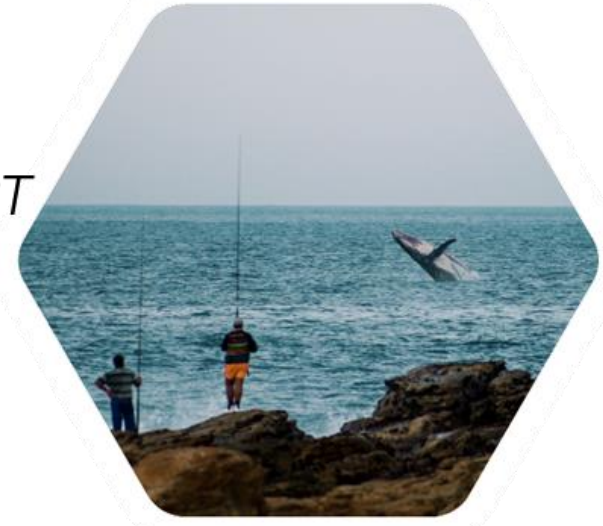
Review of Environmental and Climate Hazards, Vulnerabilities, and Risks Related to the City of Port Elizabeth and Its Location in Algoa Bay, South Africa

CICLICO DESKTOP REPORT



This report was prepared as background to the CICLICO project.

Disclaimer: The views expressed do not represent those of the institutions nor the funder.

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PHOTO CREDIT

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EXECUTIVE SUMMARY

The purpose of this literature review is to provide context to the Cities and Climate Change in Coastal Western Indian Ocean (CICLICO) project by describing the environment of Algoa Bay; understanding local climate change impacts; identifying the main hazards, risks, and vulnerabilities for the area; and communicating findings to relevant stakeholders. This report provides a coarse desktop assessment of Algoa Bay's main vulnerabilities, particularly relating to the coastal and marine environment.

Nelson Mandela Bay has a mild climate, attractive beaches, and is an important business hub for manufacturing. It supports diverse terrestrial, coastal, and marine habitats, making it popular for sports and eco-tourism. Persistent drought combined with poor maintenance and a lack of forward thinking has, however, resulted in frequent water shortages and ongoing restrictions. There are also concerns regarding water quality, especially pertaining to untreated effluent entering the Swartkops Estuary and flowing into the nearshore, resulting in harmful algal blooms (HABs).

Climate change is predicted to exacerbate current hazards and create new ones; for example, range shifts in marine species in response to warming temperatures and prey availability have been noted. Increased upwelling events and ocean acidification may also affect the abundance of diversity of organisms. Rising sea levels is of particular concern, as it is predicted that popular swimming beaches, public infrastructure, and development, including national roads and houses, could eventually be reclaimed by the ocean.

The socio-economy of the Bay is reflective of the country in general, and is characterised by high poverty, high HIV/Aids infection rates, unemployment, female-headed households, a large youth population, and inadequate housing. Service delivery and the maintenance of infrastructure are poor and mostly reactive. The 2020 Covid-19 pandemic has further highlighted the dire conditions of government healthcare facilities in the city. Crime, gangsterism, and the poaching of perlemoen are also problematic in and around the Bay area.

Overarching these noted hazards is poor governance by the municipality due to political instability and infighting. Adapting to and mitigating for climate change will require an extensive budget and cooperation between Government, non-governmental organisations (NGOs), local businesses, and residents. Detailed disaster management plans also need to be put in place, along with adequately trained response teams. Such approaches and resources are, however, difficult to gain and implement for an area that already struggles to effectively provide services to all residents.

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ACRONYMS AND ABBREVIATIONS

AIC	African Independent Congress
ANC	African National Congress
BAIC SA	Beijing Automotive Group South Africa
BBC	British Broadcasting Corporation
CICLICO	Cities and Climate Change in Coastal Western Indian Ocean
CSIR	Council for Scientific and Industrial Research
DA	Democratic Alliance
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
DEDEAT	Department of Economic Development, Environmental Affairs and Tourism
DEFF	Department of Environment, Forestry and Fisheries
DIN	Dissolved Inorganic Nitrogen
ECSECC	Eastern Cape Socio Economic Consultative Council
ENSO	El Niño-Southern Oscillation
FINSA	Financial Services of South Africa
HABs	Harmful Algal Bloom
IDZ	Industrial Development Zone
IOL	Independent Online
IMESA	Institute of Municipal Engineering of Southern Africa
IDP	Integrated Development Plan
IPCC	Intergovernmental Panel on Climate Change
NDMC	National Disaster Management Centre
NGOs	Non-governmental Organisations
NMBM	Nelson Mandela Bay Municipality
Prasa	Passenger Rail Agency of South Africa
PPE	Personal Protective Equipment
SAB	South African Breweries

SANCCOB	Southern African Foundation for the Conservation of Coastal Birds
SMMEs	Small-, Micro-, and Medium Enterprises
StatsSA	Statistics South Africa
STIs	Sexually Transmitted Infections
UDM	United Democratic Movement
UF	United Front
USA	United States of America
WESSA	Wildlife and Environment Society of South Africa
WWTW	Wastewater Treatment Works

1. INTRODUCTION

South Africa is particularly vulnerable to climate change owing to its locality, an economy dependant on climate-sensitive sectors, high levels of poverty, and health related impacts (Department of Planning, Monitoring and Evaluation [DPME], 2017; Eckstein, Künzel, Schäfer, and Winges, 2020; Perine and Keuck, 2018). A large portion of South Africans live along the coast and are, therefore, vulnerable to rising sea levels and increased storm damage (Celliers, et al., 2013). Extreme weather events have also become more prevalent, resulting in increased frequency and intensity of fires, floods, hailstorms, and droughts (Department of Environmental Affairs and Tourism [DEAT], 2017; Skowno et al., 2019). These events, coupled with busier oceans from diversified activities, mining, coastal development, and deteriorating water quality pose increasing challenges to coastal ecosystems (Skowno et al., 2019).

The South African Weather Services (SAWS, 2020) has shown that the country's annual average temperature is increasing by 1.6°C per decade, which is higher than the average global trend. Rising temperatures, along with altered and unpredictable weather patterns, are increasing the frequency and intensity of droughts; thereby creating water security challenges in an already water scarce country (DEAT, 2017). Water shortages endanger food supply, agricultural livelihoods, water-sensitive industries (e.g., mining), and increases chances of fires. Existing pressures, such as competition from invasive species, disease, habitat degradation and loss, decreased freshwater flow, and pollution are further amplified by climate change (Skowno et al., 2019).

These factors, combined with South Africa's history of Apartheid and pre-existing socio-economic problems (i.e., rural-to-urban migration, poor service delivery, and efforts to undo Apartheid-era segregation) place extreme pressure on Government to deliver basic services and ensure economic growth (Ngepah et al., 2019; Perine and Keuck, 2018). Even with effective mitigation and adaptation measures, the country continues to struggle to meet its development and economic growth goals, including job creation and poverty reduction (Department of Environmental Affairs [DEA], 2012). As a result, most of the population are extremely vulnerable and exposed to social, economic, and environmental shocks (Ngepah et al., 2019). Unless governance dramatically improves, risks will continue to increase due to climate changes interacting with increased human vulnerability.

Numerous efforts have been made to address climate change in South Africa; however, actual implementation of these efforts has been slow (National Treasury, 2018). Furthermore, while the country is signatory to multiple climate change adaptation policies, inclusion of such

policies into (local) legislation and management has been limited. It should be noted that a national Climate Change Bill was passed in 2018 with the aim of transitioning South Africa to a climate resilient and lower carbon economy and society (Republic of South Africa [RSA], 2018). Yet, building resilience to climate change is difficult in cities focussed on meeting 'day-to-day requirements' such as the provision of basic services (Ngepah et al., 2019). Limited resources and political instability make planning for future scenarios challenging.

Adaptation and mitigation planning are vital in reducing the vulnerability of municipalities to the potentially devastating impacts of climate-induced hazards (Aswani et al., 2019). Understanding the way in which the climate is expected to change as well as all possible impacts on the community (i.e., socio-economic assessment) as a result thereof is necessary; after which appropriate adaptation and disaster risk management measures can be determined. This report, thus, provides a valuable literature-based review of the environmental and climate hazards, vulnerabilities, and risks related to the city of Port Elizabeth and its location in Algoa Bay.

Algoa Bay has been described as one of the most vulnerable coastal areas in South Africa to climate change owing to its locality (le Roux and van Huyssteen, 2013). The area is already experiencing climate induced changes, including hotter days, more frequent droughts, more intense floods, greater wind speeds, a change in the prevailing wind directions, rising sea levels, and increased extreme storm surges (Nelson Mandela Bay Municipality [NMBM], 2015a). These impacts are likely to increase in magnitude and frequency over time. In addition, ongoing droughts have placed strain on farmers and have resulted in water shortages in the city (Rogers, 2019a). Poor infrastructure maintenance and a lack of forward planning has also resulted in ongoing water shortages and restrictions (NMBM, 2020). Other pressing issues include, amongst other concerns, the country's national energy crisis, increased offshore bunkering, potential mariculture operations, exploratory offshore oil and gas mining, and poor water quality.

The purpose of this literature review is to provide context to the Cities and Climate Change in Coastal Western Indian Ocean (CICLICO) project by describing the environment of Algoa Bay; understanding local climate change impacts; and identifying the main hazards, risks, and vulnerabilities of the area. The review's findings can be used for communication with relevant stakeholders. Specifically, this report provides a course assessment of Algoa Bay's hazards, risks, and vulnerabilities, particularly relating to the coastal and marine environment. It should be noted that the review is constrained by the quantity and quality of information available on likely changes in key environmental or climatic variables as well as by the current knowledge regarding species and/or community responses to changing environments.

This report is considered a living document that can be updated as and when new information becomes available. There is also scope to calculate vulnerability indices and present these results on a vulnerability map. Vulnerability maps are a useful visual tool for planners to identify regions of greater risk to coastal hazards and, ultimately, better inform mitigation and development strategies (Musekiwa et al., 2015)

2. METHOD

A comprehensive review of Algoa Bay and its environmental and climate hazards was conducted using a desktop literature review approach that included both published and 'grey' literature. To provide context to the CICLICO project, information regarding Algoa Bay's locality, physical environment, and climate were summarised. The socio-economy of the area was defined, which, combined with the Bay's environmental features, elucidated Algoa Bay's inherent vulnerabilities. For clarity, tables are presented in this project to summarise the main hazards for the area, with further explanation provided in the paragraphs that follow. An attempt has been made to rank hazards in Algoa Bay based on ancillary data; mostly recent newspaper articles. There is future potential to rank hazards based on the opinions of experts and relevant stakeholders in Algoa Bay. Table 1 defines how hazards, vulnerabilities, and risks have been defined in this study.

Table 1: Definitions of hazards, risks, vulnerabilities, and adaptive capacity as applicable in this study of Algoa Bay, South Africa

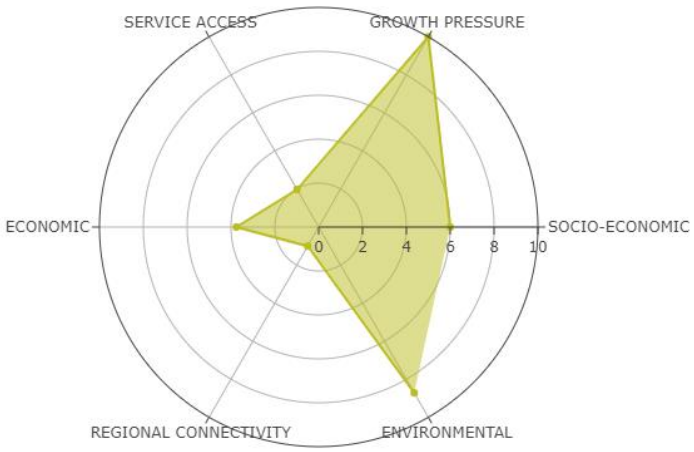
Terminology	Definition
Hazards	A hazard is the potential occurrence of a natural or human-induced physical event, trend, or impact that may cause loss of life, injury, and/or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.
Risks	A risk is defined in relation to a hazard, and is best described as probabilistic in nature (i.e., the likelihood of a hazard acting as a trigger to events that could have an undesirable outcome). High risks occur when there is a high probability of a hazard occurring, and/or when a system is highly vulnerable (i.e., with limited capacity to adapt).
Vulnerability	Vulnerability (i.e., sensitivity or susceptibility) is the propensity or predisposition to be adversely affected. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed. Factors such as wealth, social status, and gender determine vulnerability and exposure to climate-related risk.
Adaptive capacity	Adaptive capacity (i.e., robustness, resilience) is the ability of a system to adjust to climate change in order to take advantage of opportunities or to cope with the consequences brought about by the change. Adaptive capacity is determined by social factors, financial capacity, institutional capacity, and the regulatory environment.

Source: Davis-Reddy and Vincent (2017)

3. VULNERABILITY OF ALGOA BAY

The Council for Scientific and Industrial Research (CSIR), in collaboration with the National Disaster Management Centre and other stakeholders, including funding from the Canadian International Development Research Centre, developed a Green Book for adapting South African settlements to climate change (Ngepah et al., 2019). The project analysed the main risks that climate change and associated hazards pose to South Africa, with a focus on their impact on human settlements. The initiative produced an online tool (https://riskprofiles.greenbook.co.za/) to support local government with the planning and design of climate-resilient settlements.

A unique set of six spatial data indicators were used to score socio-economy, economic, physical, and environmental factors, which allowed for the comparison of relative vulnerabilities for settlements, as illustrated in Figure 1. Of the 213 municipalities in South Africa, Nelson Mandela Bay is considered low risk in terms of vulnerability to climate change (Figure 1). However, the area's economic and physical vulnerabilities are high, with economic vulnerability increasing from 4.8 in 1996 to 6.7 in 2011 (Le Roux et al., 2019), consistent with the city's high growth pressure (Figure 1).



Note: A high vulnerability score (i.e., closer to 10) indicates a scenario where an undesirable state is present.

Figure 1: Multi-dimensional vulnerabilities of Nelson Mandela Bay as per the Green Book scores (a)

Source: Green Book (2019)

Table 2: Vulnerability of Nelson Mandela Bay as per the Green Book scores

Multi-dimensional vulnerability	Definition	Province (33)	Country (213)
Socio-economic	Social inequalities are the factors that shape and influence the susceptibility and coping mechanisms of communities. Indicators for social vulnerability attempt to consider, firstly, the sensitivity to natural hazards of a population and, secondly, the ability of the population to respond to and recover from the impacts caused by the natural hazard.	2	57
Economic	The potential risks posed by hazards on economic assets and processes within the settlements and their municipalities.	28	150
Physical	Vulnerability of the built environment, its fabric, and built structures (i.e., buildings and infrastructure). Focusses mainly on the conditions that exist before a hazard occurs (i.e., exposed elements and their characteristics) and the expected degree of loss which results from the occurrence of a hazard of a given magnitude.	1	5
Environmental	The impacts on the ecological infrastructure on which settlements are dependent	26	142

Note: The lower the ranking of the municipalities, the more vulnerable to climate-related change.

Source: Green Book (2019)

According to the Green Book, the NMBM has adequate policies, guidelines, and plans in place to build climate resilience (Ngepah et al., 2019). These include the:

- Integrated Development Plan (IDP), most recently updated in June 2020 (NMBM, 2020);
- Enterprise Risk Management Policy of 2017 (NMBM, 2017);
- Climate Change and Green Economy Action Plan (NMBM, 2015a);
- Spatial Development Framework of 2015 (NMBM, 2015b);
- Integrated Environmental Policy of 2012 (NMBM, 2012); and
- Disaster Management Plan of 2010 (NMBM, 2010).

Some efforts are already in place, such as the management of undeveloped urban open spaces, interventions to address the city's water challenges, and the eradication of informal settlements (Ngepah et al., 2019). Aside from benefitting the community, these activities help to build resilience to natural hazards. Although these policies are in place, it should be noted that there is currently limited reporting thereon, and thus the extent of implementation is

difficult to determine. Further detail pertaining to the legislation of Algoa Bay is available in in the Legal Policy Report for Algoa Bay (Institute of Coastal and Marine Research, 2020).

3.1 Physical Environment

Algoa Bay, in the Eastern Cape, is home to the NMBM, which consists of over 1 million citizens (Statistics South Africa [StatsSA], 2017). The NMBM includes the major city of Gqeberha (previously Port Elizabeth), as well as Kariega (previously Uitenhage), Despatch, and surrounding agricultural areas. The NMBM is situated on the southwestern region of the Eastern Cape Province, south of the Cacadu District, and extends from the mouth of the Van Stadens River to the Sundays River, with the Winterhoek Mountains to the north-west and the Van Stadensberg Mountains to the south-west (Stewart and van Gend, 2007).

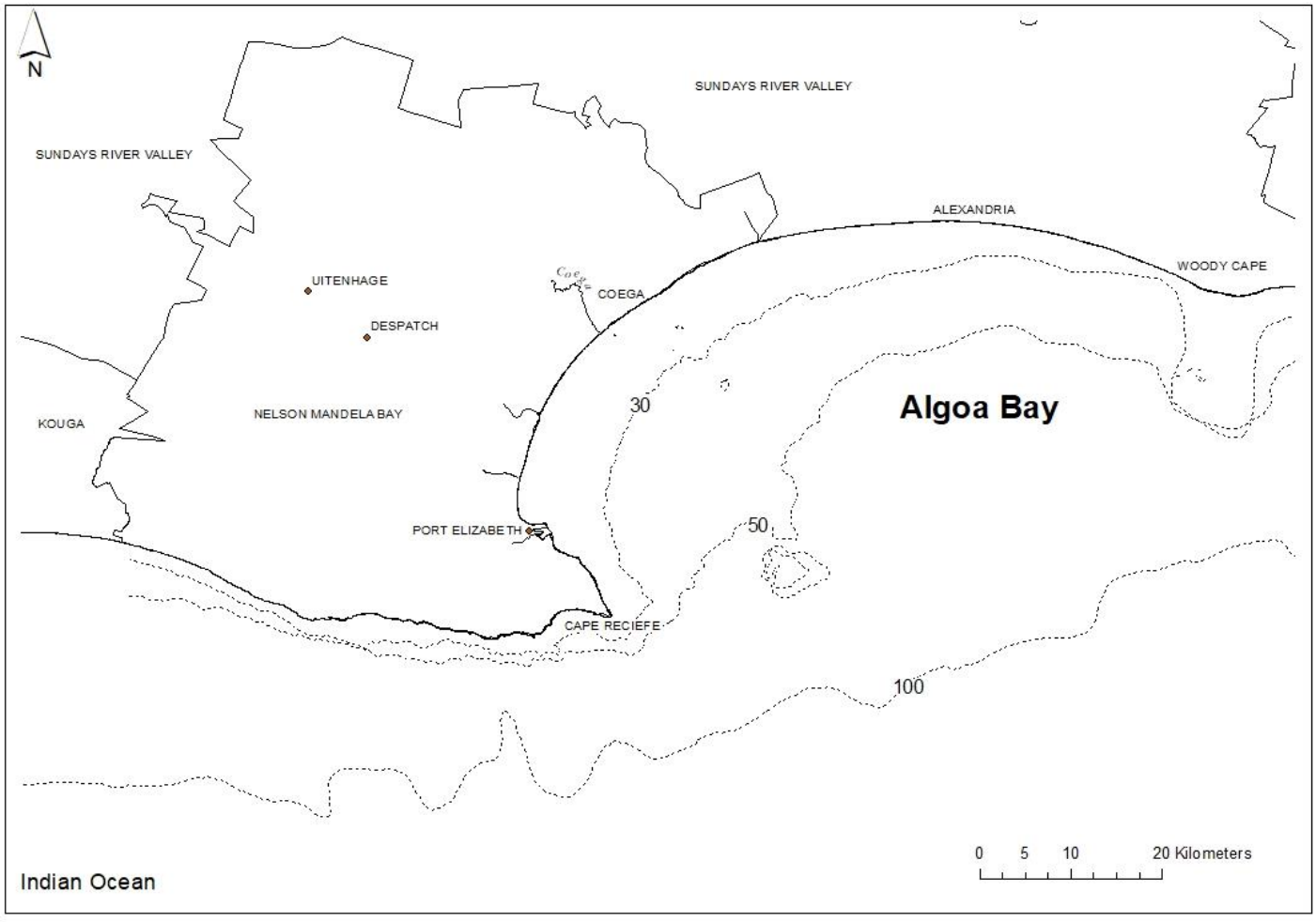


Figure 2: Map of Algoa Ba

Algoa Bay consists of a series of ancient coastal dunefields covered with a mosaic of Southern Coastal Forest, Subtropical Thicket, and Coastal Fynbos that characterise the southern part of the municipality. The area is considered to be a 'global biodiversity hotspot' due to the presence of both the Cape Floristic Region and the Albany Centre of Endemism (Myers, et al., 2000). Five of the seven biomes converge in the Bay, namely: Fynbos, Subtropical Thicket, Southern Coastal Forest, Nama-Karoo, and Grassland (Low and Rebelo, 1998; Mucina and Rutherford, 2006).

As a result of its location as a transition between the cool Agulhas shelf waters and the warm Agulhas Current, Algoa Bay is home to a high diversity of coastal and marine life. The area supports diverse habitats, including productive estuaries, peritidal tufa stromatolites, surf zones, rocky and sandy beaches, and the nearshore environment (Dorrington et al., 2018). Four major rivers, namely Sundays, Swartkops, Maitland, and Van Stadens, as well as their associated estuaries occur within the Bay. The highly urbanised, permanently open Swartkops Estuary is considered nationally important for its biodiversity (Bornman et al., 2016). However, pollution has been problematic since the 1950s, with the following sources flowing into the estuary: wastewater treatment works (WWTWs), saltpans, sand/clay mining, brickworks, tanneries, and the motor and wool industries (Baird, Hanekom, and Grindley, 1986). The Sundays Estuary is permanently open and flows into the Indian Ocean, approximately 40km east of Port Elizabeth.

The Alexandria Dunefield, the largest and least degraded coastal dunefield in the southern hemisphere, stretches 4km along the eastern sector of Algoa Bay, providing fresh water and nutrients to the adjacent marine environment via submarine groundwater discharge (Campbell and Bate, 1998). This dunefield forms part of the Greater Addo Elephant National Park and is a tentative World Heritage Site. In addition the Maitlands Dunefield, on the other side of the Bay, supports what is believed to be the highest density of the near-threatened African black oystercatcher in the country (Bornman and Klages, 2003).

Algoa Bay has rocky intertidal shores and sandy beaches, both exhibiting high diversity along a gradient of inundation. Recent unpublished work by Parker-Nance and Dorrington (n.d.) suggests a diversity of sponges, ascidians, and sea fans in the area. The Bay also has the greatest number of endemic fish species recorded along the South African coast (Turpie, Beckley, and Katua, 2000). Pilchard, anchovy, east coast round herring, and saury are some of the most abundant pelagic species in the region of Algoa Bay (Smale and Buxton, 1998).

3.2 Climate

Nelson Mandela Bay has a temperate climate, with temperatures averaging between 17-25ºC (NMBM, 2015a).The Bay forms a transition area between winter and summer rainfall and, therefore, experiences bimodal rainfall with peaks in autumn and spring. Known as the 'windy city', Port Elizabeth has predominantly southwest winds during the winter, northwest winds during autumn, and easterly winds during the summer and spring (Schumann and Martin, 1991). Historically, Nelson Mandela Bay has had an extremely variable climate; however, land and sea temperatures have increased over time. Over the past 40 years, average temperatures have risen by 0.25°C per decade (NMBM, 2015a). In February 2020, Port Elizabeth experienced its hottest temperature (i.e., 40.2ºC) in the last 55 years (Herald Reporter, 2020). In comparison, the number of rain days across the southern coast of South Africa, Port Elizabeth included, has consistently decreased over the past 5 decades (SAWS, 2020).

3.2.1 Water supply

Ongoing droughts in the past decade, coupled with a growing population, has resulted in consistently low dam levels and numerous water shortages in the Bay. Since 2016, Port Elizabeth has had water restrictions in place, with level C water restrictions enforced in July 2018, which means that only 50L can be used per person per day (Eyewitness News [EWN], 2018). 'Day zero' threats have been looming over the city since February 2020, when combined dam levels were at 22% (Ellis, 2020a). In July 2020, levels dropped to 17%; however, good rainfall in August, the wettest August in 14 years, helped augment the dams (AlgoaFM, 2020a). When in September 2020 the hypothesised 'day zero' was reached, the combined dam levels were at 19% (Groundup, 2020). Currently, the Bay experiences a water deficient of 40 to 50ML a day, coupled with infrastructure failure caused by national load-shedding, which has resulted in frequent water outages (Ellis, 2020b). Some areas of the city have gone without running water for a week at a time, with tankers supplying residents and businesses a few litres of water a day.

Poor maintenance and leaks are attributed to nearly 50% of the Bay's daily water wastage (SA Updates, 2020). Over 175 000 leaks have been repaired in the last year, and residents are urged to report leaks. There are plans in place to help alleviate water shortages in Algoa Bay, including repairing reticulation leaks, managing water pressure, rehabilitating reservoirs, replacing water meters, and replacing leaking pipes. National Treasury has also allocated funding to address the Bay's water crisis; however, major upgrades have yet to be made (AlgoaFM, 2020b). It is estimated that R6 million is needed to provide water tanks and emergency relief to all residents in the NMBM (SA News, 2020).

Presently, there are plans in place to extract water using biofiltration from the CoegaKop wellfield, located 30km from Port Elizabeth (SA Updates, 2020). When operational, the Coegakop water treatment plant could supply a sustainable daily yield of up to 20ML (du Toit et al., 2018). The digging of boreholes is also being used as a means to supplement the Bay's water supply (AlgoaFM, 2020b). However, experts warn that too much groundwater extraction in a coastal area could result in the ground table being salinised in the next 5 to 10 years (van Aardt, 2018). There is, therefore, further need to develop appropriate technologies; especially for upgrades and the rehabilitation of integrated water and sanitation delivery plans.

Almost half of the wastewater treatment works in the NMBM are dysfunctional. Treated water often fails to meet international and national health standards, and there is often discharge of raw sewerage into rivers and the ocean (Adams, Pretorius, and Snow, 2019). The discharge exceeds design capacity at the Kelvin Jones, Despatch, and KwaNobuhle WWTWs (i.e., 75ML·d−1, 77ML·d−1, and 79ML·d−1, respectively) (Department of Water Affairs, 2009). The Fish Water Flats WWTW, near Swartkops, treats about 70% of the NMBM's domestic and industrial wastewater (Coastal and Environmental Services [CES], 2016). This WWTW was constructed in 1976 and is in continual need of rehabilitation and maintenance due to being located close to the coast, which offers a highly corrosive environment that causes major damage to its structure. Since 2012, there have been plans in place to upgrade the facility and include a biogas plant (CES, 2016); however, up to the writing of this review, only maintenance has taken place.

The Cape Recife WWTW in Summerstrand supplies water for irrigation purposes to the Nelson Mandela University, Humewood Golf Course, and Pine Lodge Resort (Dayalan, 2019). Raw sewage is treated at this plant to a level that is acceptable according to the National Water Act (36 of 1998) and is used for irrigation so as to prevent the use of potable water for the maintenance of gardens and open spaces. In 2018, environmental authorisation for the upgrade of this WWTW was issued to double its capacity, allowing more areas in Summestrand and Humewood to be watered (Dayalan, 2019). To date, these upgrades have not been completed.

The Swartkops river and estuary is heavily polluted from sewage effluent and surrounding industries (Adams et al., 2019; Bornman et al., 2016; Nel et al., 2015)n. High *Escherichia coli* and enterococci levels, especially in the summer months, have further affected recreation at the estuary (Adams et al., 2019). The annual Redhouse River Mile swimming event has, as a result, been relocated, and cleansing ceremonies performed by traditional healers in the upper reaches of the estuary can no longer use water from the river. High trace metal concentrations (e.g., copper, zinc, iron, and cadmium) from the surrounding industries have also been

identified in sediment and riverine vegetation (Phillips, Human, and Adams, 2015). These heavy metals bioaccumulate within organisms, as seen by liver abnormalities in fish (Nel, Strydom, and Bouwman, 2015) and the weakening of Kelp Gull eggshells (van Aswegen et al., 2019). Adams et al. (2019) suggests that the following improvements may likely reduce the intensity and frequency of phytoplankton blooms and related health risks: 1) upgrading the three WWTWs flowing into the Swartkops Estuary, and 2) managing urban runoff into the Motherwell Canal.

3.3 Economy

Nelson Mandela Bay is an important economic hub in the country, ranking 6th in terms of gross value added out of 213 municipalities (Ngepah et al., 2019). The primary economic activities in the NMBM are manufacturing, finance, and business services. There are 300-plus auto component manufacturers in the Bay, including Volkswagen, General Motors, and Ford (Young, 2019). More recently, the Chinese automaker, FAW, and the Beijing Automotive Group South Africa (BAIC SA) built car manufacturing factories at the Coega Industrial Development Zone (IDZ). Of further note is that more than 10% of the world's catalytic converters are produced in the NMBM and shipped globally (Venter, n.d.). The Bay also boasts well-established petrochemical, rubber, plastic, corrugated packaging, textile, and pharmaceutical manufacturing industries (Nelson Mandela Bay Business Chamber, n.d.). Both Coca-Cola and South African Breweries (SAB) have large beverage production plants in Port Elizabeth (Drinks Insight Network, n.d.). In 2018, Coca-Cola opened its African headquarters in Humewood (AlgoaFM, 2018).

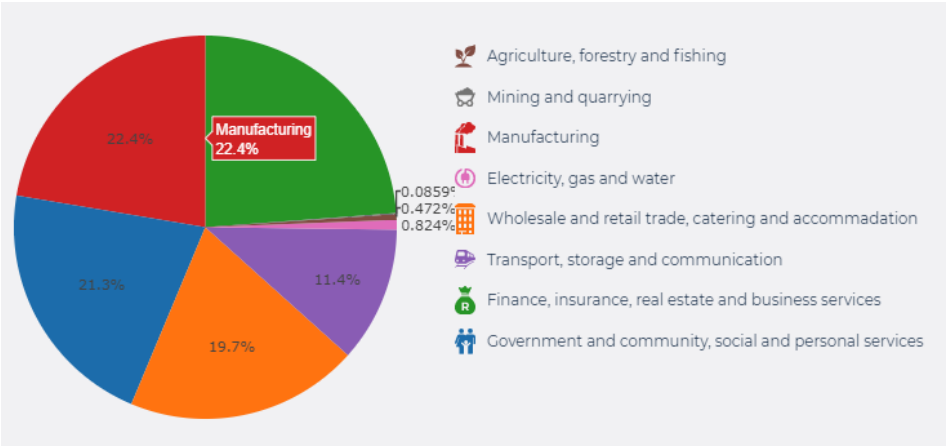


Figure 3: The contribution that the different economic sectors make to the total gross value added of the Nelson Mandela Bay Municipality

Source: Ngepah et al. (2019)

Near to Port Elizabeth, the Sundays River Valley and Langkloof areas are major producers of citrus, apples, and pears (Venter, n.d.). The Eastern Cape produces 75% of the world's mohair and is the second largest wool producer in the world. The NBMB has various processing and spinning facilities to process these raw products. Furthermore, the Port Elizabeth harbour is utilised to export deciduous and citrus fruit as well as annual wool harvests (Bloom, 2012). Manganese ore, railed from the Northern Cape, and other petroleum products are also handled at the harbour. With lots of open space and high wind speeds, Port Elizabeth is becoming a renewable energy hub, with numerous wind and solar energy farms having recently been, or currently being, constructed (Venter, n.d.).

The fishing industry also makes extensive use of the Port Elizabeth harbour for catches of pelagic, demersal, and line fish, as well as squid (*Loligo vulgaris reynaudii*). Sardines, mackerel, and hake are the main fin fish caught in Algoa Bay (Bloom, 2012). Cuttlefish and squid form the largest part of the fisheries' exports, with products shipped primarily to Italy, Spain, Malaysia, Taiwan, and Hong Kong. Within the Algoa Bay area, line fishers mainly target reef fish (e.g., silverfish, red roman, santer, red stumpnose) (Hutchings, Porter, and Clark, 2013). Unregulated demersal long-line fishing for sharks that are exported for shark fin soup has been problematic along the coast (Winker, Parker, da Silva, and Kerwath, 2020). Shark fishing is reducing numbers of critically endangered smooth hammerheads and great white sharks, which, in turn, is affecting the ecosystem balance and reducing ocean tourism (Financial Services of South Africa [FINSA], 2020a).

Abalone (*Haliotis midae*), locally known as perlemoen, poaching is also problematic along the Eastern Cape coastline. This high value species, which is sold as a delicacy to Asian countries, is a slow grower, and excessive poaching is preventing the recovery of its populations (Skowno et al., 2019). In 2013, a project was undertaken to reseed the Eastern Cape using hatchery-reared abalone (van Wyk, 2018). The ranched abalone were seeded at Cape Recife in Port Elizabeth and heavily guarded by a private security company. The first harvest of ranched abalone was in 2018, and it is hoped that legally supplying abalone to the Asian markets could reduce poaching efforts in the future.

In 2009, the deep-sea port of Ngqura, situated 20km northeast of Port Elizabeth, at the mouth of the Coega River, began commercial shipping operations (Coega Development Cooperation, n.d.). Over time, the surrounding area has been developed as an IDZ, with 11 000 hectares of land boasting power stations, a road, water, telecommunications, and a rail network (Shelembe, 2019). Over 40 operational investors are part of the special zone, including chemicals, logistics, automotive, services, agro-processing, and energy sectors. At the end of 2017, the value of private sector investment at Coega was just under R7 billion. To

date, the full economic potential of Coega has yet to be realised, especially in regard to the local level development of small-, micro-, and medium enterprises (SMMEs).

Licenses to operate high risk marine bunkering at the Port of Ngqura were issued in 2016, despite outcries from marine scientists, environmentalists, and tourism groups (Matavire, 2019). Since then, bunkering operations have been steadily increasing, with large international vessels frequenting the Bay for refuelling. At any given time, 50 boats can be present in the Bay for refuelling, with over 1 000 having been bunkered in the first quarter of 2018.

Although Algoa Bay is fairly sheltered by Cape Recife and Cape Padrone, even in calm conditions the risk of an oil spill is high. In July 2018, 200-400L of fuel was spilled when a receiving tank overflowed 10km from the Port of Nqura (Rogers, 2019b). This spill was considered a Tier 1 incident by the Department of Environment, Forestry and Fisheries (DEFF), as it could be resolved using local resources and without national assistance.

Oil spills can have major environmental impacts, and can affect other ocean industries, such as tourism, water sports, and fisheries. The 2018 incident, alone, led to more than 100 birds, mostly endangered African penguins, being oiled and requiring rehabilitation (Southern African Foundation for the Conservation of Coastal Birds [SANCCOB], 2019). Another oil spill in 2019 led to concerns that proper procedures for refuelling are not being followed. Further concern has also been raised that Government does not have capacity to effectively deal with oil spills and, thus, private entities need to be called in to assist in clean-ups (Matavire, 2019).

Following this incident, there have been calls to halt bunkering in the Bay until a proper strategic environment assessment has been undertaken. To date, the requested assessment report has not been published (Matavire, 2019). Furthermore, while restrictions were placed on night-time bunkering, this restriction was lifted in November 2019 (Bankes-Hughes, 2019). Since then, new bunkering licenses have been approved, with a large bunker barge planned to be built and operational towards the end of 2020, however it seems this date will not be realised (Safety4Sea, 2019).

3.3.1 Proposed developments

In 2016, the Eastern Cape Socio Economic Consultative Council (ECSECC) published an Eastern Cape Infrastructure Plan for achieving various goals by 2030. For the NMBM, the following infrastructure improvements were detailed:

- Manganese terminal relocation;
- Tank farm relocation;

- Commercial marina development and waterfront;
- Boat repair/building facility;
- Tramways building redevelopment;
- Expansion of Nelson Mandela Bay logistics park;
- Fishwater Flats WWTW: Domestic and industrial effluent to recycled for use by industry;
- Complete the Nooitgedagt WWTW to bring more Orange River water to the NMBM;
- Desalination plant on Lower Sundays River to supply Coega industries;
- Coega air cargo terminal;
- Expansion of the Dedisa power station to 2000Mw;
- New road from Baywest to the coast;
- New Passenger Rail Agency of South Africa (Prasa) line from Motherwell to Coega; and
- Aquaculture facilities at the Coega IDZ

To date, only the Tramways building has been redeveloped and the safety and aesthetic appeal of the lower Baakens area is improving. These are the only goals that have been completed; the rest are in the planning phase or are still in the distant pipeline.

Of high interest at the moment are the developments of fish farms in the Bay. Following detailed environmental impact assessments, Algoa Bay was identified by the DEFF as a region suitable for mariculture development (Isaacs, 2019). A public outcry in 2015, in the form of a petition signed by 1700 residents, delayed implementation of the venture (Rogers and Wilson, 2020). Aside from being unsightly and attracting sharks to popular beaches in Algoa Bay, mariculture has a number of potentially negative consequences, including the entanglement of whales and dolphins, the spread of disease and parasites to wild fish populations, the smothering of the benthic environment below the cages, waste discharge, and the genetic contamination of wild stocks by fish farm escapees (FINSA, 2019a). Antibiotics used in the farms may also affect the hormone levels of surrounding organisms; thereby influencing various species' reproductive success (Rogers and Wilson, 2020). Dissolved organic, chemical, and particulate waste could also result in deteriorating water quality and potentially impact benthic habitats (i.e., reefs), popular dive sites, benthic fauna and flora, biodiversity, and algal blooms.

In March 2020, the DEA granted permission for the development of a fin fish farm near the Port of Ngqura as well as two shellfish farms – one across from the city's southern beaches, and another just north of the Port Elizabeth harbour (Rogers and Wilson, 2020). These farms

are meant to improve the socio-economy of the area, create new jobs, provide training opportunities, and transform the fisheries sector within the region. The three farms will be run by separate companies, and the first farm promises to be operational in 2021. However, there are still ongoing debates as to whether the value of the farms will outweigh their (negative) effects on the tourism and property sectors (Rogers and Wilson, 2020). Further studies have been requested to address these and other concerns regarding the farms (FINSA, 2019b).

Initially, the Summestrand site was earmarked for fin fish farms; however, the prevalence of water sport events and activities in this popular tourist area could jeopardise the economy, therefore, a bivalve farm has been suggested instead (Isaacs, 2019; Oirere, 2019). The harbour shellfish farm site will be situated next to the existing mussel farm. The harbour represents an urban industrial area with a mostly modified shoreline fringed by railway tracks and the Settlers Highway (M4). This site is also located in a significant maritime heritage site of the Bay, as it has the highest concentrations of recorded historical shipwrecks dating as far back as the 1500s.

The proposed Ngqura fin fish farm, which will most likely focus on farming cob and yellowtail, will run adjacent to the recently promulgated Addo Marine Protected area (Massie et al., 2019). Most marine conservationists have accepted the approval of the two shellfish farms along the beachfront; yet, they remain highly concerned about the Ngqura fin fish farm's locality adjacent to the Addo Marine Protected Area and the islands and reefs that it supports. The Algoa Bay branch of the Wildlife and Environment Society of South Africa (WESSA) are advocating for the restoration of the Swartkops Estuary and establishing the fin fish farm at the mouth of the estuary rather than near the Addo Marine Protected Area (Daniels, 2019a).

3.4 Socio-economic Setting

The demographics of the NMBM presented in this section have been summarised from Snow (2018), and the IDP (NMBM, 2020). Based on a population of 1 152 115 people in 2016 (588 persons/km^2), Figure 4 (data presented by Snow, 2018) provides an overview of the NMBM's socio-economic status. The NMBM supports 368 518 households, most of whom consist of four-person households (StatsSA, 2017). Ibhayi (sub-divided into New Brighton, Zwide, and KwaZakhele), Kariega, KwaNobuhle, the Northern Areas, and Motherwell are the most densely populated areas in the Bay. Over 40% of these households are female-headed, and nearly half of the population currently lives in poverty (ECSECC, 2017). As seen by the income graph in Figure 4, there is a large income inequality gap within the NMBM. Furthermore, more than 60% of the population is made up of Black South Africans, with isiXhosa being the dominant language spoken in the area.

Youth accounts for more than 30% of the total population, which is steadily increasing; although this increase is less than that found within the larger metropoles (ECSECC, 2017). A weak economy has resulted in ongoing high levels of unemployment (> 30%) and low levels of educational, with 75% of the area's population not having even a senior certificate. Crime is also a primary concern in Algoa Bay, with high incidence rates of gang violence, hijacking, and robbery – particularly in New Brighton, Northern Areas, and Motherwell. Within the first 6 months of 2019, more than a 100 gunshot wound-related deaths were recorded at the Gelvandale Mortuary in Northern Areas (African News Agency [ANA], 2019). Ongoing gangsterism and turf wars also continue to cause social disruption in the area and require specialised tactical teams to intervene and help safeguard residents. In addition, many arrests and confiscations of illegal firearms and ammunition take place in the area (ANA, 2019).

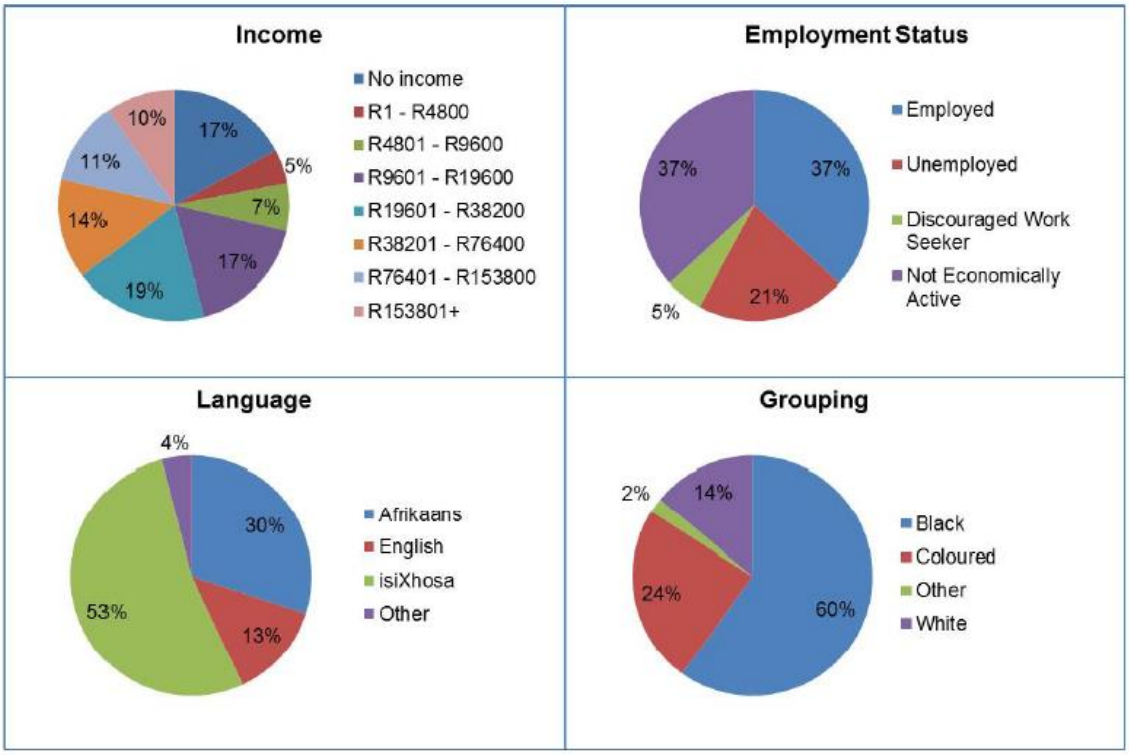


Figure 4: Overview of socio-economic status for Nelson Mandela Bay Metropolitan
Source: Snow (2018)

3.4.1 National energy crisis

For the past 2 decades, Eskom, South Africa's sole energy provider, has been unable to keep up with energy production demands (Pretorius, Piketh, and Burger, 2015). Inadequate maintenance of aged coal-fired plants (responsible for producing 85% of the country's electricity) as well as failure to develop more energy plants or, preferably, switch to renewable energy sources over the years has resulted in an ongoing energy crisis in the country. To

relieve pressures on the national grid load-shedding was implemented in 2007, whereby electricity is systematically cut off for a few hours across the country (Hadden, 2015). Aside from periodic load-shedding, rolling blackouts are also common, due to substation failures and their need for repairs.

The energy crisis has had a profoundly negative impact on the South African economy and has resulted in large electricity tariff increases (Pretorius et al., 2015). The mining sector, which forms a primary part of the nation's economy, has been hard hit by load-shedding to the point where some mines have had to close down. Small businesses tend to be the worst affected by load-shedding, as they do not have the resources to purchase generators and/or other energy saving measures and, therefore, run at a loss when their businesses grind to a halt during power outages. Disruptions to the power supply are also detrimental to machinery and appliances; for example, cellphone towers are often unable to recharge during frequent outages, which limits connectivity and reception and, as a result, further limits economic activity. During prolonged periods of power outages, Port Elizabeth, specifically, has experienced water shortages, as pump stations are unable to run (Daniels, 2019b). Residents have also reported an increase of criminal activity during load-shedding due to a lack of both public and private lighting as well as the dysfunction of security systems.

3.4.2 Political instability

From 2011 to 2016, the African National Congress (ANC) was the governing authority for the NMBM. Over those 5 years, three mayors and five municipal managers were instated and replaced. This instability enabled corruption to take hold in the city, as described by Crispian Olver in his book, *How to Steal a City: The Battle for Nelson Mandela Bay*, published in 2017. Olver was Director General of Environmental Affairs and Tourism at the time, and had been sent to the Bay to help the ANC rally before the elections (Olver, 2017). The book describes how factionalism and greed cost the ANC the NMBM, as Olver notes that people in positions of power were issuing jobs, contracts, cash, and gifts to loyal followers (Delport, 2017). Community and union 'rumblings' and 'street protests' were used as emergencies to bypass normal tender procedures to gain contracts at inflated prices; and irregular and wasteful expenditure by officials resulted in serious cash-flow issues that resulted in the NMBM hiking the tariffs of already stretched ratepayers.

In August 2016, a coalition government was voted into the NMBM. This government comprised the following political parties: the Democratic Alliance (DA), United Democratic Movement (UDM), the African Independent Congress (AIC), United Front (UF), and the ANC (Sain, 2018). Athol Trollip of the DA was elected mayor. During Trollip's short time as leader, the situation

improved in the Bay as funds were managed prudently, with clean-ups and construction being initiated and numerous developments planned (Whitfield, 2020). Trollip terminated more than R650 million in corrupt contracts, suspended officials, and opened council meetings to the public. While the South African Customer Satisfaction Survey had voted the NMBM the second least trusted metro in the country in 2016, by 2018 it was voted the second most trusted (Whitfield, 2020).

The current coalition government includes members of the 'black caucus', made up of the ANC, Patriotic Alliance (PA), UDM, and AIC (Nkosi and Kimberley, 2020). The group smeared good governance as 'racist', and eventually ousted Trollip in August 2018, after 5 motions of no confidence (Whitfield, 2020). Mongameli Bobani of the UDM was then instated as mayor; however, within a year, he was also removed under a vote of no confidence (The Citizen, 2019). Since December 2019, no new mayor has been elected; instead, the NMBM is currently relying on the acting executive mayor, Tshonono Buyeye, this hindering effective governance and decision making.

In July 2020, documents were issued by the Eastern Cape government for the NMBM to be placed under administration (i.e., to be managed by the state instead of the local municipality) due to its failure to elect a new mayor in over 6 months as well as its irregular election of acting city manager, Mvuleni Mapu (Kimberly, 2020). The need for state administration was further exacerbated by a recent visit by the Eastern Cape health department to hospitals in the city, which found dire conditions and the poor management of the Livingstone Hospital (Ellis, 2020). The issues were more greatly highlighted during the global Covid-19 pandemic, which further necessitated that the city to go under administration (Ellis, 2020c). However, it was ultimately decided that sending assistance in the form of Department of Health workers to the area would be more beneficial.

Mvuleni Mapa and some associates were arrested in August 2020 on charges of acts of misconduct, which included alleged supply chain policy violations in respect of various housing projects (EWN, 2020). Economic development head, Anele Qaba, has, since, been named as the NMBM's interim municipal manager (Pillay, 2020). In recent years, a situation of 'divide and rule' has emerged in the Bay, as parties fight for power (Sain, 2019). This approach has resulted in filthy conditions, both literally and figuratively, in the city (Sain, 2019). For example, two members of the black caucus were murdered in the last two years, with their deaths linked to tensions about business dealings involving SMMEs in the Bay (Mphande, 2019; Wilson, 2019). These changing coalitions, the lack of leadership, and corruption have all hindered the municipality's ability to run the city effectively.

It should be noted that political instability is not unique to Port Elizabeth, but is indicative of the country in general. For example, the state is currently unable to effectively monitor and manage service delivery at the municipal level, which has resulted in serious health (threatening) issues for citizens (e.g., water shortages, sewage spills, and failures to collect refuse). Such State inability is abundantly evident across South African cities, especially in the Eastern Cape (Robins, 2020). Middleclass suburbs tend to not experience the extent of disfunction that lower economic suburbs do, as issues such as water or electricity outages are quickly rectified by their local councillor or ratepayers association. Poorer communities, however, constantly endure breaking basic infrastructure, usually with very slow and ineffective responses from local authorities.

3.4.3 Failing infrastructure

The maintenance and asset management of both ecological and built infrastructure is poor in most South African municipalities (Federation of Canadian Municipalities [FCM], 2020). Many municipalities invest in developing new infrastructure that is, more often than not, politically motivated rather than maintaining and upgrading already existing infrastructure. Furthermore, while many municipalities are able to identify problem areas and develop remedial actions in terms of asset management, they still often fail to implement these measures due to a suite of constraining factors (e.g., capacity, skills, and funds). Coastal management is not at the forefront of most, if any, municipal agendas in the Eastern Cape, even when such coastal areas are under their jurisdiction.

The NMBM has admitted that it has “serious infrastructure problems”, after several communities complained about recurring sewage blockages (Sizani, 2019). Residents in informal settlements such as Soweto-on-Sea, Booysens Park, and Missionvale have been requesting the replacement of sewage pipes for the last 3 years, as blocked drains are causing raw sewage to flood into their streets and homes (Mgidi, 2020). Even after being cleared, the drains quickly block again and, aside from human health concerns, there are further worries of this wastewater flowing into rivers and being drunk by livestock.

Inadequate drainage is problematic throughout the city, as city planning did not prepare for the city’s growth. During heavy rainfall events, water tends to dam up on many important roads in the city; thereby impeding traffic and creating dangerous road conditions. Potholes are also problematic, with incidences of buses being damaged by large potholes in areas like Lorraine (Pijoos, 2019). Potholes are often repaired haphazardly and tend to reappear following the next rainfall event. Frustrated residents throughout the city have acted together to repair

potholes in their neighbourhoods, as they are tired of complaining about poor service delivery (Sizani, 2020).

The current Deputy Director of the NMBM, Chandre Barnard, reported on the Bay's bulk water maintenance system at the 2019 Institute of Municipal Engineering of Southern Africa (IMESA) Conference in Durban. Here, Barnard (2019) described a maintenance backlog of over a decade that has resulted in ongoing reactive management. The systematic failure of infrastructure has largely been attributed to a lack of system processes and adherence stemming from inadequate first level management. Under previous management, historic documents regarding maintenance and stock lists had been lost, employee turnover was high, and vacancies remained unfilled. These problems have compounded over time and have been exaggerated further by cases of vandalism, limited budgets, and the loss of intellectual assets.

Failing infrastructure is not only limited to the poor maintenance of pipelines and roads, but extends to informal settlements, healthcare, and education facilities. There is currently a dire need for more schools and the renovation of existing schools in the Eastern Cape (Ngcukana, 2020). Although the national government has set aside money to improve education in the province, few improvements have yet been made. In some cases, contractors have left sites, including schools in the western areas of Port Elizabeth, as they have not been paid. Critics lament that the money meant for school and other development remains in departmental accounts due to "inefficient planning, blatant mismanagement and incompetence" (Cassim, 2019).

3.4.4 Inadequate healthcare

Overcrowded hospital wards, dilapidated infrastructure, food shortages, broken down ambulances, and neglected state mortuaries plague the Eastern Cape (Allan, Overy, Somhlaba, Tetyana, and Zepe, 2004). The healthcare system in the province has been on the brink of collapse for over 2 decades. The Eastern Cape Health Crisis Action Coalition has been lobbying since 2013 to improve conditions, including fixing damaged infrastructure; improving the availability of medication, supplies, and supply chain management; gaining more human resources; and addressing the management of hospitals, emergency medical services, and patient transport (Mpulo, 2020).

The Covid-19 pandemic has also cast a spotlight on the Department of Health's inability to deliver healthcare to the country as a whole. The British Broadcasting Corporation (BBC) did an exposé on the dire conditions at Livingstone Hospital in Port Elizabeth during the (first) peak of the Covid-19 outbreak in July 2020 (Harding, 2020). The report revealed that rats feast on blood and waste on hospital floors, patients sleep under newspaper and experience oxygen

shortages, and babies die in understaffed maternity wards (Harding, 2020). The hospital also lacked sufficient personal protective equipment (PPE), porters, and cleaners; all of which resulted in overworked doctors and nurses having to clean the hospital. Similar conditions have been noted at Dora Ngiza Hospital in Zwide, Port Elizabeth (Venter, 2020). Such unsanitary conditions expose patients and staff to the spread of disease. The problems are also not unique to the Eastern Cape; rather the issues experienced in these noted hospitals are representative of the crumbling healthcare system across the country.

4. CLIMATE-RELATED HAZARDS

The key hazards associated with climate change and their resultant vulnerabilities and risks, as well as management and adaptive capacity for Algoa Bay, are provided in Table 3. The key hazards presented in this table have been summarised from the NMBM Climate and Green Economy report issued in 2015, further detail is provided in the paragraphs that follow.

Table 3: Expected climate induced changes in Algoa Bay

Key hazard	Expected changes	Vulnerabilities	Risks	Management and adaptive capacity
Temperature	• More hot days and heatwaves • Higher minimum temperatures • Fewer cold spells • Higher average temperatures • Increased water temperatures	• Elderly, expecting women, children, obese people and those with other comorbidities at high risk • Homeless people exposed to elements • Substandard housing • Limited access to potable water • Inadequate sanitation services	• Species range shifts (e.g., kelp expansion, endangered penguin and colonies, sardine run) • Reduced fish catches • Increased heat-related illness and mortality • Spread of vectors and outbreaks • Decreased productivity in manual labour • Overloading of health and emergency services	• Monitoring and protecting endangered species populations • Policing fishing quotas • Improving service delivery to all communities • Improving health and emergency services • Reducing the heat island effect (i.e., 'green' the city) • Retrofitting buildings to ensure adequate cooling
Rainfall and drought	• Decreased average rainfall • Decreased number of rainfall events • Increased rainfall intensity • Increased magnitude of droughts	• [See above] • Existing water shortages (as well as irregular supplies) and constraints on increasing supplies • Poorer communities susceptible to food insecurity • Limited ability to cope amongst the elderly and female-headed households • Disaster and relief management unable to support all farmers • Invasive alien plants in catchments (e.g., gumtrees)	• Crop failures and loss of livestock • Food price increases • Farm closures and job losses • Malnutrition and starvation • Biodiversity loss (e.g., vegetation degradation, starvation of animals, loss of wetlands) • Changes in estuary salinity (i.e., affect nursery function for economically important fish species)	• Innovative farming solutions • Implementing water saving initiatives (i.e., through education, installing rainwater tanks) • Providing water tankers to communities without access • Repairing damaged infrastructure to reduce leaks • Removing invasive alien plants • Recycling water • Constructing dams • Interbasin water transfer schemes • Investing in desalinisation

Key hazard	Expected changes	Vulnerabilities	Risks	Management and adaptive capacity
Floods	• Increased intensity (i.e., 1:100 year flood will increase in magnitude)	• Substandard housing • Homeless people exposed to elements • Inadequate stormwater drainage • Ineffective disaster management plans	• Death, injury, and disruption to livelihoods, food supplies, and drinking water • Spread of water-borne disease • Polluted wastewater entering aquatic ecosystems • Infrastructure damage (i.e., to low lying roads, bridges, and buildings) • Loss of common-pool resources, sense of place, and identity	• Proper housing solutions • Improving stormwater drainage
Fire	• Increased frequency and intensity	• Substandard housing and lack of access roads for emergency personnel • Reliance on coal and wood burning for cooking • Ongoing drought conditions • Low maintenance of appropriate fire breaks and controlled burning • Ineffective disaster management plans	• Death, injury, and disruption to livelihoods • Infrastructure damage • Food insecurity • Loss of biodiversity	• Proper housing solutions • Appropriate evacuation procedures • Regular maintenance of appropriate fire breaks and controlled burning • Funding for fire stations, fire fighting equipment, and training
Sea level rise, wind patterns, and storm surges	• 58-75cm rise in sea levels • Higher probability of extreme storm surges • Stronger easterly winds; weaker westerly winds	• Development within the coastal setback lines • National roads in close proximity to coast • Damage to infrastructure from storm and high sea events (already problematic) • Marine transport routes necessary for trade (e.g., cargo shipping, fruit exports, car exports)	• Erosion of coast and infrastructure damage (including loss of popular beaches such as Hobie) • Inundated low-lying areas (e.g., Baakens Valley and Port Elizabeth harbour) – further changes predicted in Figure 5 • Possible damage to and even loss of transport vessels that hinders export capabilities • Increased potential for oil spills and cargo loss • Increased salinity in estuaries and potential loss of nursery habitat • Saltwater intrusion into boreholes in the Summerstrand area	• Reinforcing coastal infrastructure (i.e., dolosse, sandbanks) • Accurately predicting and warning of severe weather • Preparing disaster management teams to deal with evacuations, clean oil spills, and so forth

Key hazard	Expected changes	Vulnerabilities	Risks	Management and adaptive capacity
Upwelling	• Increased frequency and intensity	• Eutrophic conditions and excessive nutrients from runoff and wastewater • Presence of red tide cysts • Subsistence fishers' reliance on fish and shellfish • Export value of economically important fish and shellfish • Locality of mussel farms (e.g., Port Elizabeth harbour, mouth of the Swartkops Estuary)	• Increase in harmful algal blooms (HABs) • Blooms of potentially poisonous species (e.g., *Lingulodinium polyedra*) • Mass extinctions and reduced health of marine organisms (e.g., economically important sardines) • Barriers to dispersal and recruitment of marine organisms • Mariculture activities that impact shellfish farming (e.g., mussel, abalone) • Fishing impacting fish and crayfish catches (i.e., restricted dispersal) • Human health	• Ensure WWTWs are treating effluent to acceptable standards
Ocean acidification	• Increased acidity	• Overexploitation of economically important shellfish and abalone • Ineffective policing of abalone poaching	• Reduced coral calcification • Slower growth and shell corrosion	• Law enforcement and preventing corruption • Abalone seeding • Closed seasons for shellfish

4.1 Temperature

With regard to coastal and marine environments, parts of the Agulhas Current have recently warmed more rapidly than 90% of the world's oceans (Hobday and Pecl, 2014; Popova et al., 2016). Sea surface temperatures off Port Elizabeth have increased by 0.25ºC per decade over the past 40 years (Theron, 2011). The south coast of South Africa is also experiencing extreme ocean temperature events (e.g., marine heat waves and cold spells) at least once a year (Schlegel, Oliver, Wernberg, and Smit, 2017). As a result of these changing conditions, species are experiencing shifts in distribution, abundance, physiology, and behaviour, resulting in changes in community composition, hybridisation, and the spread of alien species (DEA, 2013).

Commercial fish species are the most vulnerable to climate change, as they are already heavily- or over-exploited (i.e., exploited at a maximum yield), which is reducing their resilience in the face of rapidly changing environmental conditions (Skowno et al., 2019). For example, in South Africa, epipelagic fish, including sardines (*Sardinops sagax*) and anchovies (*Engraulis encrasicolus*) are steadily shifting eastwards in response to climate change (Crawford and Ryan, 2011). These changes impact the fishery economy, as important catch species are less abundant and fishing boats are having to travel further out to sea in order to reach their catch quotas. Such additional travel may result in the loss of livelihoods for subsistence fishermen.

In response to the shifting sardine distribution, marine birds, in turn, are moving to follow their prey. Endemic and endangered African penguins (*Spheniscus demersus*) and Cape Ganets (*Morus capensis*), along with other seabirds, are tracking the shift in epipelagic fish to the south coast (Crawford and Ryan, 2011). However, the lack of breeding islands between Cape Agulhas and Port Elizabeth is posing a problem as the birds are unable to rest and establish colonies (Crawford and Ryan, 2011). African penguin numbers have plummeted from 1.5-3 million individuals in the early 1900s, to ~23 000 breeding pairs in 2013, which has prompted the species to be declared endangered (Connan, Hofmeyr, and Pistorius, 2016). Until the 2000s, African penguins mainly bred along the west coast of South Africa; however, now, over half of the population nest in Algoa Bay, primarily on St Croix and Bird Island. The species is highly threatened by industrial fisheries (limited prey availability) and requires urgent intervention.

Similarly, kelp beds (*Ecklonia maxima*) have been slowly moving eastwards along the coast and may eventually occur in Algoa Bay (Bolton, Anderson, Smit, and Rothman, 2012). Such occurrences could create an entirely new ecosystem that may displace the previous habitat

(Bolton et al., 2012). Marine mammals and sharks are also likely to experience shifts in distribution, social behaviour, mortality events, and changes in reproductive success (Bega, 2019). Such changes could negatively impact boat-based cetacean tourism in the Bay.

4.2 Fire

Prolonged drought and limited rainfall create conditions that favour the spread of fire (Intergovernmental Panel on Climate Change [IPCC], 2018). Dry vegetation and debris have a high fuel load and, when combined with fire-prone alien vegetation, can create high intensity fires that are fanned by frequent the wind in the area. Wildfires are often the consequence of lightning strikes and/por glass or partly lit cigarettes being thrown into the bush. There have also been cases of deliberate fires caused by arsonists.

Algoa Bay supports highly industrialised economic activity and, therefore, associated risks, including hazardous materials spillages, explosions, industrial fires, and air and/or water pollution (NMBM, 2010). Aside from the (potential) destruction of property and loss of life, fires can cause long-term lung problems in people and animals as a result of smoke inhalation (IPCC, 2018). There is also loss of identity and community following fires, as residents may be displaced and lose their belongings. Valuable crops and resources can be destroyed due to fire. Intense fires can remove all biomass in an area, which could lead to the erosion of topsoil from wind and rainfall. However, it should be noted that some habitats are fire-adapted, such as fynbos, and, therefore, require periodic burning to enable the germination of seeds and resprouting (Kraaij et al., 2018; van Wilgen, 2009). Fynbos habitats that are not burnt frequently tend to gradually be replaced by thicket species.

In 2017, the worst wildfires recorded in South Africa's history occurred in the Knysna area. The fires covered 150 000 hectares and destroyed 1 000 homes, causing seven deaths in total (Khosa, 2019; Kraaij et al., 2018). At the same time, fires raged closer to Algoa Bay (in the Thornhill, Van Stadens Gorge, and Rocklands areas), where farms and properties, including the Woodridge School, were destroyed, and two lives were lost (Cronje, 2017). Fire trucks could not access water from the hydrants due to electricity outages and, thus, the municipality urged residents to take water to the area to assist with the blaze.

Aside from these larger events, shack fires in the informal settlements are common, since these settlements are high density and lack the proper service roads that could enable fire trucks to enter in cases of emergency. In 2019 alone, over 70 people in Area Q at the Walmer Township were left homeless after a fire devastated 24 shacks (Ellis, 2019).

4.3 Rainfall and Drought

There have been notable decreases in late summer rainfall, increases in average rainfall intensity, and longer dry seasons over southern Africa (Niang et al., 2014; Tadross et al., 2009). Between 1960 and 2010, decreases in rainfall and the number of rainfall days have been observed over parts of South Africa (MacKellar, New, and Jack, 2014). In the last century, the southern interior of the country has received greater annual rainfall; whereas the north and north-west parts of the country have experienced drying (Engelbrecht et al., 2015). Furthermore, the El Niño-Southern Oscillation (ENSO) has modulated rainfall in the winter rainfall region of South Africa (Philippon, Rouault, Richard, and Favre, 2012). ENSO is a recurring, but often irregular, climatic pattern involving variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean (Philippon et al., 2012). El Niño (warmer) years are associated with higher than normal rainfall amounts, particularly in the months of May, June, and July (Philippon et al., 2012).

In the last decade, South Africa has experienced some of the worst drought conditions on record. Largely attributed to an El Niño event in 2015-2016 that caused drought conditions across most of the country (Forbes Africa, 2019). Following the 2015-2016 droughts, the Eastern Cape has still to recover to its previous rainfall rates (Heywood, 2019). The SAWS has stated that Nelson Mandela Bay has experienced nearly 4 consecutive years of rainfall below 500mm (the usual average is 635mm). Extended droughts have affected numerous industries in the NMBM, especially SAB, Coca-Cola Fortune, Clover and Parmalat, Cadbury, and Sappi (Matavire, 2018; Saving Water SA, 2011). Changing climatic conditions have further affected the distribution of fish and squid; thereby negatively impacting the area's fisheries industry.

4.4 Sea Level Rise, Floods, and Storm Surges

Since the early 1900s, 34 flooding events have been recorded in Nelson Mandela Bay (Sampson, 2018). The worst flood in the area's recent history occurred in 1968 (Sampson, 2018). Fifty years later, in September 2008, the Bay was particularly hard hit by an extreme weather event that caused widespread damage to infrastructure and coastal properties (Malonde, 2019). Increased storm intensity, combined with poor stormwater drainage systems and urban-induced soil erosion, could result in increased cases of flash flooding.

Informal settlements are particularly vulnerable to floods and fires, due to their placement in undesirable areas, inferior building materials, and inadequate road access for emergency vehicles (DEA, 2012). Damaged road and rail infrastructure caused by flooding could also potentially disrupt public and commuter traffic and negatively impact emergency responses

during extreme events. In addition, flooding can cause the contamination of water supplies, with faeces and other contaminants resulting in outbreaks of disease.

Relative sea levels rising rates along South Africa's coastline range from 1.87mm/year for the west coast, +1.48mm/year for the south coast, and +2.74mm/year for the east coast (Mather, Garland, and Stretch, 2009). Similarly, sea level rise predictions for Port Elizabeth range from 1.82 ± 0.49mm·year^{-1} to 2.97 ± 1.38mm·year^{-1} (Bornman et al., 2016; Church et al., 2013; Church and White, 2011; Mather et al., 2009). Rising sea levels, coupled with more intense sea storms and increased wind speeds, cause larger wave heights and increased storm surges, particularly in winter (Rautenbach, Daniels, de Vos, and Barnes, 2020; Stocker et al., 2013). Even without more frequent storm surges, higher sea levels mean storms have a greater impact on the coastline. Most of the South African coastline consists of low-lying beaches and estuaries that could enable rising sea levels and storm surges to flow inland (Kings, 2017). These storm surges, in turn, could cause the erosion of shallow intertidal areas; change intertidal profiles; and potentially damage infrastructure such as sea walls, railway lines, harbours, and coastal properties (Mather and Stretch, 2012).

While, under 'normal' circumstances, the coast would realign following such events, many areas are currently constrained by development. This 'coastal squeeze' has, thus, resulted in the loss of important intertidal habitats and restricted beach access (Potts, Götz, and James, 2015; Veldkornet, Adams, and van Niekerk, 2015). Areas where development has encroached too closely on the high water level, or that have too low an elevation above sea level, are most vunerable to high swells. False Bay, Table Bay, the Saldanha Bay area, the Southern Cape coast, Mossel Bay to Nature's Valley, Port Elizabeth, and various developed areas of the KZN coastline have all been identified as vulnerable areas (Lück-vogel, le Roux, Eichhoff, and Theron, 2018; Rautenbach et al., 2020; Theron and Rossouw, 2008). In situ and modelled data for Cape St. Francis (100km west of Port Elizabeth) indicate a potential 17% increase in wave height, which, in turn, suggests an increasing height of storm surge swells with a return period of 1 year from 6.7 to 7.8m (PRDW Africa, 2009).

Climate Central (https://www.climatecentral.org/) provides data and maps to visualise post-2100 sea level rise based on research by the Proceedings of the National Academy of Sciences of the United States of America (USA). Climate Centre delineates projected sea levels along the Port Elizabeth coastline under a 2ºC and 4ºC temperature increase until end of the century in comparison to pre-industrial times. Increased sea levels are likely to push into the permanently open Swartkops Estuary; thereby flooding the low-lying residential areas of Kwazakhele and Soweto-on-Sea and, further upriver, inundating the industrial township of Perseverance (Rogers, 2015). Algorax and the Fishwater Flats WWTWs are predicted to be

the hardest hit by large swells. At the Port of Ngqura, the sea may begin to push up and flow into the conduits and Coega River (Rogers, 2015).

The wide sandy beaches may mostly mitigate rising sea levels, with the main changes expected near Kings Beach – a main swimming beach, where the manganese ore dumps and oil storage tanks are situated – and the Pollok Beach parking lot (Rogers, 2015). A large part of the Port Elizabeth Harbour would, then, be under water, as would the Settler's Freeway and Burman Road (Rogers, 2015). Historic development and invasive exotic vegetation have blocked the sand migration corridor and impeded sand supply to the area's beaches. More intense wave action could will likely cause increased rates of coastal erosion along with subsequent sedimentation (Lück-vogel et al., 2018). As a result, infrastructure at Sardinia Bay has been inundated, and sections of the popular Hobie Beach eroded. Currently, the Ngqura harbour at Coega uses a sand bypass system to ensure that the port does not become too shallow (Baloyi, Mahlathi, Wessels, Ubbink, and Smit, 2017). Altered sediment supply from changing climatic conditions may, however, require more intensive sand bypass measures or periodic dredging that hold their own consequences.

High seas and storm events have resulted in ongoing damage to coastal infrastructure, such as at the Summerstrand Lifesaving club, New Brighton Beach parking lot and ablutions, Bluewater Bay Lifesaving Club, walkways along the beachfront, and overwash onto the N2 national road towards Bluewater Bay (Department of Economic Development, Environmental Affairs and Tourism [DEDEAT], 2016). The municipality is also constantly removing accumulated sand from the public walkways along the beachfront and Swartkops River mouth parking lot, which is a costly and ongoing effort.

The noted developments were built before coastal setback lines were determined (DEDEAT, 2016). Setback lines for the Algoa Bay coast were calculated in 2016 as a means to buffer the coast and features such as estuaries. Coastal setback lines are used to prevent development within the highwater mark; thereby enabling managers to better prepare for future issues related to rising sea levels. In order to increase resilience, a mixture of cement sea walls and imitation sandbag dunes have been placed along the Port Elizabeth beachfront. Dolosse (i.e., large cement structures that fit together) are common along the harbours and ports of South Africa, as well as in the rest of the world (Independent Online [IOL], 2016). These structures, invented by a South African in the 1960s, help to protect the coast from wave action, and are sturdy enough to not be washed away. Protection measures are, however, often unsightly and may restrict access to public space. As a means of mitigating a 4ºC temperature increase, innovative engineering solutions are needed; especially if there is to be any hope of protecting South Africa's beaches.

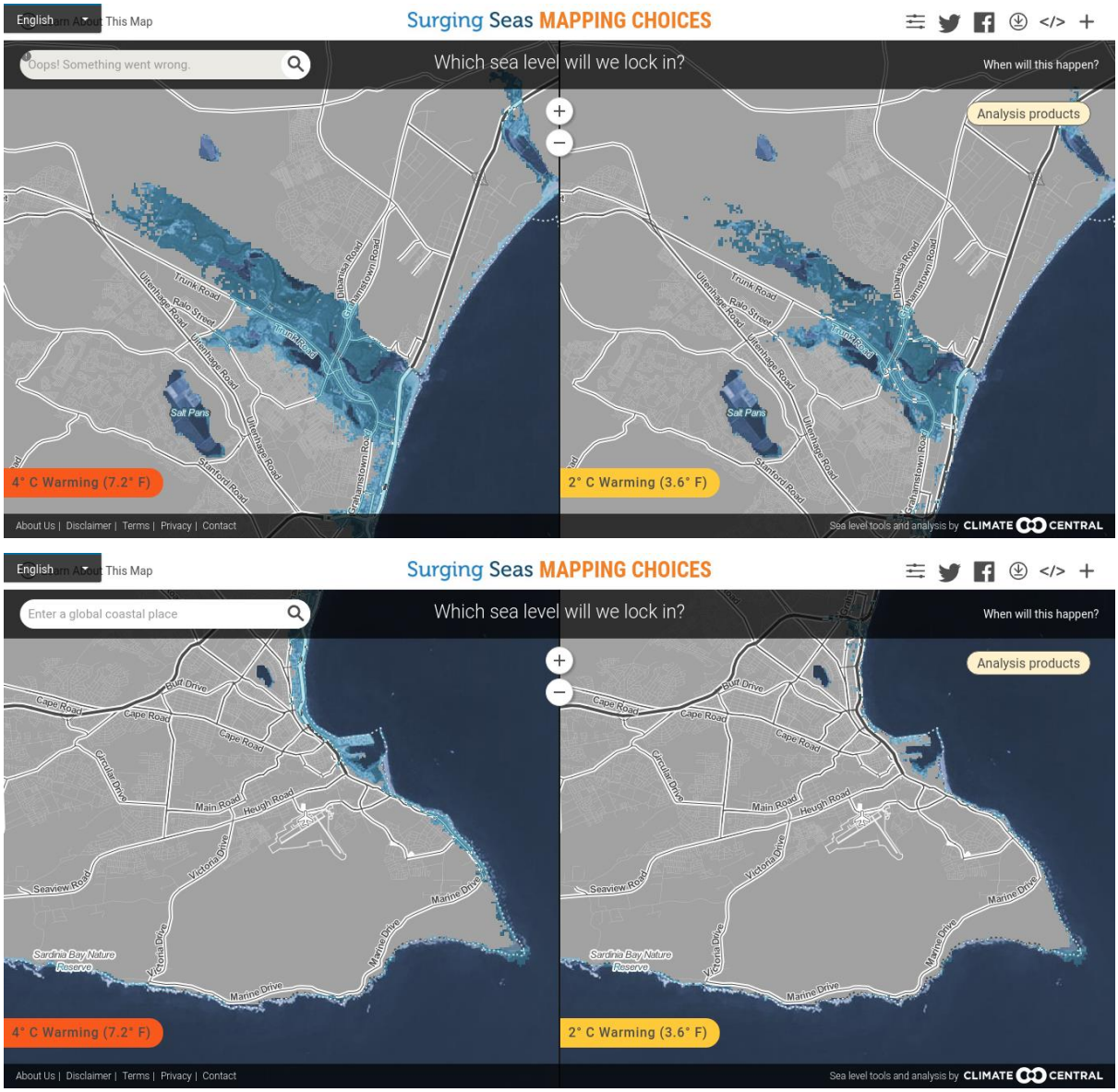


Figure 5: Projected sea levels along the Port Elizabeth coastline under a 2ºC and 4ºC temperature increase until end of the century compared to pre-industrial times

Source: Climate Central (n.d.)

Reduced freshwater inflow into estuaries may result in more saline conditions and effect sediment supply and turbidity. Such changes, in turn, may trigger shifts in species distribution. For example, chokka squid (an important commercial species in the Port Elizabeth fishing industry) are likely to be pushed further offshore towards clearer water (Augustyn et al., 2018). Physico-chemical changes may also enable introduced species to outcompete native species, as they tend to have broader tolerance ranges (Whitfield et al., 2016), while environmental stress could increase species' susceptibility to disease (Hoegh-Guldberg and Bruno, 2010). Bornman et al. (2016), in a study on the effects of sea levels on the Swartkops Estuary, found that although the estuary is highly urbanised and has lost much of its salt marsh habitat, it is

still accreting sediment at a higher rate than the current sea level rise. However, future rising sea level rates are uncertain, and further large increases may result in the banks of the estuary becoming permanently submerged.

4.5 Increased Upwelling

Average wind velocity is expected to increase throughout all seasons in South Africa. A 10% increase in wind speed increases wave height by 26% and coastal sediment transport rates by 40-100% (Theron, 2011). Changes in the prevailing wind patterns also influence the frequency, timing, and intensity of coastal upwelling events (Goschen, Schumann, Bernard, Bailey, and Deyzel, 2012; Goschen and Schumann, 2011). Such issues could have serious implications for coastal productivity and resources, with studies on the west coast of South Africa indicating the reduced recruitment of rocky shore organisms (Harris, Sink, Skowno, and van Niekerk, 2019). Permanent upwelling cells also act as barriers to the dispersal of many fish species. Furthermore, increased upwelling may advent the early larvae of important commercial fish, such as sardine and anchovy, too far offshore.

More frequent hypoxic events are currently occurring in the Benguela Current system, which are likely caused by intensified upwelling. Such events results in algal decay and subsequent mass mortalities (Stephen and Hockey, 2007). Temperature changes also facilitate invasive HAB-forming organisms (Whitfield et al., 2016). A significant rise in HABs has been recorded along the south coast of South Africa (Kelly et al., 2019). In a study on the impact of land-derived inorganic nutrient loading on the coastline of Algoa Bay, Lemley, Adams, Bornman, Campbell, and Deyzel (2019) found persistently high Dissolved Inorganic Nitrogen (DIN) levels inshore that are creating eutrophic conditions. The high ammonium levels in the area are due to discharge from three WWTW. Furthermore, the highly urbanised Swartkops Estuary (DIN) and agriculturally influenced Sundays River (dissolved inorganic phopsherous) add considerable load to the nearshore environment. Lemley et al. (2019) results have indicated more frequent phytoplankton blooms since 2013 as well as a strong seasonal trends in bloom conditions. The study also showed an increase in zooplankton *biomass* as opposed to an increase in zooplankton *numbers*, which has been attributed to a shift towards mesozooplankton dominance. Lemley et al. (2017) further noted the increased frequency, magnitude, and seasonality of HABs (*Heterosigma akashiwo* and *Heterocapsa rotundata*) in the estuarine waters of Algoa Bay.

In 2014, atypical climatic and oceanographic conditions (e.g., reduced wind velocity, strong stratification, and increased water temperatures), combined with eutrophic conditions, resulted in a red tide bloom along the coast between East London and Wilderness (Whitfield et al.,

2016). Red tide blooms are not uncommon along the coast of South Africa; however, they usually consist of the non-toxic species, *Noctiluca miliaris* (Bornman, 2014). Yet, the 2014 red tide bloom was the first recorded HAB along the Eastern Cape coast that consisted of a bioluminescent, toxic species called *Lingulodinium polyedra*. This particular species produces yessotoxins that bioaccumulate in bivalves and is toxic to mice (Bornman, 2014). The effects of this species on humans are not yet known (Gerssen et al., 2010; Paz, 2008). The dieback of the bloom resulted in hypoxic conditions that led to mass fish mortalities. The species also produces cysts that can remain in the environment, and which can reseed and bloom when conditions again become favourable (Bornman, 2014). Subsequent re-occurrences of *L. polyedra* have been largely restricted to the nearshore environment of Algoa Bay; likely due to land-derived nutrient enrichment from nearby WWTWs.

4.6 Ocean Acidification

On average, the pH of surface seawater has decreased by 0.1 units, worldwide, due to the oceanic uptake of anthropogenic CO_2 (Zeebe, Zachos, Caldeira, and Tyrrell, 2008). By 2100, it is predicted that the average seawater pH may fall by as much as 0.5 units (IPCC, 2018). Increased acidity reduces the saturation state for carbonate minerals and prevents marine calcifying species from producing shells and growing skeletons (Harris et al., 2019). Calcium and aragonite are important for the development of gravity sensory organs such as statoliths and otoliths and, thus, embryonic development of organisms are affected. Economically important species, such as abalone, are also affected, and mariculture operations may suffer (Joubert, 2017).

4.7 Socio-economic Impacts

4.7.1 Health

Many South Africans live in poverty and suffer from health conditions related to their surrounding environment. The country has some of the world's highest rates of tuberculosis and HIV infections (Low, 2019). As temperatures rise, the risk of health complications, including dehydration, heat stroke, cardiovascular and/or kidney diseases, and even death are likely to increase (Amengual et al., 2014). Individuals who suffer from poor diets and/or obesity may be particularly susceptible to these issues.

The depletion of the ozone layer, which has been associated with elevated temperatures, has been linked to chronic lung disease and increased mortality (Amengual et al., 2014). Children, the elderly, the ill, the poor, and the marginalised are particularly vulnerable to persistent climate extremes, as they do not have access to resources that could help them withstand

extreme events. Such resources include financial buffers, access to adequate drinking water, shelter, air conditioning, and medical assistance (Barata, 2017; Reckien et al., 2018).

In addition, climate change is likely to increase the coverage and seasonality of vector- and rodent-borne diseases that affect crops, livestock, and humans (Barata, 2017). There may also be an increase in waterborne diseases such as cholera, malaria, rift valley fever, and schistosomiasis (DEA, 2012; Western Cape Government, 2018). Warmer temperatures, combined with unreliable electricity generation and water stress, may also result in more occurrences of food-borne diseases such as salmonella and listeria (Western Cape Government, 2018). A major listeria outbreak occurred South Africa in 2017, which was caused by contaminated pork products, with 180 deaths recorded, and likely many more having gone unreported (Chersich, Scorgie, Rees, and Wright, 2018a).

Climate change could also result in population displacement, which, in turn, could cause increased violence and/or risk-taking behaviours that may lead to an even greater rise in the transmission of sexually transmitted infections (STIs) such as HIV (Wright, Garland, Norval, and Vogel, 2014). Furthermore, declines in mental health have been attributed to changing climatic conditions, and anecdotal evidence suggested higher suicide levels in South African farmers during the ongoing droughts of 2015 (Chersich et al., 2018b).

4.7.2 Infrastructure

The amount of concrete and other man-made hard surfaces in cities cause an effect called ‘urban heat island’ (IPCC, 2018). This phenomenon results in urban areas being warmer than the surrounding areas; thereby making these areas more susceptible to heat extremes and poor air quality. Municipalities should, therefore, ensure that citizens can safely move around outdoors and have sufficient ventilation or air conditioning indoors (IPCC, 2018; Western Cape Government, 2018). Heating and cooling of commercial, agricultural, and industrial sectors may be expensive, as the retrofitting of existing buildings and operations tend to be costly. As conventional energy prices continue to increase, however, there is a need to enhance energy efficiency and invest in greener energy sources.

During the 2013/2014 financial year, extreme weather-related events cost the South African insurance industry over R1 billion in claims (Davis-Reddy and Vincent, 2017). Comparatively, in 2008, a storm surge along the western and southern coasts of South Africa resulted in damage to coastal property and infrastructure that was estimated at R1 billion (Smith, 2013). Severe floods in the Western Cape between 2011 and 2014 affected 41 000 people and resulted in further financial losses to the total of R1.6 billion (Western Cape Government, 2018). KwaZulu-Natal and Mpumalanga both experienced fires in 2008 that resulted in an

estimated loss of R7 billion in revenue due to large plantations being burnt down (Davis-Reddy and Vincent, 2017). Then, in 2015, intense fires affected 57 000 people in Cape Town, and many homes were damaged or had to be evacuated as a result of the fires (Davis-Reddy and Vincent, 2017).

More recently, damages from the Knysna fires and storm-related flooding in Cape Town between June and October 2017 is estimated to have cost more than R4 billion (Otto et al., 2018). In addition, over 4 million residents and many businesses in Cape Town were left without water during an intense 5-month drought in 2018 that cost in excess of R2.1 billion, with a large impact on tourism in the area (Otto et al., 2018).

4.7.3 Tourism

Climate change is a threat to tourism, as tourists prefer predictable, pleasant weather conditions and seasonality (Fitchett, Grant, and Hoogendoorn, 2016). Changes in temperature, rainfall, and wind impact tourism, particularly in Algoa Bay, where the majority of attractions are outdoors. Hotter conditions require more energy and water for cooling tourists, which can increase stress on already limited resources (Santos-Lacueva, Clavé, and Saladié, 2017). Increased frequency of extreme-weather events, as well as outbreaks of disease and pests, can further affect tourists' perceptions of a destination. Damage to infrastructure and roads may affect accommodation and transport, and coastal erosion may result in the loss of the Bay's Blue Flag sandy beaches. Declining biodiversity, especially of the charismatic species (i.e., whales, sharks, dolphins, and penguins) that are drawcards to Algoa Bay, could limit marine tourism as a result of fewer sightings and/or shorter seasons (Kelly et al., 2019). The Bay hosts a number of popular reef dive sites, and these may also be threatened by changing water temperatures, rough sea conditions, reduced clarity, and pollution; thus, affecting dive operators' potential earnings.

5. RANKING OF HAZARDS FOR ALGOA BAY

In 2010, SRK Consulting assisted the municipality in producing a comprehensive disaster risk assessment. The risk profile was based on data received from stakeholder consultations as well as baseline data collected during their study (.

). The top-rated risks for the NMBM were identified as:

- Floods, especially affecting informal settlement and infrastructure;
- The effects of fire, explosions, and spillage of hazardous materials;
- Severe storms;

- Human disease, including diseases that can lead to rapid onset as well as slow onset disasters – diseases and conditions included under this category are HIV/AIDS, tuberculosis, cholera, and asthma; and
- Drought.

Table 4: Disaster risk profile for the Nelson Mandela Bay Municipality

Hazard Name	Prioritized Risk Ratings
Hydro-meteorological Hazards - Floods (River, Urban & Dam Failure)	0.85
Hazardous Material - Hazmat: Fire/Explosion (Storage & Transportation)	0.85
Hazardous Material - Hazmat: Spill/Release (Storage & Transportation)	0.82
Hydro-meteorological Hazards - Severe Storms (Wind, Hail, Lightning, Fog)	0.81
Disease / Health - Disease: Human	0.78
Hydro-meteorological - Drought	0.78
Environmental Degradation	0.76
Fire Hazards - Formal & Informal Settlements / Urban Area	0.76
Fire Hazards - Veld/Forest Fires	0.73
Pollution - Water Pollution (Fresh and Sea)	0.72
Major Event Hazards (Cultural, Religious, Political, Recreational, Commercial, Sport)	0.71
Oceanographic - Storm Surge	0.71
Transport Hazards - Road Transportation	0.70
Civil Unrest - Xenophobic Violence	0.69
Structural Failure	0.68
Pollution - Land Pollution	0.68
Civil Unrest - Terrorism	0.67
Oceanographic - Sea Level Rise (Climate Change)	0.67
Pollution - Air Pollution	0.65
Civil Unrest - Demonstrations / Riots	0.65
Oceanographic - Tsunami	0.65
Transport Hazards - Rail Transportation	0.64
Infrastructure Failure / Service Delivery Failure	0.64
Civil Unrest - Armed Conflict (Civil/Political War)	0.61
Disease / Health - Disease: Animal	0.61
Geological Hazards - Earthquake	0.60
Transport Hazards - Air Transportation	0.58
Transport Hazards - Water Transportation	0.57
Civil Unrest - Refugees / Displaced People	0.51
Infestations - Plant Infestations (Intruder Plants)	0.44
Disease / Health - Disease: Plants	0.41
Radio Active Fall-out	NA

Only one risk identified in Table 4, namely sea level rise, was specifically linked to climate change. However, many of the other noted risks are likely to be accelerated by the changing climate. At present, no updated version of this table has been produced for the Bay; yet, there is evidence that in the past decade, the situation has become more dire in many aspects and/or little to no effort has been made to implement strategies to manage these noted

concerns. For example, both the hazardous oil tank farm and manganese exports facility along the beachfront have yet to be relocated.

As already noted, the region has been gripped by an ongoing severe drought, with the Nelson Mandela Bay declared a drought disaster zone in November 2019 (Nkosi, 2019). There have also been localised occurrences of flash floods following heavy rainfall – a notable example of which occurred in July 2019 where heavy rain, combined with spring high tide and strong winds, resulted in the flooding of the N2 passed Swartkops and businesses in the Baakens Valley (Malonde, 2019). Since droughts are, usually, eventually broken by floods, there are speculations that a 1:100 year flood is due soon (Roswell, Palmer, Cambray, and Irwin, 2020).

A further issue is that the Eastern Cape has the third highest HIV/Aids infection rate in the country, and numbers are steadily rising (Simbayi and Zungu, 2017). The province is the least equipped to treat these patients due to limited resources, a lack of standardised training, and competing clinical care priorities (Hansoti et al., 2019). The unexpected Covid-19 pandemic has further stretched the Eastern Cape's capacity, which has experienced some of the highest mortality rates from the infection (Department of Health, 2020). With the pandemic far from over, there is concern over how healthcare facilities and professionals will be able to shoulder the ongoing burden.

The most recent IDP for the Bay described the following main risks pertaining to the area: water scarcity and water losses, theft of electricity, fraud and corruption (particularly in conclusion of contracts), sub-standard work by contractors in housing delivery, and infrastructure backlogs (NMBM, 2020). Some service delivery areas, such as the building and maintenance of roads, infrastructure, electricity networks, and refuse removal are also not being met to their full potential across the municipality; particularly in outlying and poorer areas such as townships. Funding has been allocated to eradicate the bucket system (i.e., the unsanitary use of buckets as toilets that need constant emptying and cleaning) and relocate informal settlements. There is also a budget to tar gravel roads, improve stormwater systems and drains, and better maintain public open spaces. All these areas of concern are need to be addressed in order to promote the growth of the city.

6. CONCLUSION

Pressing hazards that are currently occurring in the Bay include ongoing drought and water shortages, poor service delivery and inadequate housing, crumbling infrastructure, stretched healthcare facilities, crime and gangsterism. The national energy crisis is further compounding the situation, as rolling blackouts affect businesses and residents, and often damage infrastructure. Overfishing and increased marine activity, including mariculture and offshore bunkering, are negatively impacting populations of endangered and vulnerable species, including African penguins. These threats are further compounded by global climate change, and new hazards are emerging that threaten the current socio-economy and biology of the area. Species are also shifting their range in response to warming conditions, increased upwelling, and ocean acidification. Rising sea levels, combined with development within the coastal zone, is further causing damage to public infrastructure and houses, and sand movement requires constant maintenance.

Overarching these issues is the inability of the municipality to properly manage the city due to political instability, corruption, and infighting. Although there are policies and plans in place to develop the city into a sustainable economy that is resilient to climate change, there is a lack of budget and ability to effectively address these challenges, since basic service delivery needs must be attended to first. Management, therefore, needs to be proactive rather than reactive to disaster situations. The loss of intellectual information due to high staff turnover should be limited through incentives and putting proper systems in place. Competent city managers that do not tolerate corruption are also needed.

It is acknowledged that the NMBM cannot solve the threats associated to climate change alone. All governmental directorates, parastatals, businesses, NGOs, academics, and residents have a role to play in mitigating negative environmental change. It is the municipality’s responsibility, however, to direct and lead the way for building climate resilience.

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