).

Apart from IDPs, other vulnerable groups include marginalized communities in flood-prone zones (for example, the Al-Akhdam minority often live in slum areas near wadis in cities and face severe flood impacts). In coastal Hadramaut, poor fishing communities living in informal housing along the shore (e.g. in low-lying neighborhoods of Mukalla) are highly exposed to both flood and storm surge.

Critical Infrastructure Exposure:

Exposure analysis also extends to key sites and infrastructure. In Marib, critical assets such as the Marib Dam itself, electricity substations, water supply wells, and highways (the Marib–Sana'a road, Marib–Hadhramaut road) lie in flood-risk areas. The Marib Dam, while a protective asset, if compromised by extreme inflow, poses a downstream risk. The main road network in Marib crosses wadis at many points, so road exposure is high (floods frequently cut the Marib–Seiyun highway and isolate communities). In Hadhramaut, Mukalla's port and coastal highway (which links neighborhoods along the seafront) are exposed to coastal flooding. The Hadhramaut Valley's only paved road runs along the wadi floor connecting villages – it is essentially in the floodway for large events, as seen in 2008 when dozens of bridges and road sections were destroyed.

3. VULNERABILITY ANALYSIS

While exposure describes who/what is in harm's way, **vulnerability** determines how severely those exposed elements suffer when floods occur. Marib and Hadramaut exhibit multiple vulnerability factors:

- **Lack of preparedness capacities:** Field surveys and community interactions revealed several critical vulnerabilities that translate into tangible impacts when hazards strike. An overwhelming majority of respondents (roughly 96.7%) admitted they have no household contingency plan to follow when early warning messages are issued. This finding underscores a pervasive gap in preparedness – most families remain unsure how to react when warned of impending floods or other disasters. Compounding this is an awareness gap: about half of those surveyed did not know which agency is responsible for issuing early alerts, indicating that essential information is not reaching or resonating with a large portion of the community. In practical terms, this means warnings may come without clarity on their source or credibility, reducing their impact.
- **Absence of local action groups or committees dedicated to emergency alerts:** Nearly three-quarters of community members (approximately 76.7%) reported that no community-level alert committee exists in their area. Such local committees – where they do exist – can greatly bolster preparedness and organize effective responses. Their absence in most surveyed locations leaves a coordination void at the grassroots level. The surveys further showed limited external support reaching the community: about 63.3% of people said they had not received any outside assistance or aid in conjunction with early warnings. This reflects a broader humanitarian gap, where vulnerable communities often fend for themselves due to

insufficient aid coverage and capacity constraints among agencies. The net effect of these issues is clearly visible in people's livelihoods. Recurring floods have disrupted residents' ability to work or attend school and caused significant financial losses, dragging many households into deeper vulnerability. In South Sudan and similar contexts, climate shocks like severe flooding contribute to protracted crises, with millions of people requiring assistance. The field findings confirm that early warning messages alone are not enough – without preparedness, awareness, local organization, and support, communities still suffer tangible harm when disasters occur.

- **Housing and Shelter Vulnerability:** A significant share of the population, especially IDPs and the rural poor, live in shelters not resilient to floods. IDP shelters (tents, makeshift huts) can be completely destroyed by even shallow flooding. In permanent communities, many houses are built of mud brick or simple concrete blocks without foundations; these structures cannot withstand water inundation. In Wadi Hadhramaut, the traditional mud-brick houses are susceptible to collapse if floodwaters undermine their mud mortar. The ground floors of buildings are often not elevated – for example, in Mukalla's coastal neighborhoods and Marib's IDP camps, living spaces are at ground level and get easily waterlogged. When floods hit, the immediate result is widespread homelessness. In the July–August 2022 floods, over 9,000 shelters were recorded as damaged across IDP sites in Yemen (946 completely destroyed), indicating the scale of housing loss, much of it in Marib and Hajjah.
- **Socio-economic Vulnerability:** Both governorates have high poverty rates, exacerbated by war. In Hadramout's case, the 2008 flood was estimated to have pushed the poverty rate from 28% to 51% in the affected areas (IFRC, 2023), a dramatic increase showing how disasters impoverish communities. Poor households have fewer resources to prepare for or recover from floods. They often cannot afford safe land (hence settle in cheap, hazard-prone zones) or sturdy construction materials. Livelihood insecurity also means people might be reluctant to evacuate (for fear of losing what little they have). In Marib's IDP camps, families are dependent on aid; when floods destroy their tents and belongings, they lack financial buffers. Additionally, many IDPs already fled conflict with minimal assets, so repeated floods drive them deeper into destitution.
- **Infrastructure and Services Weakness:** Vulnerability is heightened by weak infrastructure – for instance, the lack of effective drainage as mentioned means water accumulates rather than being channeled away. Electricity and communications often

fail early in disasters, hampering response. In Marib, when floods in 2024 knocked down power lines, thousands of people were left without electricity for days (IOM, 2024). Water systems (wells, pipelines) are fragile; floods commonly contaminate water sources, leading to health crises (cholera, etc.). The limited healthcare facilities in these regions can be overwhelmed treating flood-related injuries or disease outbreaks. These systemic weaknesses mean floods have cascading effects – a flood is not just a water issue but quickly becomes a health, food security, and protection issue.

- **Environmental Degradation:** As noted, deforestation and erosion mean that floods carry heavy sediment loads, which can ruin agricultural land and fill up reservoirs. The Marib Dam reservoir, for example, is gradually silting; this reduces its capacity to buffer floods over time, effectively increasing vulnerability downstream. In Hadhramaut, the loss of terraces and vegetative cover in uplands means communities lose the natural buffer that slowed runoff historically. Over decades, this has made identical rainfall produce worse flooding now than in the past.
- **Lack of Early Warning and Preparedness:** An often overlooked vulnerability factor is the limited early warning coverage in Yemen. There is no nationwide flood forecasting system currently fully operational. Communities usually get little to no warning of sudden floods. In 2008, people in Hadhramaut had <24 hours notice of the impending storm. In Marib, flash floods can strike with virtually no warning. The country's meteorological service and humanitarian early warning systems are constrained by conflict and resource gaps. Additionally, many residents lack awareness or knowledge of flood risks – particularly displaced people who may be unfamiliar with the local hazard history. When floods hit at night, sleeping families can be caught off guard. Without organized preparedness (like safe shelters on higher ground, community evacuation plans, or even simple measures like sandbagging around tents), the community's capacity to cope is low. Local coping strategies exist – e.g. some villagers know to move livestock to higher ground when skies darken – but these traditional measures are strained by the increased magnitude of floods.
- **Special Vulnerabilities – IDPs, Women, etc.:** We have highlighted IDPs as extremely vulnerable; to elaborate, in flood situations they often lose their shelter and whatever few assets they own. Relief may be slow to reach some camps if roads are cut. After floods, IDP women and children are at risk of exploitation or abuse if their camp conditions deteriorate (protection concerns heighten when people are displaced again or in crowded emergency shelters). Health-wise, children can fall ill from wading in dirty floodwater, and malnutrition can worsen if food aid is disrupted. Vulnerability

is also high for elderly or disabled persons who may be unable to flee rapidly rising waters – tragically, flood mortality in Yemen often includes such individuals who couldn't escape their homes in time.

SECTORAL IMPACTS OF FLOODS

Floods in Marib and Hadhramaut impact all sectors of society and the economy. The following sections detail the observed impacts by sector, drawing on historical data and recent flood events:

Impact on Population (Displacement and Human Loss)

Flood events often lead to mass displacement of populations. People are forced to flee flooded homes, frequently in a sudden and chaotic manner. For instance, the 2008 Hadhramaut floods displaced 25,000 people overnight, as whole villages evacuated. In more recent events, displacement largely affects IDPs and those in precarious housing. In 2020, approximately 223,000 people were displaced by flooding across Yemen; many of these were already displaced families in Marib who had to move again when their camps flooded. Table 2 presents a summary of displacement and housing impacts from selected events in Marib and Hadhramaut:

Governorate	Notable Flood Events	Population Affected	Displaced (Households)	Houses/Shelters Destroyed	Houses/Shelters Damaged
Marib	2020 monsoon floods (dam overflow); 2021 flash floods; 2023 windstorms & floods.	50,000+ people affected in 2020; 13,995 HH affected in 2023 (Marib+Hajjah).	~37,000 HH displaced (2020); 4,300 HH displaced (2021) (est. IDP camps).	937 shelters destroyed (2023, national, majority in Marib/Hajjah); ~600 shelters destroyed (Aug 2024 Marib sites).	9,243 tents damaged (2023); 2,800 shelters damaged (Aug 2024).

Hadhramaut	2008 Wadi Hadhramaut flood; 2015 Cyclone Chapala; 2023 Cyclone Tej.	650,000 people affected (2008); ~18,000 affected (2015); 3,000 families affected (2023).	5,000 HH displaced (2008) (beyond immediate); 3,000+ HH evacuated (2015); 305 HH displaced (2023).	1,072 houses destroyed (2008 PDNA); 250 homes destroyed (2015, coastal); dozens homes destroyed (2023).	6,000 houses damaged (2008); 500+ houses damaged (2015); hundreds damaged (2023, incl. 23 in Mukalla from Shaheen).

Table 2: Population and housing impacts of floods in Marib and Hadhramaut. (HH = households; data compiled from PDNA 2008, OCHA/IFRC 2020–2023, CCCM Cluster, etc.)

As seen, floods commonly destroy thousands of shelters. The death toll varies by event but can be significant when flash floods catch people by surprise. Human fatalities have occurred in almost every major flood: 13 people died in the 2021 floods in Marib's region; at least 2 children were killed in flash floods in Hadhramaut in 2020; and 4 deaths were recorded in Marib from a windstorm-flood in 2023 (IOM, 2023). The psychosocial impact on survivors is also notable – families who lose members or see their homes washed away often suffer trauma.

Beyond immediate displacement, floods cause longer-term population movements. In Marib, repeated flooding of IDP sites has prompted efforts to relocate camps to safer areas (e.g., moving some families from flood-prone Al Rawda camp to new sites). However, such relocations are challenging and slow, leaving many still in harm's way.

Impact on Housing and Settlements

Floods ravage housing and settlements, as partially reflected in the numbers above. Key points:

- **Shelter Destruction:** Entire neighborhoods have been devastated, especially in rural wadis. In 2008, some villages in Hadhramaut were "95% destroyed" according to the PDNA, as buildings of mudbrick literally dissolved in floodwaters. Modern concrete houses can fare better structurally, but many still collapse or incur heavy damage if water flows inside at force. For IDP camps, as already described, flimsy shelters stand no chance – for example, *floods in Marib in April 2022 completely destroyed 1,586*

shelters and damaged 3,600 more in various sites (Shelter Cluster data), leaving thousands without shelter.

- **Infrastructure within settlements:** Floods damage not just houses but the infrastructure of communities – local roads, footbridges, drainage, water and power lines inside towns. In Marib city, the April 2020 flood swamped streets and knocked out dozens of electricity poles, plunging neighborhoods into darkness. Urban flooding also causes sewage overflows, contaminating residential areas and posing public health risks. In Mukalla 2021 (Cyclone Shaheen), storm runoff inundated the ground floors of clinics and schools, rendering them temporarily unusable. Markets and shops are also hit – goods can be ruined by water and mud, impacting local commerce.
- **Loss of Personal Property:** Residents often lose nearly all their possessions when homes flood. Furniture, clothing, food stocks, and personal documents get soaked or washed away. This loss of assets reinforces poverty and makes recovery harder. After the 2022 floods, assessments in Marib found that many IDP families had lost the few assets they owned, such as bedding and cooking utensils, necessitating distribution of new non-food item kits.
- **Historic and Cultural Sites:** Hadramout's famed mudbrick architecture (e.g., the high-rise houses of Shibam) is at high risk. The 2008 floods caused sections of Shibam's ancient wall to collapse and heavily damaged over 200 historic houses there and in Tarim. Restoration took years and some heritage was irretrievably lost. These cultural losses, while not always quantified in dollars, are significant.

Impact on Agriculture and Livelihoods

Floods can be a double-edged sword for agriculture in Yemen's dry environment – mild floods deposit silt and can recharge soil moisture, but severe floods are destructive:

- **Crop Damage:** Fields can be eroded or buried by sand and debris. The 2008 Hadhramaut floods wiped out a large portion of that year's harvest in the Wadi Hadhramaut. According to the FAO assessment, nearly 23,000 feddans (~9,650 ha) of cultivated land were damaged in Hadhramaut/Mahrah – orchards, grain fields, and vegetable plots were ruined. Farmers lost not just crops but also the topsoil fertility in places. Similarly, floods in Marib's agricultural areas (which are mostly small-scale farms along wadis) have destroyed sorghum and wheat fields and washed away irrigation channels. In 2023, heavy rains in Marib's valley drowned crops that were almost ready for harvest, leading to local food shortages.
- **Livestock Loss:** Many rural families keep goats, sheep, or cattle. Floods can drown livestock tied in sheds or grazing near rivers. In Dhamar 2023 (central Yemen), a flood

washed away an entire flock of sheep. In Hadhramaut 2008, thousands of livestock were lost – one report noted "heavy livestock losses affecting pastoralists" (exact numbers hard to come by, but significant). This is a major economic blow to households for whom animals are a source of income, food, and savings. The loss of a cow or a dozen goats can push a family into crisis.

- **Irrigation and Agriculture Infrastructure:** Yemen relies on traditional and modern irrigation structures (spate irrigation channels, small dams, wells). Floods often damage these systems. In 2008, an estimated 28 spate irrigation intakes in Hadhramaut were destroyed. Wells can be contaminated or silted up by floodwater. Terraced fields, common in Yemen's highlands, can collapse under heavy runoff, though in Marib and Hadhramaut terracing is less common than in the west. The Marib Dam, crucial for irrigating downstream fields, had its sluice gates damaged in the 2020 overflow incident, disrupting water supply for agriculture temporarily.
- **Food Security and Livelihoods:** Agricultural losses from floods directly hit food security. For subsistence farmers, losing a season's crop means immediate food shortage and dependency on aid. On a larger scale, if key crop-producing areas are affected (Hadhramaut produces dates and some cereals, Marib produces grains, fruits, and vegetables in certain pockets), local markets see supply dips and price spikes. Moreover, many rural residents (farmers, laborers) lose their source of income when fields are flooded. The 2008 disaster was noted to have caused *"loss of livelihood for half the population in the two governorates"* of Hadhramaut and Mahrah, and raised poverty rates accordingly. In Marib, many IDPs work as casual labor on farms or as herders; when floods kill livestock or ruin farms, those employment opportunities vanish.

Impact on Infrastructure (Roads, Bridges, Utilities)

Floods in these regions exact a heavy toll on infrastructure:

- **Roads and Bridges:** Due to the terrain, roads often follow valley floors or cross dry riverbeds. Flash floods can wash out roads and destroy bridges, cutting off communities for days or weeks. In 2008, more than 80 bridges and culverts were damaged or destroyed in Hadhramaut and Al-Mahrah (including major highway bridges) and 617 km of roads were affected (PDNA figures). The Marib–Sana'a road, a lifeline, has been severed multiple times by flooding or rain-induced landslides. In 2022 and 2023, seasonal floods made many rural roads impassable in Marib's southern districts and in parts of Hadhramaut, delaying humanitarian deliveries. The destruction of transport links not only hampers immediate relief efforts but also disrupts trade and movement for weeks. For example, after Cyclone Tej, the coastal

highway in eastern Hadhramaut was submerged and a section collapsed, halting transport between Al-Mahrah and Mukalla for over a week.

- **Electricity and Power:** As mentioned, electrical infrastructure is vulnerable. Overhead power lines and poles can be knocked down by floods or storm winds. Floodwaters can infiltrate power stations or generators. Marib city's grid has faced outages after floods; similarly, parts of Mukalla lost power in 2015's cyclone. The reliance on diesel generators in some areas (e.g. for pumping water in agriculture) also means that if fuel supplies are disrupted by floods (roads cut) or equipment is damaged, those services stop.
- **Water and Sanitation:** Flash floods often damage water supply systems. Wells can be contaminated with floodwater (leading to unsafe drinking water). Piped networks may be broken by debris or erosion. During the 2020 floods, several water wells and pumping stations in Marib and Al Jawf were reported damaged, cutting off clean water to tens of thousands. In coastal towns, floods can inundate sewage treatment plants (where they exist) or cause pit latrines to overflow, creating sanitation crises. After major floods, spikes in water-borne diseases like cholera, malaria, and dengue occur – partly due to infrastructure breakdown (water contamination and stagnant water breeding mosquitoes). For instance, following the 2016–2020 flood seasons, Yemen saw surges in cholera cases in affected areas.
- **Public Buildings and Services:** Schools, hospitals, and other public buildings are not spared. Floods in 2022 damaged or destroyed at least 20 schools across Yemen (OCHA), including some in Marib and Hadramaut. Health centers can be put out of action right when they are needed most. The 2008 floods destroyed 4 health facilities and 16 schools in the affected areas (PDNA). Relief operations sometimes have to use schools as temporary shelters for displaced people, disrupting education even if the school wasn't physically damaged.
- **Economic Infrastructure:** Beyond roads, floods impact markets, businesses, and productive infrastructure. Markets can be flooded (e.g. central markets in Sey'un and Mukalla have flooded, ruining stock for shopkeepers). Small industries like grain mills or workshops can be damaged. In Hadhramaut, the loss of irrigation schemes in 2008 had a multi-year economic impact until repairs were made. The port of Mukalla suffered heavy silting and infrastructure damage in 2015, affecting the local fishing and shipping economy for months.

FUTURE RISK OUTLOOK

Looking ahead, if current trends continue or worsen under climate change, flood risk in Marib and Hadhramaut will likely intensify in the coming decades:

- **In Marib**, the combination of a growing population (especially displaced communities) and changing climate suggests that disasters like the 2020 floods could recur more frequently. With rainfall extremes projected to increase, even the Marib Dam (designed to modulate floods) could face overflow situations more often. If not addressed, the dam's safety could be at risk from extreme inflows. The downstream IDP sites and Marib city's expansion areas remain in harm's way. Unless relocation or major protective works occur, tens of thousands of people could be affected by any repeat of the 2020-level flooding or worse. Informal settlements will likely grow as conflict continues, potentially in hazard-prone zones, raising risk. On the positive side, improved early warning or pre-emptive evacuation (as part of anticipatory action) could reduce casualties in future events, even if the hazard intensifies.
- **In Hadhramaut**, climate projections of stronger cyclones imply that events like 2008 or Cyclone Tej might strike once every few years rather than once a decade. The coastal city of Mukalla is particularly exposed to such future events – a direct hit by a major cyclone in a high sea-level future could be catastrophic without improved defenses. Inland, the Hadhramaut valley might see more frequent severe flash floods (for instance, a current 1-in-50 year flood could become a 1-in-25 year event by mid-century under RCP 8.5). This puts the agricultural heartland at significant risk of repeated devastation, potentially outpacing the ability to recover between events.
- **Cascading Risks:** An important aspect of future outlook is how flood risk interplays with other crises. Yemen is facing economic hardship, and its communities have low resilience. If a major flood strikes during an ongoing conflict flare or disease outbreak, the impacts could be magnified. Floods can also trigger secondary hazards like landslides (as heavier rains saturate soils in hilly areas – already seen in parts of Hadhramaut and adjacent regions), or dam failures (if small dams can't withstand extreme rainfall). There is also the risk of floods mobilizing landmines and unexploded ordnance in conflict-affected areas – this has been reported in Hodeida and other areas where floodwaters moved mines into new areas (IOM, 2023), posing a deadly hidden threat. Marib, having seen conflict, could face similar issues of mines in floodplains.
- **Economic Development and Risk:** If peace and development take hold, there may be more investment in infrastructure, which could either reduce risk (through better drainage, etc.) or inadvertently increase exposure (if development occurs without considering flood zones). Proper urban planning could ensure new housing is built

away from high-risk wadis or elevated, but without it, reconstruction and growth could lock in greater future losses.

In quantitative terms, models like the World Bank's risk assessments estimate that by 2050, the annual economic damage from riverine and flash floods in Yemen could increase substantially (some estimates suggest a doubling under high climate change scenarios, though exact figures are uncertain). The population in flood zones will also rise with population growth – in Marib's case, potentially dramatically if IDPs settle long-term.

The future risk underscores that the window for proactive measures is now. If anticipatory action can be institutionalized – e.g., having trigger-based financing to evacuate and support people before a forecast flood – then even in a future of stronger floods, the human toll can be mitigated. Conversely, inaction will mean each flood event becomes more damaging than the last as vulnerabilities compound.

4. RECOMMENDATIONS FOR FLOOD HAZARD MANAGEMENT.

To address the flood hazard in Marib and Hadhramaut and reduce its impacts in line with anticipatory action principles, we recommend a comprehensive strategy spanning early warning, infrastructure, and community resilience measures:

STRENGTHEN EARLY WARNING SYSTEMS (EWS):

Developing and improving flood early warning is a top priority. This includes installing hydrological monitoring (rain and river gauges) in upstream areas of Marib and Hadhramaut to detect floods early. An effective EWS would link meteorological forecasts (e.g. heavy rainfall or cyclone warnings) with on-the-ground alerts. The system should ensure warnings reach vulnerable communities in time. For example, implementing a community radio/SMS alert in Marib's IDP camps could warn residents of coming heavy rains and advise evacuation to higher ground. An Early Warning Center in Hadhramaut (perhaps at the governorate level) could monitor cyclone developments and coordinate alerts. Training and drills should accompany the hardware – communities need to know how to respond when warnings are issued. Developing such systems is feasible with modern technology and will save lives by giving people crucial lead time. Early warnings should also be impact-based – indicating which locations should evacuate (e.g., "Wadi Hadhramaut expected to flood to X level, villages A, B, C must move").

INFRASTRUCTURE INVESTMENTS FOR FLOOD CONTROL:

Significant infrastructure improvements are needed to mitigate flood hazard. Key actions:

- **Riverbank Protection and Dams:** Construct or rehabilitate small retention dams and embankments in strategic locations. In Hadhramaut, reinforcing embankments along critical stretches of Wadi Hadhramaut can contain moderate floods. Building check dams in upstream tributaries can slow runoff. In Marib, examine the structural integrity of Marib Dam and increase spillway capacity if needed to handle larger floods safely. Where feasible, build earthen dikes around high-density IDP sites or towns to deflect floodwaters (several camps in Marib would benefit from perimeter berms).
- **Drainage Systems:** Urban areas need upgraded drainage. In Marib city and Mukalla, invest in enlarging stormwater drains, clearing existing channels, and constructing new drainage where absent. For IDP camps, provide simple drainage earthworks – e.g., digging diversion ditches upslope of camps to channel water away. Improving drainage in camp settings can drastically reduce flood pooling.
- **Bridges and Roads:** Reconstruct critical bridges with flood-resilient designs (higher span, stronger abutments). Where roads frequently wash out, consider culverts or causeways that allow water to pass without destroying the road. Elevating road segments in flood plains can maintain access during floods. Donors should prioritize funding the repair and climate-proofing of key transport links (like the Mukalla coastal highway and Marib's road network). This will reduce isolation of communities during disasters.
- **Protective Infrastructure in Communities:** Small-scale projects, such as floodwalls around important facilities (hospitals, water wells) and elevated platforms in villages where people can take shelter with belongings, should be implemented. The concept of community safe havens – raised earth mounds or multi-story solid structures – can provide refuge for people and livestock during flash floods, especially in flat IDP sites.

Infrastructure measures, however, must be coupled with maintenance. It's critical to involve local authorities and communities in maintaining drains, clearing debris from channels, and monitoring dam safety, so that these investments remain effective.

SUSTAINABLE LAND AND WATER MANAGEMENT:

Addressing environmental root causes will reduce flood severity. Efforts should be made to restore vegetation cover in upstream watersheds of Hadhramaut and Marib. Tree planting, protecting remaining forests, and promoting terraced farming or other soil conservation can slow runoff. Encourage agroforestry and reforestation projects in upland areas (possibly as cash-for-work initiatives for locals/IDPs). In parallel, implement sustainable drainage and land use planning: avoid new construction in identified flood zones. Local governments

should enforce zoning that discourages settlements in high-risk wadi beds. Where people are already settled, explore relocating the most vulnerable households – for example, relocating families living directly in Wadi Masila's path to safer ground and converting that land to green space that can flood naturally. Additionally, maintain Marib Dam's reservoir capacity by dredging if needed to manage sediment build-up.

Rainwater harvesting and better water management can also be beneficial – capturing rain through cisterns or small dams reduces the uncontrolled runoff that causes floods while easing water scarcity. Traditional practices, like Yemen's ancient water distribution systems, can be revived or adapted to current conditions to mitigate floods.

COMMUNITY-BASED DISASTER RISK REDUCTION:

Empower communities with knowledge, organization, and small-scale resources to mitigate and respond to floods. Establish or strengthen local disaster management committees in villages and camps. These committees can identify local risks and coordinate preparedness – e.g., pre-designating evacuation routes and safe points (such as a sturdy building on higher ground). Conduct flood drills before the rainy season, especially in IDP camps, so that people practice moving to safety quickly. Provide basic rescue equipment to communities: inflatable boats or even simple flotation devices and first aid kits in flood-prone areas could save lives in sudden floods.

Promote community awareness and education on floods. This means teaching people to recognize warning signs (like rapid rise in wadi flow), instilling the importance of evacuating when advised, and informing them how to protect documents and assets (e.g., keeping important documents in waterproof bags, storing food off the ground). Public awareness campaigns can be done via radio, mosques, and schools. When communities understand their risk and how to act, mortality and injury drop significantly.

SPECIAL PROTECTIVE MEASURES FOR IDP SITES:

Given IDPs' extreme vulnerability, targeted interventions are needed:

- Site Improvements: As an anticipatory action, before peak flood season, humanitarian agencies should reinforce IDP shelters (e.g., raise them on sandbag platforms, dig drainage around tents). Distribute plastic sheeting and sandbags for families to divert water. Identify particularly low-lying sites and prioritize them for temporary evacuation or infrastructure support when heavy rain is forecast.
- Relocation to Safer Land: In the medium term, relocate the highest-risk IDP camps. For instance, any camp found to be in a wadi should be moved to nearby higher

ground in the dry season, with support to rebuild shelters there. This is complex but necessary; incentives and assistance to move can be provided.

- Stockpile and Rapid Response: Pre-position emergency supplies (food, water, blankets, repair kits) near high-risk communities so that if a flood hits, relief arrives within hours. Also, plan evacuation shelters – identify sturdy structures or elevated areas where IDPs can be brought ahead of a forecast flood, and ensure transport is available.

EMERGENCY RESPONSE AND ANTICIPATORY ACTION PROTOCOLS:

Develop clear protocols for anticipatory action when flood risk thresholds are reached. For example, if the meteorological service forecasts >100 mm of rain over Marib catchment, that could trigger release of anticipatory funding for early actions: evacuating the most at-risk households, distributing cash or supplies so people can strengthen their shelters, clearing drainage channels, etc. Having these pre-agreed triggers and actions (possibly through mechanisms like the Start Fund or IFRC's Forecast-based Financing) will make early action timely and systematic. Donors should support such mechanisms, and the government's fledgling disaster management agencies should be involved in institutionalizing the process.

POLICY AND COORDINATION:

To strengthen anticipatory action, flood preparedness must be embedded in both provincial and national disaster risk reduction (DRR) strategies. Local authorities in Marib and Hadhramaut should annually develop Flood Contingency Plans, clarifying roles, available resources, and response gaps before the rainy season. Effective anticipatory action depends on strong coordination between humanitarian actors, government agencies, and communities. Currently, fragmented efforts and siloed operations hinder efficiency. To address this, regular joint planning among meteorological services, civil defense, NGOs, and local leaders is essential. Establishing coordination forums or task forces can help align roles, review early warning systems, and harmonize contingency plans. At the national level, early warning systems should be integrated into broader DRR frameworks, including linking local hazard maps with emergency response platforms to guide action. Practical steps include joint simulation drills, unified alert procedures, and community feedback loops. When national technical capacity is connected to localized preparedness, flood risks can be managed more effectively, leading to faster, better-coordinated responses and stronger community resilience.

LONG-TERM CLIMATE ADAPTATION:

Finally, align immediate anticipatory actions with a long-term adaptation vision. This includes advocating for and investing in climate-resilient infrastructure (as mentioned), but also

diversifying livelihoods so that floods don't have as catastrophic an economic impact. Support farming communities to adopt flood-resistant crops or to have access to insurance (in the future, perhaps a micro-insurance for crops/livestock could buffer losses). Strengthen urban planning in Mukalla and Marib to incorporate flood risk maps – e.g., reserve certain areas as flood zones (no building) and incorporate parks or retention basins there.

4. CONCLUSION

The risk of flooding in Marib and Hadhramaut is no longer episodic—it is intensifying, widespread, and accelerating due to climate variability and compounding humanitarian stresses. This report has demonstrated that floods, more than any other hazard, pose a recurrent threat to both life and livelihood in these governorates. The analysis highlights how high population exposure, particularly among displaced persons, intersects with critical infrastructure gaps, weak early warning systems, and limited preparedness, resulting in repeated cycles of loss, displacement, and economic disruption.

While the challenges are significant, the pathways for action are clear. This impact profile provides the foundation for a scalable anticipatory action model, centered on early warnings, community engagement, adaptive infrastructure, and multi-stakeholder coordination. Implementing the recommendations will require sustained commitment from national and local authorities, donors, and humanitarian partners—but the potential gains are substantial. Proactive measures taken before floodwaters rise can prevent deaths, reduce displacement, and minimize recovery costs.

Looking ahead, as climate change reshapes Yemen's hazard landscape, anticipatory action must become a core pillar of disaster risk governance. With the right tools, political will, and community partnership, Yemen can shift from crisis response to forward-looking risk management, even in the most fragile settings. This report invites all stakeholders to act urgently and collectively, because the next flood is not a question of if, but when.

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