MILITARY INTEGRATED ENVIRONMENTAL MANAGEMENT AT THE DONKERGAT MILITARY-TRAINING AREA

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DECLARATION

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SUMMARY

Donkergat Military-training Area (DMTA) at Langebaan, South Africa, hosts diverse, primarily seaborne, training and war fighting endeavours of South African Special Forces (SF) soldiers. The facility borders the Atlantic Ocean, Langebaan Lagoon (a Ramsar site) and Meeuw Island. The question arises how to compatibly accommodate military activity in this sensitive environment?

The research aimed to build an inventory of environment-operation interaction impacts on the DMTA, document and analyse the efficacy of management procedures in a MIEM (military integrated environmental management) framework and design and test an electronic spatial decision support system (SDSS) to enable replication elsewhere. Hence, five objectives were pursued, namely to inventorise the physical resource base and concomitant environmental sensitivities of DMTA; to inventorise the military activity impacts on the resource base; to overview management measures to reduce further unrestrained progress of environmentally harmful impacts through MIEM solutions; to develop an SDSS to practically manage the sensitive environmental resources and military activities; and to finally project these measures against a theoretical backdrop of integrated military and marine environmental management. A mixed-mode methodology was followed.

The surveys culminated in a comprehensive, reference manual-like inventory of terrestrial and marine floral and faunal life forms – reported to species level in the appendices. Similar data on physical and human-made landscape features were compiled and the conservation status and vulnerabilities of life forms, especially birds, were established. The surveys recorded evidence of notable military impact on the environment concerning infrastructure, ecology and cultural-historic heritage. A comprehensive electronic spatial database of all these features was compiled on a GIS platform.

As point of departure for effective operational and environmental management, the requirements for a MIEM framework were determined. Operational measures for combating a wide range of impacts, as well as the success of their application were compiled to guide continued and future management. An SDSS running off a GIS platform, was designed, described in detail and tested for a range of operational and environmental management applications. This application required the sensitivity rating of a range of geographical phenomena captured in the DMTA GIS database and the execution of a multicriteria evaluation (MCE) procedure that resulted in an integrative environmental sensitivity map.

DMTA is unique and hence it is recommended that it be retained as a specialised military-training facility. It is recommended that the SDSS be refined, exported and adapted for application at other SF and South African National Defence Force (SANDF) military-training areas. Refinement should harness the Internet and related data-capture and communications technologies. By implementing this system as part of the legally prescribed MIEM in the SANDF, the impact of military activities on the environment can be minimised and 'sacred' or 'sacrificed' areas identified. It is recommended that ecosystem indicator monitoring of features like birds, water quality, sediment quality, benthic macrofauna, surf-zone fish and rocky intertidal macrofauna at DMTA should be intensified to support planning of new developments. DMTA should become the benchmark ecosystem for status comparison in the Saldanha Bay area. It is also recommended that parts of the training area be incorporated in the Ramsar definition for the Langebaan Wetland system.

KEYWORDS

South African Special Forces (SASF), military-training, Donkergat military-training area (DMTA), military environmental impacts, military integrated environmental management (MIEM), spatial decision support system (SDSS), multicriteria evaluation (MCE)

OPSOMMING

Donkergat Militêre Opleidingsgebied (DMOG) by Langebaan, Suid-Afrika, huisves diverse, hoofsaaklik seegebonde opleiding en oorlogspogings van die Suid-Afrikaanse Spesiale Magte (SM). Die fasiliteit grens aan die Atlantiese Oseaan, Langebaanstrandmeer ('n Ramsar-vleiland) en Meeuweiland. Die vraag ontstaan hoe om militêre aktiwiteit by hierdie sensitiewe omgewing aan te pas?

Die navorsing was daarop gemik om 'n inventaris van die omgewing-operasionele wisselwerking en impak op DMOG te bou, die doeltreffendheid van deurlopende bestuursprosedures in 'n Militêre Geïntegreerde Omgewingsbestuursraamwerk (MGOB) te dokumenteer en ontleed en 'n elektroniese ruimtelike besluitnemingstelsel (RBSS) te ontwerp en te toets wat ook elders toegepas kan word. Dus is vyf doelwitte nagestreef, naamlik die inventarisering van fisiese hulpbronne en hulle omgewingsensitiwiteit op DMOG; die dokumentasie van militêre aktiwiteitsimpak op die hulpbronbasis, omgewingsbestuursmaatreëls vir die hantering en oplossing van skadelike impakte binne MGOB-verband te ontwikkel; 'n RBSS vir die hantering van die sensitiewe natuurlike hulpbronne onder militêre aktiwiteit te skep en te toets; en uiteindelik hierdie maatreëls teen die teoretiese agtergrond van geïntegreerde militêre en mariene bestuur te projekteer. 'n Gemengde-modus-metodologie is gevolg.

Die opnames het uitgeloop op die skep van 'n omvattende verwysingshandleiding of inventaris van land- en mariene plantaardige en dierlike lewensvorms – tot op die vlak van spesieslyste soos in die bylae saamgestel. Soortgelyke data vir die fisiese en mensgemaakte landskapskenmerke is opgestel en die bewaringstatus en kwesbaarheid van lewensvorme, veral voëls, is bevestig. Die opnames lewer bewyse van noemenswaardige militêre impak op die omgewing in terme van infrastruktuur, ekologie en kultuur-historiese erfenis. 'n Omvattende elektroniese ruimtelike databasis van al hierdie eienskappe is in GIS-formaat opgestel.

As vertrekpunt vir effektiewe operasionele en omgewingsbestuur, is die vereistes vir 'n MGOB-raamwerk bepaal. Operasionele maatreëls vir die bestryding van 'n wye verskeidenheid van impakte, sowel as die sukses van hul aanwending, is saamgestel om voortgesette en toekomstige bestuur te lei. 'n Werkende RBSS op 'n GIS-platform, is ontwerp, in detail beskryf en getoets vir 'n verskeidenheid van operasionele en omgewingsbestuursprogramme. Hierdie toepassing het vereis dat sensitiwiteitsgradering van 'n reeks geografiese verskynsels in die DMOG GIS-databasis bepaal moes word. Daarna is 'n multi-kriteria evalueringsproses (MKE) uitgevoer, wat gelei het tot 'n

geïntegreerde omgewingsensitiwiteitskaart as afvoerproduk vir besluitsteun deur bestuurders en bevelvoerders.

DMOG is uniek en daarom word aanbeveel dat dit behou word as 'n gespesialiseerde militêre opleidingsfasiliteit. Verder word aanbeveel dat die RBSS verfyn, uitgebrei en aangepas word vir toepassing op ander SM en Suid-Afrikaanse Nasionale Weermag (SANW) militêre opleidingsbasisse. Verfyning moet die Internet en verwante datavasleggings- en kommunikasie-tegnologie benut. Deur die implementering van hierdie stelsel as deel van die wetlikvoorgeskrewe MGOB in die SANW, kan die impak van militêre bedrywighede op die omgewing tot die minimum beperk word en ‘gewyde’ of ‘geofferde’ gebiede rasioneel geïdentifiseer word. Daar word aanbeveel dat monitering van ekosisteem aanwysersfunksies soos voëllewe, die gehalte van water, sedimentgehalte, bentiese makrofauna, brandersonevis en rotsagtige intergety makrofauna op DMOG verskerp word om ingeligte beplanning van nuwe ontwikkeling te ondersteun. DMOG moet die maatstaf vir ekosisteemstatusvergelyking in die Saldanhabaai-gebied word. Dit word aanbeveel dat dele van die opleidingsgebied se kuslyn in die Ramsar-definisie vir die Langebaan Vleilandstelsel opgeneem word.

TREFWOORDE

Suid-Afrikaanse Spesiale Magte (SASM), militêre opleiding, Donkergat militêre opleidingsgebied (DMOG), militêre omgewingsimpak, militêre geïntegreerde omgewingsbestuur (MGOB), ruimtelike besluitssteunstelsel (RBSS), multikriteria evaluasie (MKE)

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ACRONYMS, ABBREVIATIONS AND TERMINOLOGY

Acronyms and abbreviations

AD1 and AD2	attack-diving one and two
AGL	automatic grenade launcher (40 mm calibre)
AHP	analytical hierarchy process
AU	animal unit (Livestock with a weight of 450 kg that increases in mass with 500 g per day on grasslands with 55% energy-absorbing value (Bothma 1995))
Bwb B	Blouwildebeest Bay
CAD	computer-aided design
CGA	Centre for Geographical Analysis
CO	commanding officer
CR	consistency ratio
CSIR	Council for Scientific and Industrial Research
CSS	combat support ship
CTC	Combat Training Centre
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
DMTA	Donkergat Military-training Area
DoD	Department of Defence
DPW	Department of Public Works
DSS	decision support system
DTM	digital terrain model
DZ	drop zone (The area where parachuting is executed, e.g. jumping of paratroopers or dropping of freight).
EIA	environmental impact assessment
EIP	environmental implementation plan

EMP	environmental management plan
EMS	environmental management system
FSE	force structure element
FSG	frigate small guided
GIT	geographical information technology
GMI	Grahamstown military institution
GPS	global positioning systems
GUI	graphical user interface
HE	high explosives
ICM	integrated coastal management
ICMA	Integrated Coastal Management Act
IRM	integrated range management
IUCN	International Union for Conservation of Nature
LMG	light machine gun
LUD	land unit database
Ma	Mega-annum, one million years
MCE	multicriteria evaluation
MIEM	military integrated environmental management
MSP	maritime spatial planning
MTA	military-training area
NEMA	National Environmental Management Act
OC	Officer commanding
OHS	occupational health and safety
OMP	operational management plan
OPV	offshore patrol vessel
ppm	parts per million
PDA	personal digital assistant

PDSC	Plenary Defence Staff Council
RFIM	Regional Facilities Interface Manager
RSM	regimental sergeant major
RIM	Robben Island Museum
SA	South Africa
SAA	South African Army
SAAF	South African Air Force
SAAO	South African Army Order
6 SAI Bn	6 South African Infantry Battalion
SAHRA	South African Heritage Resource Agency
SAN	South African Navy
SANParks	South African National Parks
SADF	South African Defence Force
SANDF	South African National Defence Force
SAPS	South African Police Service
SASF	South African Special Forces
SDSS	spatial decision support system
SF	Special Forces
SOP	standard operational procedure
SWP	standard work procedure
TSO	technology for special operations
WCNP	West Coast National Park
WLC	weighted linear combination

Terminology

Attack-diving (AD)	Diving, breathing pure oxygen with 'oxygear' (see closed-circuit breathing apparatus) up to a depth of 10 m
Barracuda	18-ft Mk I driven by 2x90 hp outboards and 21-ft Mk II powered by 2x115 outboard motors
Basic swimming	The first phase of seaborne training to train learners in water competency enabling them to commence with Module 1.
Beaufort scale	Scale by which the sea condition according to wind strength and wave height is measured. The experience of the operators and the urgency of the task at hand will determine if activities will be terminated or executed bearing the Beaufort scale in mind.
Blind	Undetonated explosive device also named a 'misfire' or 'dowwert' (Afrikaans)
Cetacean trap	A locality where whales often strand or beach themselves along the shore. These are areas where minima in the earth's magnetic field cross the shoreline and where offshore reefs occur.
Closed-circuit breathing apparatus	Named 'oxygear' and used by attack divers to approach a target without the emission of bubbles that can compromise their position.
F470 or Foursting	15-ft inflatable boat powered by a 50-hp outboard motor
Fin	Operators surface swimming on their backs using their legs and fins for propulsion. Finning can be executed in a variety of formations and backpacks, weapons and equipment fitted with flotation devices can be dragged behind the swimmers.
FX barrels and simunition	Training weaponry used for battle simulation, enabling operators to engage each other with real weapons.
Hurricane	26-ft semi-rigid boat powered by 2x200-hp outboard motors
Karst	Landscape type originating on limestone layers such as Langebaan limestone through sinkhole formation. The distinctive landforms are a result of water solution along joints and fissures that dissolves calcareous material, enlarging cracks and joints and creating underground waterways and caves.
Module 1	The second phase of seaborne training that focuses on surface swimming as

	method of in- and exfiltration
Module 2	The third phase of seaborne training that focuses on boats as the vehicle for in- and exfiltration
Module 3	The fourth phase of seaborne training that involves co-operation with the SAN and SAAF, ship-scaling techniques and launching of quad bikes from Barracudas.
Operator	A Special Forces soldier who, after completion of one year of military service, did selection and the SF cycle of 18 months. Seaborne operators do an additional one year of training at DMTA and can specialise as attack divers.
Platter charge	Demolitions used to blast through walls or doors, such as sheet explosives with high detonation speeds of up to 8 200 m per second, mainly used to cut through steel.
Pro	Soda lime (a mixed hydroxide of sodium and calcium) in pellet form for absorption of carbon dioxide from the exhaled breathing gas in diving apparatus, known as ‘oxygear’.
Pyrotechnics	Explosive devices such as signal flares and smoke grenades
RV	Romeo Victor: Predetermined rendezvous place for a specific time. During operations emergency RVs for aircraft, boats, personnel and ships that open and close at predetermined times are identified.
Range	A defined facility on which weapons are fired to achieve military-training objectives for live or inert fire.
Ramsar	The Convention on Wetlands of International Importance especially as Waterfowl Habitat was adopted in February 1971 by the International Conference on the Conservation of Wetlands and Waterfowl at the town of Ramsar in Iran. The short name for the convention has taken the name of the town where it was adopted.
Sacrificed or sacred area	An area designated for specific training where ecological conservation is a low- or high priority.
Sea state	Condition of the sea according to the Beaufort wind scale

Stun grenade	Explosive device that detonates twice in quick succession, used for temporarily disorientation. Especially used during room-clearing situations.
Tandem	Parachuting where a free-fall parachutist carries a passenger or load.
US	In military parlance, ‘unserviceable’
Wahoo	42-ft semi rigid boat powered by 2x440 inboard Yanmar motors
Wetland	Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.
Whaleen	Tripe and unused whale body parts dumped in the ocean during the whaling-era. When strong winds and currents occur over a number of days the whaleen on the ocean floor in Salamander loosens and gives off a terrible smell. Because of this, the name Stink Bay originated.

CHAPTER 1 THE MILITARY-ENVIRONMENTAL NEXUS

"Whatever befalls the Earth befalls the sons of the Earth. Man did not weave the web of life; he is merely a strand in it. Whatever he does to the web, he does to himself."

Chief Seattle (1854)

The military of any country, including South Africa (SA) needs access to natural areas for training of offensive and defensive combat-readiness programmes. On these ‘sacrificed’ areas soldiers, war machinery and munitions are employed to prepare forces to execute their core function – war fighting. The present focus on environmental issues is global in nature and the integration of environmental considerations into military activities is a growing challenge worldwide. The dilemma of having to accommodate the imperative of military presence, occupation and activities in a sensitive and diminishing natural environmental setting needs to be expounded to provide a background for an understanding of the operational management challenges the modern military faces. Research approaches to this dilemma must be unpacked and justified in expositions of specific aims, objectives, methodologies, methods and research designs. This chapter explores these essential elements in the context of South Africa.

1.1 THE MILITARY AND THE SOUTH AFRICAN ENVIRONMENT

In SA the South African National Defence Force (SANDF) controls one of the largest state land portfolios: some 400 000 to 500 000 hectares of land (DOD Instruction 2000). This land is, however, not untouchable as the country faces major interconnected environmental challenges which are growing exponentially, so provoking pertinent questions about the right of ownership of these areas by the military. Factors that influence the environment, such as soaring population growth, wasteful use of natural resources, degradation of wildlife habitats, extinction of plants and animals, poverty and pollution, put pressure on military areas in many ways, two fundamental ones being the increased demands from environmentally-conscious factions about the correct management of natural resources and the vexing and growing issue of land claims in SA. Land belonging to the Department of Defence (DOD) is already being handed back to the Department of Public Works (DPW) for reallocation to other users (DOD Instruction 2000). The scrutinising eye of the non-military on the land managed by the SANDF obliges the military to be an example of an environmentally-sustainable user to neighbouring settlements. SA Special Forces (SASF) that have been operating on South African land since the 1970s are not exempted and they must implement measures that guarantee environmentally-sustainable use of designated areas through Military Integrated Environmental Management (MIEM).

SASF has used a variety of natural areas for training and operational preparation since its establishment in the 1970s but after the end of the Angolan war several of their bases, such as Doppies in the Caprivi Strip and Hellsgate and Duku Duku in KwaZulu-Natal closed and were handed back to the civilian sector. These bases were located in sensitive ecological environments but with operational preparedness as the main concern, minimum emphasis was placed on sound environmental management practices. On the West Coast of South Africa, SASF still have pristine pieces of land where a seaborne unit, namely 4 Special Forces Regiment (4SFR) is situated. This operational base is the locale where intensive training and preparations, sometimes of a very sensitive and covert nature and mainly commencing after last light, are executed. Because of the secrecy of some of the tests and rehearsals, the training area gets locked down, not permitting any unauthorised person, vehicle or vessel into the area. Donkergat Military-training Area (DMTA)[1], although under the management of the elite of the SANDF, is not exempted from the critical eye of the outside world, especially as it is part of the Langebaan Lagoon, a wetland of international importance according to the criteria of the Ramsar Convention that was established in 1971. The first conservation measures aimed specifically at the Langebaan Lagoon were implemented in 1973 when this water system up to its high-water mark was proclaimed a reserve in terms of the Sea Fisheries Act. Langebaan Lagoon was designated to the List of Wetlands of International Importance (no 398) on 25 April 1988 (Cowan 1995), 10 years after the then South African Army (SAA) took control of Donkergat[2]. Bordering a Wetland of International Importance and situated on a peninsula with a very sensitive ecosystem oblige the managers of DMTA to implement MIEM, but this was neglected and numerous environmentally harmful impacts (‘real-world problems’) evolved since 1978.

From 1978 the consequent impacts of military activities went unnoticed on DMTA because the military area is restricted and access controlled. The upshot of this covert nature of activities and facilities on DMTA was that environmental accountability was not adhered to and contentedly obscured from the broader army and general public. The White Paper on Defence dated 14 May 1996, transfers the responsibility and accountability directly to commanding officers of military

[1] DMTA refers to the1384 ha training area including waters of the Atlantic Ocean and Langebaan Lagoon.

[2] Donkergat refers to the area where the whaling station complex was situated between Riet- and Salamander Bay.

bases or units (SANDF 2003; South Africa 1996b). Environmental concerns are not in the general frame of mind of the Special Forces (SF) area user. Placing excessive accountability for environmental affairs on the shoulders of commanding officers where this responsibility is subject to new legislation on natural resources that compels the military to abide by the environmental laws of the country seems ill-advised. The delicate ecological environment on and around DMTA necessitates devoted conservation measures to ensure its long-term availability as an operational and training facility for 4SFR. Research on management procedures for DMTA is lacking and since the military took control of DMTA in 1978 until commencement of this study, no research has been done to document positive or negative trends caused by infrastructural or war fighting activities. To address this shortcoming, this study initiated surveys on MIEM implementation. To be as comprehensive as possible, the status of the study area, its history, orientation, administrative attributes and ecological phenomena in conjunction with the variety of military actions being executed there, had to be taken into consideration. To obtain a better understanding of the status and composition of DMTA and to highlight the conservation value of the area a first step calls for an underlying, background site history to orientate interested parties about DMTA and the numerous activities executed there.

1.2 THE DEVELOPMENT OF A NEXUS

The Donkergat area is rich in European history of discovery commencing when the first seafarer, Joris van Spilbergen, a Dutch explorer, entered Saldanha Bay on 28 November 1601. He named the bay *Agoada de Saldanha*, a name that was actually allocated to Table Bay in 1503 by Antonio de Saldanha, who was misled by his pilot who assured him he had rounded the Cape of Good Hope. The name Saldanha Bay was thus accidently accredited to someone who never saw it (Burman & Levin 1974). An overview of the early years, the whaling-era, the war years and the time up to what DMTA is today shows an association between history and 4SFR as home to seaborne SF operators. Unfortunately, opposing interests developed between the military and civilian sector as Langebaan urbanised into a pristine holiday destination after 1978 when SF claimed land on this part of the West Coast. Since the early 2000s the town of Langebaan and the surrounding area developed as a water- and wind-sport mecca with tourists flocking from all parts of the world. Figures 1.2 and 1.3 show signs in the background of this type of higher-order urban development of the town since the late 1990s.

This development was accompanied by directly conflicting situations such as noise- and visual pollution, trespassing of restricted area and land disputes. When the Angolan war ended, an even more critical approach towards military activities developed as the question about the need for such an exclusive seaborne operational base was raised. In addition, scientific research conducted on

DMTA was minimal (Van Veelen 1997) but intensive research projects were undertaken in the adjoining areas such as the West Coast National Park (Hockey 1985) and the surrounding islands (Cooper & Brooke 1981), and palaeontological studies at Langebaanweg (Hendey 1982). To enlighten the historical conservation value of the area,

Figure 1.1 Military activity and Langebaan (1990s)

Figure 1.2 Tourism development in Langebaan (2014)

conspicuous events during bounded historical stages (1700-1900, 1900-1950, 1950-present) are summarised next.

1.2.1 Early history: 1700-1900

The history of earlier seafarers is part of the heritage of 4SFR as a seaborne unit and its relevance is conveyed to new members during their induction. This relevance is also portrayed in the unit's emblem, a Viking helmet which was adopted because the Vikings were notorious for their raids using the oceans as means of infiltration (Figure 1.3). The Old Norse word *vikings* means 'prepared', which the unit must always be, and the wings attached to the helmet represent the ever-present airborne capability of the regiment. The compass rose depicts the capability to operate in any direction, the black and gold signifying night and day and the three-dimensionality of air, land and sea shown in the background montage. The seaborne specialty of 4SFR inspired the 4.1 Commando slogan of 'Iron fist from the sea'. Such are the self-image and credo of the unit operating from DMTA.

The islands between Donkergat and Langebaan that are negotiated daily by members of 4SFR, were discovered by European seafarers, most probably by French hunters during the early years. There is no clear evidence that the Khoikhoi hunter-gatherers and nomadic herders, who roamed the area long before any European presence, made use of the islands but although they had no boats they were excellent swimmers (Schaefer 1993) and did avail themselves of whale meat collected at

Figure 1.3 Emblem of the 4Special Forces Regiment (4SFR) and the 4.1 Commando slogan

'cetacean traps' (Brand 2008) so indicating that they most probably visited the islands when the tide was favourable.

The first recorded event of European presence were about Jon Olafsson, an Icelander, casting anchor off Schaapen (Schapen) Island in 1623 and finding evidence of sealing and/or whaling, an indication that the French operated in the area around Donkergat, using Schaapen and Meeuw Islands to stockpile skins and oil (Burman & Levin 1974; Schaefer 1993). The origin of the name Donkergat ('dark hole') is not known but legend has it that sailors believed in the existence of a bottomless hole in the ocean surrounding the north of the peninsula. Soon after his arrival in the Cape in 1652, Jan van Riebeeck sent a vessel to Saldanha to reconnoitre the area. The crew made contact with the indigenes and purchased sheep to stock on Schaapen Island as food for passing ships such as the *Salamander* after which Salamander Bay (Figure 1.4) was named (Burman & Levin 1974). Such behaviour was a practice of the Dutch and they later colonised coastal islands with European rabbits (*Oryctolagus cuniculus*) for the same purpose. There is no record of these rabbits being introduced to Meeuw Island but some still thrive on other offshore islands (Skinner & Smithers 1990) and a healthy population is present on Schaapen Island. According to Green (1933), in about 1843 a secret fresh-water spring- probably from the period when the French visited the area, was unearthed on Meeuw Island. The fountain was sealed with masonry and cement and the water channeled to the sea to end eleven feet below the high-water mark. No evidence of this water source could be found on the island but VOC coins, the mark of the Dutch East India Company, were collected on the island by the secret's discoverers.

Important subsequent historical benchmarks are the whaling period and the war years both of which activities directly influenced the ecology of DMTA. Whaling brought the first significant infrastructure, such as buildings, roads, excavations and dumping grounds, while the Second World War resulted in the essential commodity of fresh water being made available on the peninsula for the first time.

1.2.2 Early twentieth-century history: 1900-1950

American and British whalers had been operating from Saldanha and other Cape bays from as early as 1788 (Burman & Levin 1974). They principally targeted the southern right whale (*Balaena glacialis*), a placid species that was harpooned by hand from small boats lowered from a mother ship. In 1909 the Norwegian Johan Bryde built a modern whaling station at Donkergat Bay (Figure 1.4) from which two steam-driven catchers operated with harpoon cannon and winches, inventions that were to prove devastating in their effectiveness against whales (Best & Ross 1989).

Another station was opened two years later by Carl Ellefsen at Salamander Bay, about a kilometer north of the Donkergat station. The Salamander station never excelled like the Donkergat station and after running into financial trouble it was sold to Irvin and Johnson in 1915. It was operational from 1911 to 1920 and from 1922 to 1930 when it closed permanently (Best & Ross 1989) with the construction of a new flensing platform being left unfinished.

Johan Bryde lost his job as manager of the Donkergat factory when a cargo of whale oil destined for Bremen was confiscated by the Royal Navy in 1914 during World War I but the name of this whaling legend lives on as Bryde’s whale (*Balaenoptera edeni*) named after him (Burman & Levin 1974; Best & Ross 1989). The Defence Department expropriated Donkergat from 1942 to 1946 during which period Saldanha Bay and Langebaan Lagoon provided anchorage for warships and flying boats. The bay was protected by four six-inch guns, four 12-pounder guns, a controlled minefield and radar (Visser 1995). That the bay had strategic importance was fortunate for it called for the laying of a water pipeline and an upgrading of the 1913 railway line, so providing the infrastructure that was to facilitate post-war development (Burman & Levin 1974). The Donkergat Whaling Station was operational from 1909-20, 1922-30, 1936-37, 1947-53 and 1957-67. Up to 1967 when the station finally closed, the region’s whaling concerns had killed about 100 000 whales, including 10 600 sperm (*Physeter macrocephalus*), 10 000 fin (*Balaenoptera physalus*), 69 300 sei (*Balaenoptera borealis*) and 6 600 blue (*Balaenoptera musculus*) whales (Best & Ross 1989). While the whaling industry flourished, developments of a military and industrial nature were taking place across the bay. These developments had significant impacts on the environment and, as will become clear, emphasise the importance of sound MIEM at DMTA to grant this military area the status of an ecologically-stable reference template.

1.2.3 Late twentieth- century history: post-1950

While the whaling-era continued, urban development and industrialisation took place on the other side of the bay, the Naval Gymnasium and Military Academy being established in 1952 and Saldanha becoming a municipality in 1954. Sea Harvest took over the growing fishing industry in 1964, annually harvesting thousands of tons of pilchards in the Atlantic. Worldwide, small pelagic fish (forage fish) such as pilchard, make up a quarter of the total annual fish exploitation which is about 22 million tons (Wikipedia 2014b). Development at the R10-million Chemfos phosphate works in 1965 uncovered the palaeontological fossil finds at Langebaanweg (Hendey 1982) fortuitously raising awareness of the sensitive and valuable paleontological resources and heritage of the area. In 1970 a Johannesburg-based company submitted plans for turning the southern half of Langebaan Lagoon into a salt pan (*Cape Times* 1970.) Fortunately, the plans were rejected but similar threats to the ecology were to raise time and again in the future. A two-kilometre causeway of rock and sand was constructed between the mainland and Marcus Island in February 1976 in preparation for the development of Saldanha Bay as the country's major iron-ore export harbour. The approach channel to the ore jetty was deepened by underwater blasting in 1977, killing large numbers of penguins, gulls and cormorants (Branch 1983). Unfortunately, the construction of the breakwater and later the iron-ore terminal had profound impacts on water-movement patterns in Saldanha Bay, dramatically reducing wave energy and seawater circulation. Two of the negative effects are lower oxygen concentrations in the water which influence the bay's fauna and flora (Clark et al. 2012) and increased wave action that causes damage to infrastructure as at Leentjiesklip (Figure 1.4). The original site chosen for harbour development had been at Jutten Bay, together with massive development of the Donkergat peninsula for recreational purposes. The plans included a bridge over the mouth of the lagoon which was to be blocked from Saldanha Bay and the opening of the Donkergat/Postberg isthmus (*Cape Times* 1974).

DMTA originated from a need identified for a seaborne unit when SF started executing transborder operations from SA. The first SF base in SA, namely 1 Reconnaissance Commando, was established at the Bluff in Durban where a whaling station, also initiated by Johan Bryde, was operational from 1908 till 1953 (Best & Ross 1989). In 1972 during the Angolan war the first SF waterborne operation was launched from the Bluff, resulting in the founding of C Group, a water-orientated specialist grouping, in 1975/76. The need for a seaborne unit was recognised and subsequent to a detailed search around the coast of SA, the Donkergat area was identified, mainly because it is secluded and easy accessible by naval vessels. In 1978 the peninsula was allocated to the then SAA and 4 Reconnaissance Commando, now 4SFR, came into being (South Africa 1979a). More land, including Riet Bay (South Africa 1979b), was added later and the area DMTA covers today, was proclaimed. As an orientation to the layout of this military-training facility, as shown in Figure 1.4, information about the size, the coastline, borderlines and gradients of the area is given in the next subsection. (The geology, geomorphology, fauna and flora are discussed in the next chapter). In the same way that Donkergat Bay and Salamander Bay provided safe anchorage to ships during the whaling era and to flying boats during the Second World War (Spring 1995) these havens are ideal for accommodating the variety of seaborne activities required from 4SFR today.

1.2.4 Present military footprint at Donkergat Military-training Area

Parts of the ocean and lagoon around DMTA fall within the training area boundaries (Figure 1.4) and together with the peninsula constitute the study area. DMTA comprises 1 384 ha and is situated in the magisterial district of Vredenburg in the Western Cape province (Figure 1.4). In the SA 1:50 000 map series, the area is covered on sheets 3317 BB and 3318 AA, and on the South African Navy chart with reference number 1011. The airspace of DMTA is bounded within a radius of 1,5 nautical miles centred on 33°05'S 17°59'E with the lower limit ground level and no existing upper limit. The specific co-ordinates of the DMTA boundary displayed in Figure 1.4 are given in Appendix A.

The DMTA coexists with the adjacent Postberg Nature Reserve, proclaimed a private nature reserve in 1969 and owned by a company previously known as Die Oude Post Sindikaat Pty Ltd. Postberg Nature Reserve is presently owned by a number of influencal individuals who possess properties on these 1 851 hectares of pristine land. Bordering Postberg is the West Coast National Park (WCNP) proclaimed on 30 August 1985 (South Africa 1985) and managed by the South African National Parks (SANParks). In August 1987, Postberg was incorporated into the WCNP (South Africa 1987), the first contractual national park in South Africa. SANParks has on numerous occasions tried to declare this contract null and void and incorporate Postberg into the bigger park, but the efforts have been to no avail. The main reasons for this quest are that SANParks must manage the game and logistics of Postberg, yet have to pay the owners during the wild-flower season from August to September to allow the public access to the area. In the past the relationship between the Postberg owners, SANParks and the military was unsound as accusations were made against the military about misconduct such as mismanaging the area, breaking into the properties at Postberg during survival courses and committing traffic offences in the park. Although the military was not innocent of the accusations, not all were accurate and an independent company was contracted to investigate the management of DMTA (Van Veelen 1997). The investigation led to the establishment of a working group called the Spespark Committee representing the three role players. This forum meets quarterly if necessary and mainly taking a proactive approach to issues such as management priorities, assistance needed for projects and vehicle control during new developments on DMTA. For SF, this committee is also used as a forum to make military activities more transparent to SANParks and the Postberg owners.

The training and operational preparedness schedules conducted on DMTA are diverse and periodically involve co-operation with the SAN, South African Air Force (SAAF), South African Police Service (SAPS) and other local and foreign arms of service. The type of training and rehearsals on and around DMTA are land, air or water related and, generally, combinations of the disciplines are executed.

SASF seaborne training and operations started on 14 July 1978 from DMTA and 4SFR developed into a highly specialised force multiplier for the SANDF. DMTA is unique in the sense that it has protected and treacherous areas for training and it provides a secure haven for preparations and rehearsals or standby situations should operational demands or emergencies arise. Details of the training areas in relation to wilderness areas, cultural-historic sites and infrastructure and the feasibility of specific activities are investigated in Chapter 4 as incorporated in the spatial decision support system model. Although a relatively small area in comparison to other much larger training areas in SA, DMTA hosts a remarkable variety of activities. If these activities are not controlled and properly managed they can certainly have significant impacts on the environment and surrounding animal and human inhabitants. It is noteworthy that environmental impact studies were never prescriptive for any military activity executed on DMTA.

Two examples of impact assessments that should have been done are the amount of explosives that can be detonated without having an effect on the neighbouring island-breeding birds and inhabitants of neighbouring towns and the cratering effect of an 81mm HE mortar exploding on Postberg ignimbrite. It can be argued that the law on EIAs and development regulations only came into effect with the NEMA of 1998 (South Africa 1998a) and by then military activities were already being executed. These activities are, however still being practised and it appears that the military was, and still is, untouchable. The realities of the above examples are that charges that scare birds on the islands and shake residencies along the shores of Saldanha Bay continue to be detonated and 81mm mortars can still be fired indiscriminately. The occurrence of uncontrolled construction activities on DMTA surfaced with the building of the new boatpark that commenced in 2008. In the beginning of 2010 it came to light that the EIA for this development did not adhere to the regulations stipulated in South Africa (2006). The venture was stopped and only resumed later, as discussed in detail in Subsection 3.4.1. These military activities and the failure to adhere to NEMA principles and how the effects can be reversed by performing damage control and setting of guidelines for proactively implementing MIEM, have determined the aim and objectives of this study. Although EIAs have not hitherto been executed for military activities such as demolitions or firing of support weapons, it is now the opportune time for EIA principles to be used in the formulation of the necessary MIEM guidelines for DMTA.

1.3 RESEARCH AIM AND OBJECTIVES

The research aimed to build an inventory of impacts of environment-operation interaction on the DMTA over time, document and analyse the efficacy of ongoing management procedures enacted to alleviate these problems in a MIEM framework and design and test an electronic spatial decision support system that puts these measures in a replicable format.

To achieve the research aim, the following research objectives were set:

Objective 1. Inventorise the physical resource base and concomitant environmental sensitivities of DMTA concerning landscape features, climatic conditions, vegetation, wildlife and cultural-historical heritage.

Objective 2. Catalogue the impacts of military activity on the resource base of DMTA.

Objective 3. Overview management measures to reduce further unrestrained progress of environmentally harmful impacts and address these challenges by formulating pro- and reactive MIEM solutions in a comprehensive MIEM plan for DMTA.

Objective 4. Develop a spatial decision support system (SDSS) that can be used to manage the sensitive environmental resources of DMTA.

Objective 5. To project these practical solutions and measures against a theoretical backdrop of integrated military and marine environmental management.

These objectives combined will contribute in the formulation of MIEM principles that can be applied at the study area as described below.

1.4 THE STUDY AREA

The most important properties of SASF at Langebaan are Avontuur where the administrative component is accommodated and Flamingo where stores, a jetty, slipway and workshops are situated. These SF properties are located in the Langebaan residential area and are not given attention to in this study. The operational base, DMTA is mainly located on the peninsula as shown in Figure 1.4. Moving anticlockwise from Donkergat Bay past Salamander Bay and Salamander Point (Figure 1.4) around the hinterland of the peninsula, the coast is rocky as far as Elands Point with the inland coastal gradient becoming steeper with the progression. From Elands Point, the land descends, changing from a rocky to a dune environment that extends to Hugo's Post situated in Jutten Bay (Figure 1.4). The isthmus connecting the peninsula to the Postberg mainland separates the waters of Jutten Bay from that of Riet Bay. Past Hugo's Post, a further beach cove, Blouwildebeest Bay, is reached. From here, past South Head the coastline is rocky as far as Plankies Bay beach to complete the western borderline to the fence that forms the boundary between the military area and Postberg Nature Reserve to the south. The fence stretches inland in a north-easterly direction past the main gate and along the high ground of Vlaeberg of the southern slopes of the Riet Bay basin before descending to the Riet Bay mouth where the borderline separates Riet Bay from Langebaan Lagoon. From here the border stretches from Riet Bay past Meeuw Island to Donkergat Bay. Around Riet Bay the land is flat and sandy becoming marshier in the south-western corner.

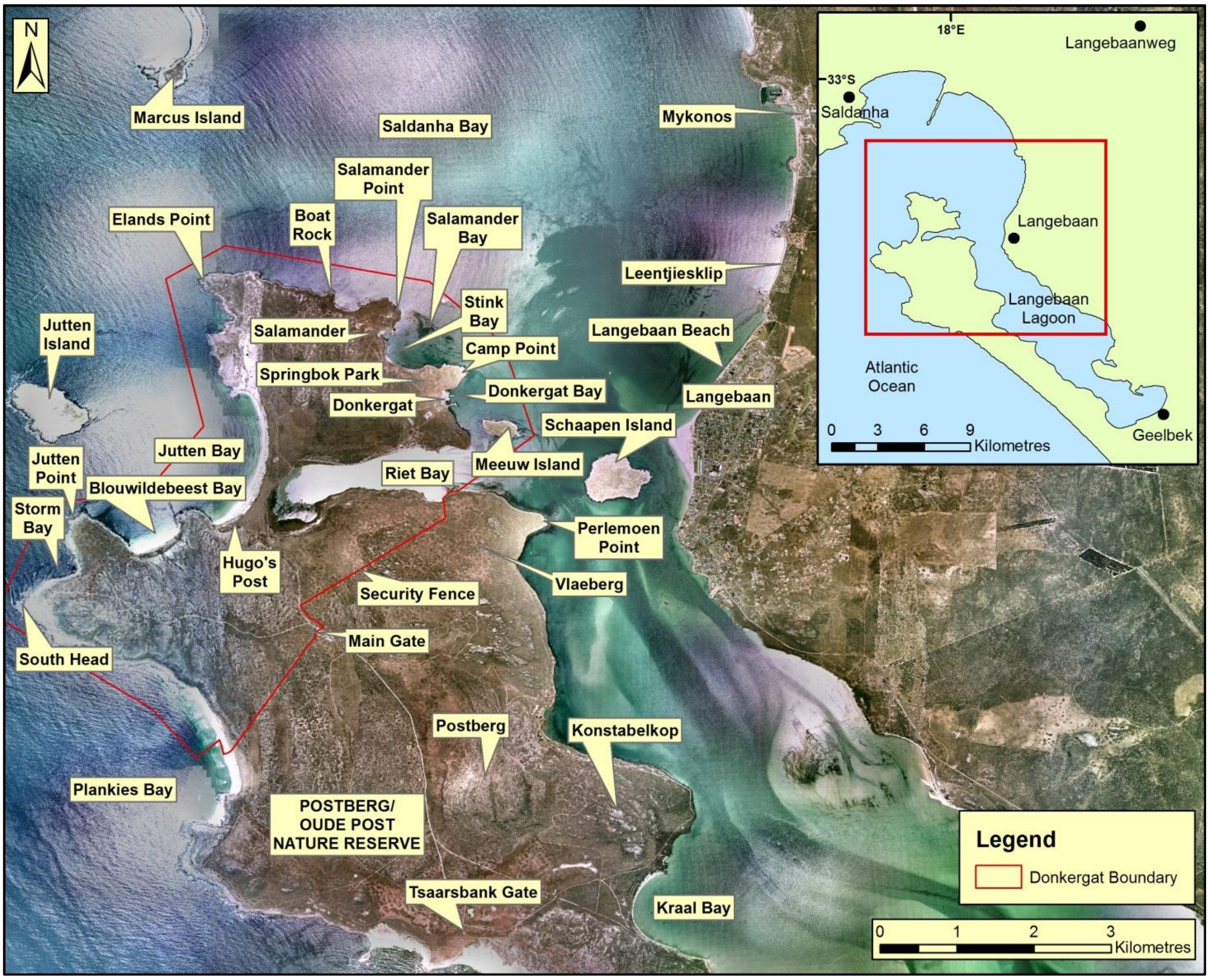


Figure 1.4 Donkergat Military-training Area

Meeuw Island (33°05'S 18°00'E) is part of the DMTA and is situated approximately 140 m east of Donkergat Bay. The island covers an area of seven hectares and with Schaapen Island (41 ha) it is one of the channel islands between Saldanha Bay and Langebaan Lagoon.

At 100 m above sea level South Head and two outcrops to the east are the highest points in the military area (Figure 1.4). Gradients are moderate with near-vertical slopes a main feature between South Head and Plankies Bay (Figure 1.4).

The main training activities are classified under waterborne, airborne, general and training by other institutions that take place in the area. These military activities hosted on DMTA are supported by the infrastructure shown in Figure 1.5. Infrastructure includes tarred roads, gravel roads, power lines, fences and radio masts and the built-up areas of Donkergat and surrounding facilities such as Mahonia, Hugo’s Post and Salamander (Figure 1.6). Interwoven with the infrastructure of the peninsula are specific military areas of interest where the training activities take place. The shooting ranges and training localities are described in Chapter 4.

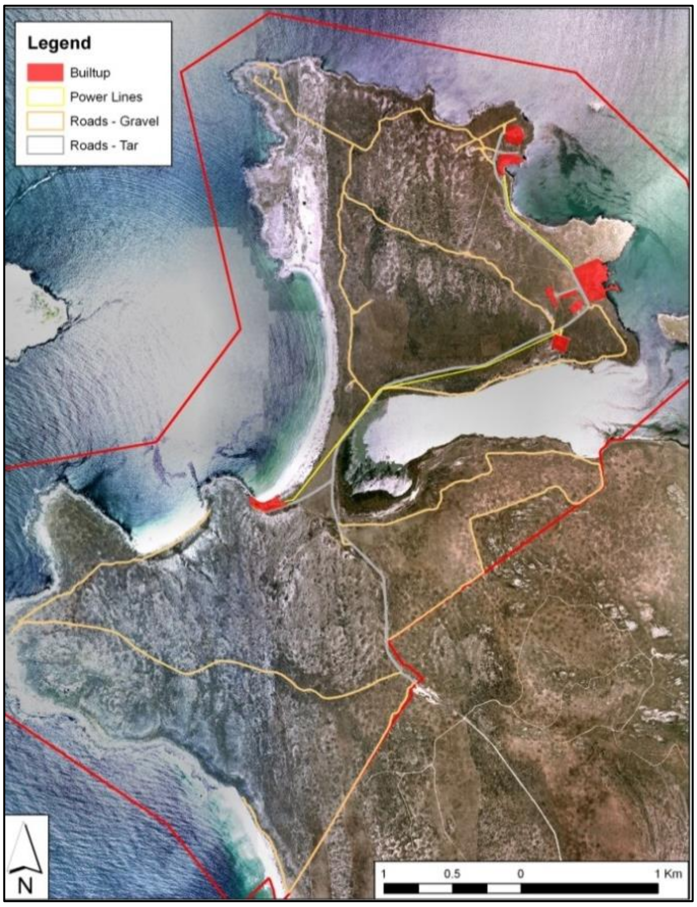


Figure 1.5 DMTA borders and key infrastructural features

1.5 METHODOLOGY

The research, by its very nature, adhered to a mixed methodological approach (Van der Merwe and De Necker 2013). In some parts a descriptive mode was applied (mainly Chapter 2) where site observations and experiences over an extended period were compiled; a descriptive-managerialist approach was used to record military impact inventories and management experiments (Chapter 3); and a quantitative-technological application (Chapter 4) was done in which an advanced geographical information technology (GIT) tool for practical environmental management was designed and tested. The research progressed by raising research questions and issues based on discovered experiences and solutions – a hypothesis-generating, rather than a hypothesis-testing approach. A variety of source materials and means of knowledge mining were employed.

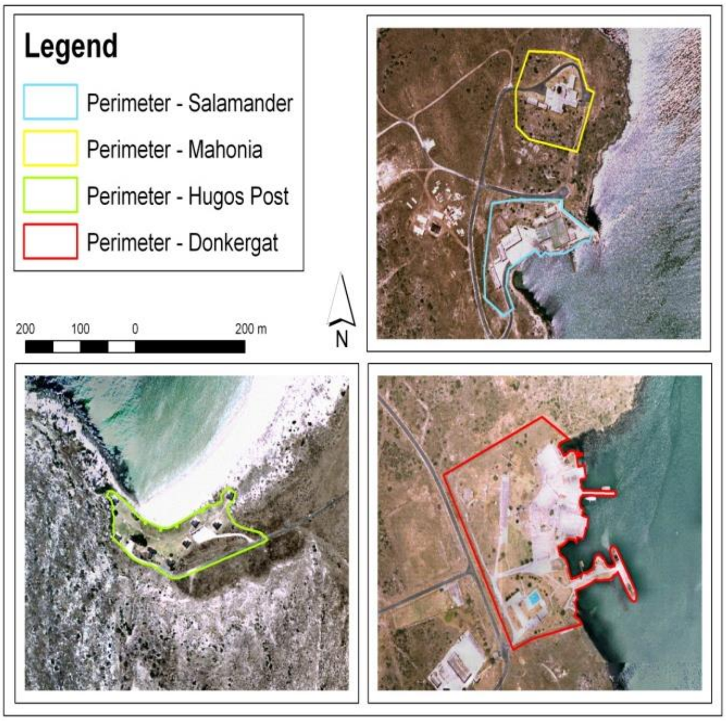


Figure 1.6 Borders of the key built-up areas in DMTA

With commencement of the study a variety of general and scientific literature, relevant to DMTA, was uncovered and a theoretical inventory was compiled to serve as a foundation for the research framework. For background information, literature on existing administrative, historical, ecological and military use of the DMTA was researched using a diversity of previously published historical sources such as those of Burman & Levin (1974) as well as recent scientific sources, such as Clark et al. (2012). The scarcity of basic information on DMTA, such as faunal and floral checklists, was identified as a serious shortcoming. By comparing the NEMA (South Africa 1998a) principles and regulations with the then state of affairs of DMTA, specific environmentally-detrimental, inherited ecological disturbances and ongoing military activities with negative effects were identified. These findings led to the assumption that the problems resulted from a lack of a practical and applicable plan that addressed environmental management. The environmental impacts on DMTA originated in the whaling-era and had continued unaddressed since this practice started in 1909. Some of the inherited ecological and ethical issues probed were the excavation site west of Donkergat dating from the whaling-era, the exceeding of the game-carrying capacity of the area and demolitions responsible for disturbances of island-breeding birds and residents of adjoining towns.

The question arose if mitigation measures could be implemented to lessen the existing impacts by developing a MIEM plan to address these and future environmental challenges. Also the formulation of a planning or operational modelling tool that can be implemented proactively before specific developments or military activities take place at certain times of the year, or under specific circumstances, was identified as a worthwhile avenue of research. This planning tool used layers of existing mapped themes as hypothetical spatial weights combination to identify minimum impact areas of military activities in the environment. This multicriteria evaluation tool or spatial decision support system (SDSS) was tested to identify specific, less vulnerable areas for different kinds of training and operational activities executed during different seasons and under varying meteorological conditions. Hypothetically this MIEM asset could be used to allow the implementation of MIEM as a cradle-to-grave environmental management approach for rehabilitation of existing negative impacts and of all new developments and operations.

1.6 METHODS

The methods employed where chosen to fit the research tasks implied by each of the research objectives. Consequently, resource inventorying, impact assessment, management frameworking and the building of a spatial decision support system were pursued by appropriate methods. These four are described respectively in the next subsections.

1.6.1 Resource inventorying

The Saldanha Bay area has rich history that is well-documented and the subject of much research. A resource inventory was compiled from a literature search on the administrative background, cultural-historical significance, geology, topography, oceanography, palaeontology, archaeology, climate, flora (different communities), fauna (bird, marine and terrestrial life), game distribution and historical migration patterns of animals. Detailed information about DMTA and the surrounding area was consolidated after thorough document study and casual observation before commencement of the survey in 1997. Much of the documentation was general articles or books but scientific papers and reliable data were obtained about, inter alia, geological identifications (Johnson 2004; Roberts & Brink 2002; Scheepers & Poujol 2002; Visser & Schoch 1973), vegetation composition (Acocks 1988; Boucher & Jarman 1977; Day 1958; Goldblatt & Manning 2000; Manning & Goldblatt 1996; Mucina & Rutherford 2006; Smith 1966; Van Oudtshoorn 1994; 1999), meteorological data (Day 1958; South African Weather Service 2009; Weather Bureau 1988), paleontological information (Hendey 1985; Roberts & Brink 2002) and animal lists (Cooper, Hockey & Brooke 1985; Cooper, Williams & Britton 1984; Schaefer 1993). Further searches revealed more information and sources that were added to make the inventories as comprehensive as possible. Terrestrial animals were the object of regular game surveys since 1997 to monitor numbers, sex ratios, condition, distribution, natalities and mortalities. As the fieldwork progressed and species were identified, checklists for the plants and animals were compiled.

The five broad vegetation communities, namely coastal shelf, granite soils, limestone soils, dune sands and marsh, as categorised by Boucher & Jarman (1977), were the basis for the study of vegetation composition. Previously-cultivated areas that mainly carry pioneer species were added as a vegetation type because some of these disturbed areas occur north and south of Riet Bay. Species identified during the study were compared with those identified by Boucher & Jarman (1977) and if they corresponded they are mentioned in the descriptions of the composition of communities.

As for birds and terrestrial animals, existing lists by birdwatchers, information from previous game counts, identification lists from sources such as Schaefer (1993) and data collected by SANParks (Yssel 2000) were used as comparative material. Some of these lists are more comprehensive than those shown in Appendixes B and C but only positively-confirmed species were considered.

To determine climatic changes and averages for the last decades, the available data for Cape Columbine, situated 30 km north of Langebaan, and Langebaanweg to the east of the town, were analysed for the period 1936 to 1990 (South African Weather Service 2009; Weather Bureau 1988). The Langebaanweg weather station is the nearest to DMTA but to get the effect of oceanic influences experienced at DMTA, the data for the Cape Columbine weather station were used.

1.6.2 Military impact assessment

Impacts of military action on the environment were documented during fieldwork undertaken from 1997 to 2006 that related to three broad feature categories: infrastructure, ecological impacts and cultural-historical heritage sites, the latter subdivided into WWII and historical whaling sites. Although these periods and activities overlapped historically, they were separated to distinguish between the structures and artefacts representing the two eras. Because most of the negative processes or activities were already happening when the survey started in 1997, the purpose when investigating a specific impact event was to ascertain:

- The category of impact involved;
- The site where the impact occurred (photographic material was collected);
- The process or activity causing the impact;
- The effect on the natural environment;
- The degree of deterioration;
- Impact reversibility to mitigate effects;
- Solutions to prevent reoccurance of problems; and
- Applicable legal implications.

Impacts were prioritised as those that must receive immediate attention, those not so serious and problems that will take long recovery times once mitigation measures have been implemented. Environmentally-harmful impacts were prioritised as shown in Table 1.1. These identified problems are simply examples of occurrences that can be expected on other SF training areas. *Immediate* actions are problems that received immediate attention, for example the cultural-historical attributes

Table 1.1 Impact identification categories

Problem	Immediate Action	Short Mitigation	Long Mitigation
Infrastructure			
Extraction excavations			x
Roads		x	
Disused cultivated areas			x
Fences		x	
Water-troughs and drinking points		x	
Cultural-Historic			
Graveyards		x	
Shipwrecks	x		
Structures		x	
Ecological			
Game movement and carrying capacity		x	x
Unserviceable seagoing vessels		x	
Sewage	x		
Military action residues			
Sweeping of shooting ranges	x		
Lack of building maintenance		x	
Vehicle manoeuvres on beaches	x		
Detonation of explosive devices	x		

and shipwrecks. Each matter had to be addressed as a matter of urgency as artefacts were being removed unauthorised from the area and wrecks were being damaged during construction of infrastructure. This criterion may, for example, not necessarily be applicable to other shipwrecks in the area so that in such instances problems can be divided into wrecks at Salamander and other wrecks. *Short mitigation* procedures will take approximately one year to complete and *long mitigations* longer, even up to 40 years as with disturbed areas that have been lying fallow on DMTA for approximately 40 years. Compilation of a prioritisation inventory is the initial step of the MIEM management plan and it is addressed in the management objectives shown in Appendix D.

Note that to reach the mitigation aims of some of the listed problems, such as game-carrying capacity, may take longer to accomplish than predicted as there are more stakeholders involved than just the military. In this case, both the short- and long mitigation columns have been marked (Table 1.1).

The problems were formulated as management objectives with time scales allocated to each (Appendix D). In particular cases, specialists from Cape Nature, IZIKO museum, the RFIM, the South African Heritage Resource Agency (SAHRA), the Council of Geoscience and other organisations had to be consulted to determine the extent of impacts, rehabilitation potential and mitigation possibilities. A similar approach to address environmental impact analyses (EIA) in the military was developed by the Joint United States–Republic of South Africa Environmental Security Working Group after the initiation of this DMTA project and can be found in the US–South Africa section of the website at https://www.denix.osd.mil/denix/Public/Training/training.html#int (ESWG 2004). The purpose of the EIA "is to integrate environmental considerations early in the decision-making process in order to identify and mitigate potential negative impacts of proposed actions" (ESWG 2004: 3). This EIA tool was developed mainly for new projects but the proposed assessment process can be applied when addressing existing impacts.

1.6.3 Environmental management frameworking

The processes, frameworks and plans of Cape Nature (Lloyd & Du Preez 1994) and other international models were used as broad guidelines to cover as many relevant aspects as possible that can be incorporated into a MIEM plan. Furthermore, the model and suggested format for the compilation of a military integrated training range management handbook, as initiated at the USA/RSA Integrated Range Management (IRM) Workshop in 2000/01 was consulted (ESWG 2001). Legislation and legal compliance were incorporated, where applicable, into the environmentally-harmful impacts that were identified. Once the environmentally-harmful impacts had been identified and categorised, feasible and cost-effective mitigation measures were experimented with to reduce the significant negative environmental impacts to acceptable levels.

The results were monitored and used as guides to restrict specific military actions or implement physical interference. Some of the MIEM projects executed in DMTA are discussed in Chapter 3.

Examples of ongoing research to find solutions for some existing environmental challenges on ground level monitoring are: erosion expansion; measuring impact of game and military activities by means of exclusion plots and marked areas; developing bird-flight diverters; implementing a game-gate and distribution system; testing a variety of materials to upgrade gravel roads; game-culling and catching programmes; and rehabilitation of heritage sites. Seasonal implications, such as the influence of demolitions on island-breeding birds and whales during the whaling season, are being researched and will be incorporated into the management plan and MIEM model. MIEM is, however, a subject that not only addresses management procedures but also aspects such as occupational health and safety (OHS). In this study, the MIEM addresses issues that could be identified and for which specific mitigation and monitoring actions, as proposed in Appendix D, could be prescribed. To finalise the management plan and identify priorities, the research being conducted in certain fields will be incorporated into the existing plan. Once the MIEM model for DMTA has been finalised, the potential exists to expand this concept and obtain data for MIEM proposals and their application to other SF areas.

1.6.4 Construction of a spatial decision support system

A multicriteria evaluation identified specific areas for the various military and recreational activities. By compiling a SDSS for DMTA and taking all available variables into consideration, a MIEM model that stipulates specific management actions was formulated that is applicable to other SASF military areas. A GIS using the original spatial data was implemented to plot the related and relevant military features; namely area boundaries, infrastructure, shooting ranges, training areas, cultural-historic heritage sites and the other natural resources and phenomena.

To accommodate military practices available documentation on standard operating procedures (SOP) army orders and unit orders were used as far as possible. Shooting-range arcs of fire were taken from the prescribed dimensions according to standard safety regulations laid down in South African Army Order (SAAO) GS3/77 (SAA 1997) and safety distances for parachuting from the South African Defence Force (SADF), Joint Warfare Manual GWU 110, Part 2, Standard Operating Procedures for Parachuting (SADF 1986) and The South African Army Infantry Formation, Instruction No. 303/2009: Air Supply (SAAIF 2009). Some SANDF regulations can be obtained from http://www.mil.za:8080/ under Policy Publications (SANDF 2014), but few SAAOs and SOPs appear here and many applicable to SF must still be updated. Consultants for the SDSS model included military personnel and specialists from the civilian sector (Appendix E). Participants were selected who had the best experience applicable to DMTA at the time of the survey. Confirmation on shooting ranges and the use of weapons were done by SSgt PL van Niekerk and Sgt B Meyer. Maj FH Sundermann confirmed all parachuting and aircraft-distance thresholds. Applicable distances for demolitions and pyrotechnics were obtained from 4SFR course handbooks and, if not available were determined in conjunction with specialists in this field, namely the author and the late WO2 WC Dettmer. Diving-related distance thresholds were dictated by the unit diving instructor Capt J van Niekerk. Boat work thresholds were derived from SOPs, handbooks and in conjunction with specialist WO1 RH Snyman. Vehicle and miscellaneous training regulations were determined from the inputs of all the specialists and SOPs. Regulations for cultural-historic heritage sites were prepared by Mrs A Aggenbach and confirmed by Prof PB Best, Lt Cmdr M Bisset and Mr D Heart. Mr C de Villiers now 80 years old, was a former employee of Union Whaling and worked at Donkergat for seven years. He assisted in the identification of structures from the whaling-era (Appendix E).

Because of their technical nature the specific model-building procedures for developing the SDSS are expounded in Chapter 4.

1.7 RESEARCH DESIGN

The research followed a relatively uncomplicated sequence of steps as depicted in Figure 1.7.

Nevertheless, a certain amount of sequentiality had to be observed, because the databases were constructed sequentially and cumulatively added insight for further application. The process began with the building of spatial inventories for the physical resource base of the DMTA, consisting of a number of physical thematic layers captured in GIS format and hence accessible for mapping and image analysis. This was augmented by GIS derivatives building on input such as the digital elevation model (DEM) from which themes like landscape slope and aspect could be generated. Some nonspatial data for climate and weather were also gathered. At the same time, the equivalent spatial database of all human related features was compiled in GIS layer format to capture structural detail of infrastructure, built military assets and heritage artefacts.

The impacts of military activity had been compiled continuously as part of the operational management system of DMTA and were incorporated as part of the overall database used for the research. Moving beyond database construction and manipulation, mapped resource features were analysed and classified according to their sensitivity to impact due to military activity.

Extensive compilation of literature information ranging from international environmental management insights to national legal, policy and military imperative documentation allowed guidelines for MIEM application to be compiled. These were reconciled with the operational imperatives of the military to draft rule sets for each type of military activity exercised on DMTA. The research culminated in the construction of a SDSS running on a GIS platform. This system was demonstrated and tested in example operational applications. The model has the potential to be expanded to serve as a functional model on which to base continuous management and maintenance principles for other military areas still in active use as it is a diverse training area with air manoeuvring, ground and maritime training areas and a variety of shooting ranges.

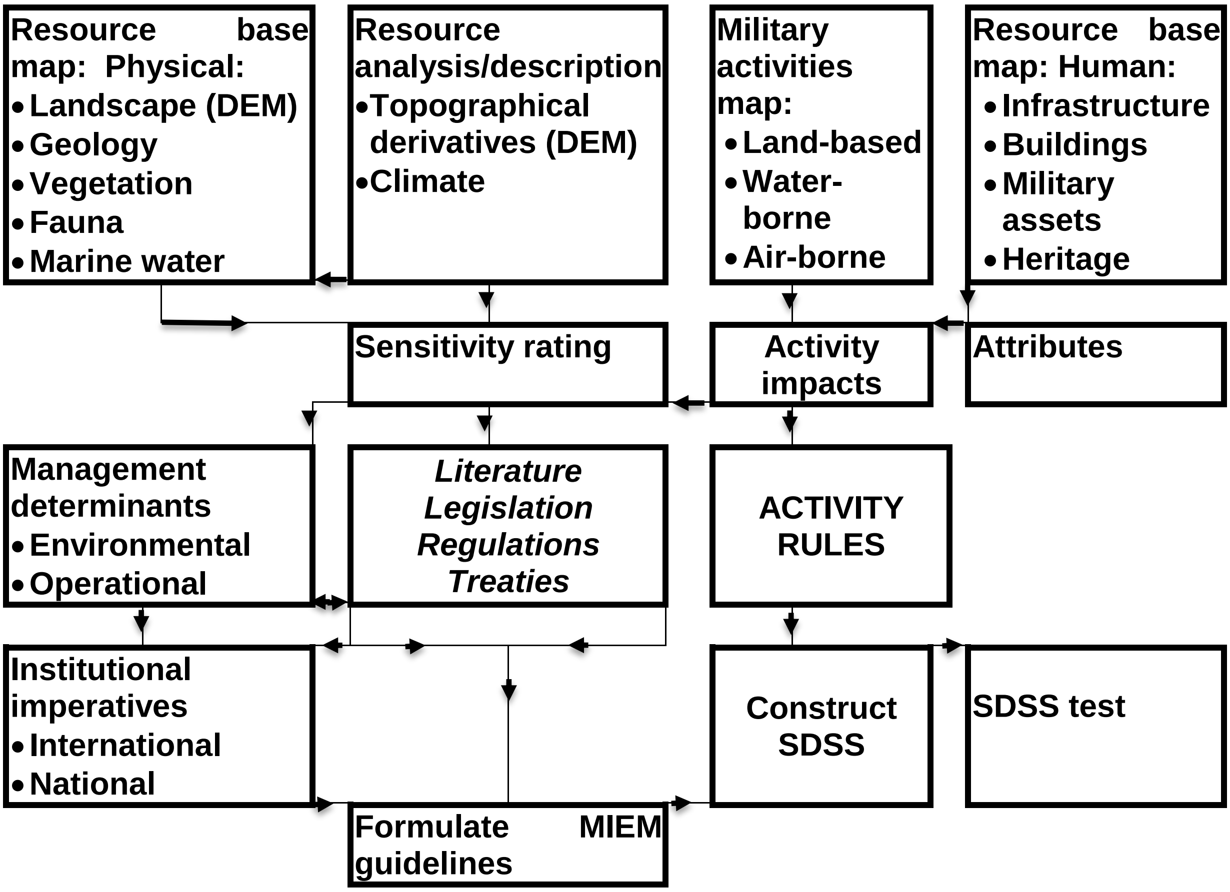


Figure 1.7 Research design

1.8 REPORT STRUCTURE

The study was introduced in Chapter 1 with the history of and an orientation to the area, followed by an overview of the use of DMTA and the military activities practised there today. With this foundation, the research aim, four identified objectives and methodology were formulated. The specific methods used to reach the aim of the study were discussed under headings similar to the objectives. Chapter 2 deals with the environmental background of the area and covers meteorology, geological features, geomorphology, fauna and flora which are important for the formulation of the MIEM plan and the resulting SDSS model. In Chapter 3 the environmentally-harmful impacts are identified and possible solutions that lead to the MIEM plan are proposed. The MIEM tool that can be implemented practically, namely the SDSS model, is explained in Chapter 4. Chapter 5 finalises the study with conclusions, summarised results, the value of the research, limitations and recommendations for further research possibilities. In the next chapter the environmental background of DMTA and the relevance of military activities on the area are discussed.

CHAPTER 2 ENVIRONMENTAL BACKGROUND OF DMTA AND THE RELEVANCE OF MILITARY ACTIVITY

Most military-training activities on DMTA take place outdoors, mainly on land or in the maritime environment where it is influenced to various extents by natural and cultural environmental factors. The ecological attributes of DMTA, such as climate and meteorology, marine-water parameters, geology and geomorphology, terrestrial vegetation, marine flora, fauna and the significance of cultural-historic heritage are inventorised in this chapter. The inventory is largely descriptive to draw attention to the relevance of the various elements to military activities. Some already implemented and other suggested management practices are highlighted to guide practical management actions – the declared function of the inventory in this MIEM initiative.

2.1 CLIMATE AND WEATHER CONDITIONS

The West Coast and the study terrain offer unique climatological conditions typical of a region that has been subjected to marked change over time and now experiences fairly harsh, arid climatic conditions that demand special consideration when performing potentially damaging activities, such as military exercises. Climatic change has played a major role in moulding the life and landscape of DMTA and the Saldanha region. It has been exposed to all the effects of a general warming of the planet interrupted by periods of glaciations which have been recorded since the onset of the Pliocene Epoch four million years ago. These periods mainly affected spatial changes in the variety and patterns of life by altering sea levels, but it was the changing of the temperature regime, accompanied by the switch from dry winters and wet, cloudy summers to the present Mediterranean system of wet winters and dry, hot summers that had the greatest effect on the diversity of life in the region (Branch 1983; Hendey 1982).

The present climate experienced at DMTA is generally mild and temperate, without frost and temperature extremes. This typical Mediterranean climate can be largely attributed to the effect of three determinants, namely the Atlantic Ocean, the midlatitude cyclones of winter and the South Atlantic anticyclone, which dominates in summer. The oceanic effects are fundamental in that the ocean is far more resistant to atmospheric temperature change than land and it has a generally tempering effect due to those factors. First, five times more energy is needed to heat water than solid matter, second, the surface-to-volume ratio is small restricting heat exchange, and third heat is continuously dissipated as the surface layers of seawater mix with deeper, colder water. The result is that the sea exercises a moderating influence on the ambient temperature of coastal localities. Besides its effect on temperature, the sea also influences precipitation. In this case the Benguela current which flows up the West Coast of Africa is cold from its passage through the waters of the Antarctic and yields less moisture to evaporation and rainfall than a warm current would (Preston-Whyte & Tyson 1988).

The average maximum and minimum temperatures at Langebaanweg for the period 1973 to 1990 were 23°C and 11°C respectively. At Cape Columbine they were 18.9°C and 11.9°C for 1961 to 1990. The highest temperatures measured at these two stations over these periods were 42°C and 40.4°C respectively. As illustrated in Figure 2.1, the seasonal temperature differences are small,

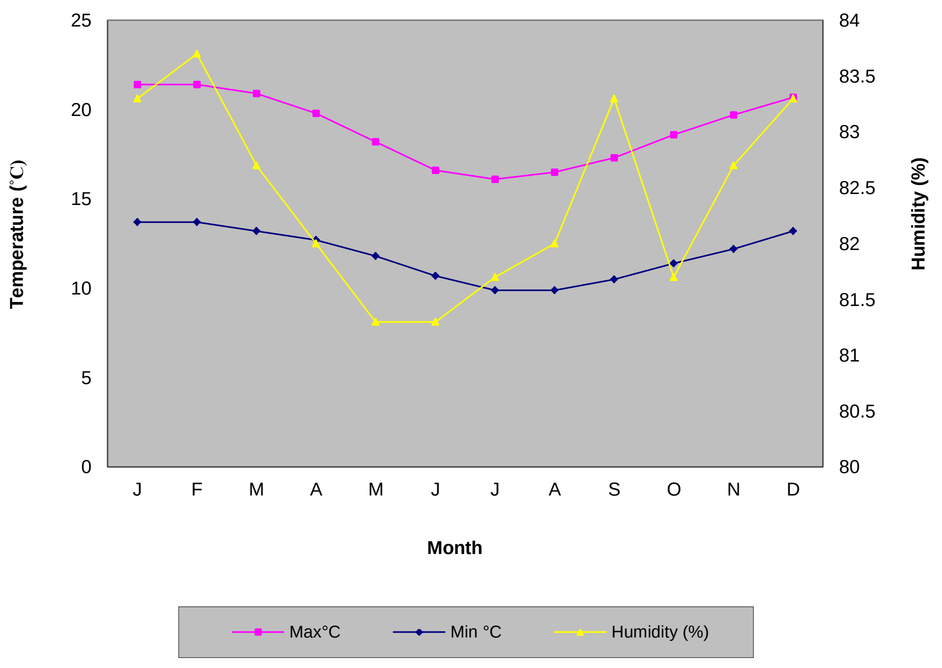


Figure 2.1 Average monthly ambient maximum and minimum daily temperatures and relative humidity at Cape Columbine (1961-1990)

dropping from average daily maxima of 21°C in summer to 16°C in winter. Comparisons of average maxima and minima show a consistent daily temperature range throughout the year of approximately 6-8°C. The average maximum and minimum temperatures for the periods 1936 to 1984 and 1961 to 1990 at Cape Columbine rose by 0.2°C from 18.7 to 18.9°C and 11.7 to 11.9°C (South African Weather Service 2009; Weather Bureau 1988) – arguably signs of a generally warming atmosphere. As expected of an oceanic location, relative humidity is constantly moderately high, although not elevated to the levels that produce the muggy conditions adjacent to warmer coastlines.

Rainfall (Figure 2.2) is concentrated in the consecutive four-month winter period from May to August with a monthly average of 40.3 mm. The summer months are dry with a minor (~12 mm/month) contribution from conventional summer rainfall to the annual total average of 240 mm. Conventionally, this amount classifies the area as arid. The cold waters of the Benguela Current are

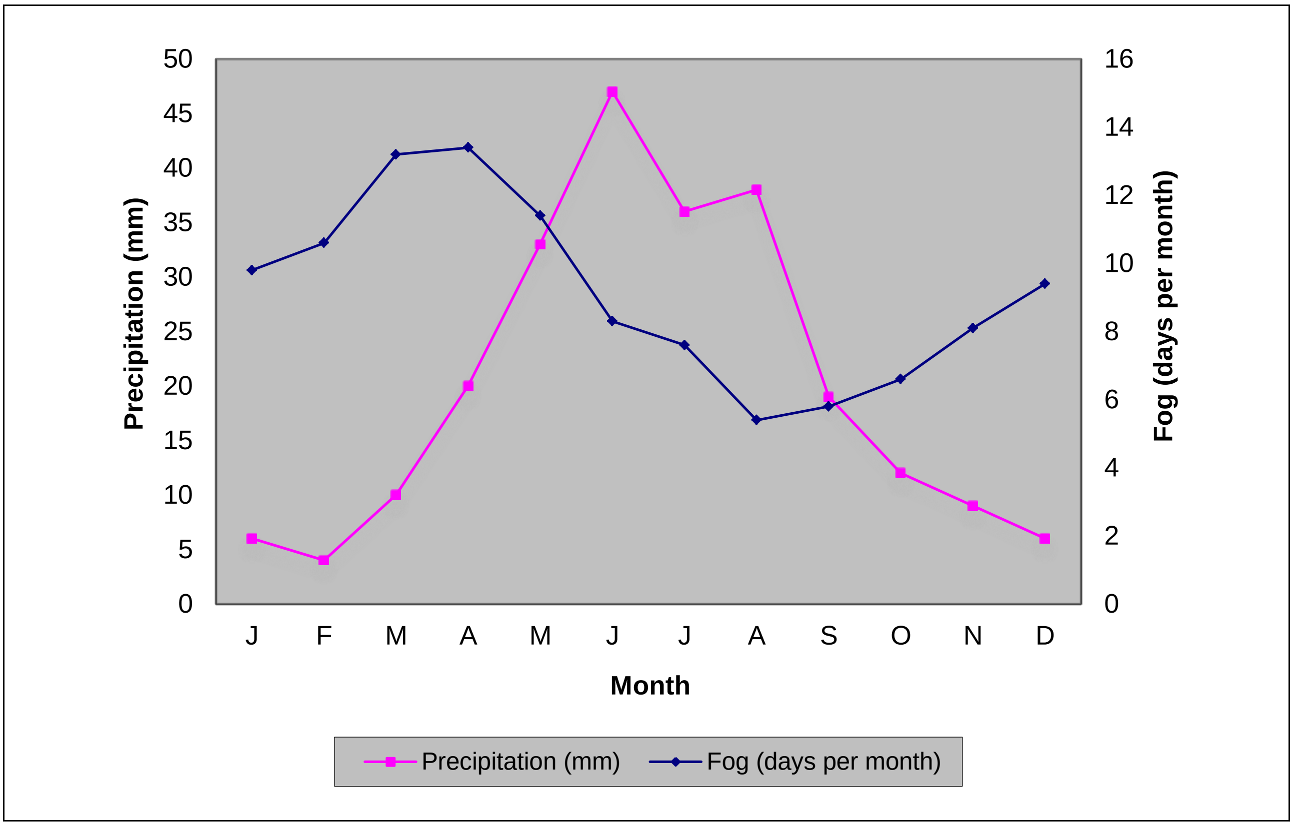


Figure 2.2 Average monthly rainfall and days with fog at Cape Columbine (1967-1990)

responsible for the occurrence of another important local form of precipitation, namely advection fog, particularly in late summer/autumn or after hot winter days, the regular (almost 10 days per month) prevalence of which is illustrated in Figure 2.2. Fog occurrence peaks during the autumn months. As warm air over the ocean cools during calm nights, its relative moisture content increases causing the condensation of minute water droplets which remain suspended in the air. In the morning the sun's rays evaporate these clouds and the last of the fog usually clears around 10:00 (Preston-Whyte & Tyson 1988; South African Weather Service 2009). Potential seaborne operators quickly become skilled to take note of indications of fog as it puts their navigation skills to the test while doing openwater boat work. Atmospheric moisture is an important source of water to trainees during long-term coastal survival courses.

Rainfall at Langebaan[1] is caused by winter midlatitude cyclones, better known as cold fronts. North-westerly winds and heavy rainshowers occur with an accompanying drop in barometric

[1] Langebaan had its own amateur meteorologist, retired, now deceased, Naval Commander, Sjoerd Schaaff who collected data on the weather between 1987 and 2007 at his Langebaan residence. The average, annual rainfall at Langebaan for his 20-year records was 350 mm with a highest rainfall of 491.5 mm in 2007 and lowest of 198.5 mm in 2000.

pressures. Wind speeds averaging up to 30 kph, occasionally galeforce strength as the front passes, are reached. The north-westerly winds are seldom as strong as the south-easters experienced in summer (Custom Weather, Inc 2014). As the fronts pass, the north-westers back southerly and windspeed drops to approximately 15 kph with milder weather following (Preston-Whyte & Tyson 1988; Weather Bureau 1988).

With the advent of summer the South Atlantic high-pressure cell strengthens sufficiently to dominate the climate of the region. Centred on 30°S over the ocean, it produces predominantly (60%) southerly winds which persist throughout the season. These are inclined to reach gale force more often (a total of around three full days per month) than the northerly winds of winter and blow on average at about 30 kph (Preston-Whyte & Tyson 1988). Gale-force winds of up to 160 kph have been experienced in Table Bay but normally the south-easter blows at 20 kph to a maximum gale-force strength of 125 kph (Custom Weather Inc 2014). It has been recorded that occasionally the winds can be devastating in Langebaan, as Green (1970) quoted Frank Wightman on board the *Wylo* anchored in Kraal Bay: “It blew so hard that I could not stand on deck – I would have been blown overboard without a lashing.”

The descending air associated with the high-pressure cell and the low vapour content of the air are together responsible for preventing the formation of rain clouds. Cloud cover (0/8=clear skies, 8/8=totally overcast) in summer (3/8) and winter (4–5/8) is almost similar, the former not being rain bearing (mainly cirrus as opposed to stratus and stratocumulus). Cumulonimbus clouds accompanied by electric storms are rare the year round, with the extreme condition of snow never occurring. Hail has fallen on occasion but is a rare phenomenon. Cloud build-up, apart from that associated with cold fronts, usually occurs in the morning and tapers off in the afternoon and evening (Preston-Whyte & Tyson 1988; Weather Bureau 1988). Weather patterns are of utmost importance to the seagoing members of the unit and detailed meteorological lectures are presented during Module 2, advanced operational coxswain, sailing and support coxswain courses.

2.2 MARINE-WATER PARAMETERS AND TRAINING ACTIVITIES

The DMTA conforms to the arid West Coast proclivity to lack significant terrestrial surface-water features. This situation is due to a combination of general aridity and deep, absorptive sandy surface depositions precluding surface run-off and channelisation. Hence, the DMTA hydrology is largely defined by the marine environment and its waters. The exposition here covers bay layout, the nature of the surrounding waters as to their inert characteristics and typical marine-water dynamics. The implications for and by military activity necessarily drive the narrative and Figure 1.4 displays locations referred to in the section.

The Langebaan *Lagoon and the salt marshes* at its southern extreme are unique in that no river feeds them and at some 5700 ha the lagoon and marshes are by far the largest in South Africa so constituting 32% of salt-marsh habitats in the country (O'Callaghan 1990). Surface swimming and boat training mainly take place on the lagoon from Kraal Bay to Riet Bay, in Donkergat Bay and Salamander Bay and around the islands and across to Langebaan. Currents, depth of water, sea-life types and abundance, the wind-chill factor and related variables are well known to trainers, enabling them to create a safe, well-controlled training environment. Operational rehearsals involving surface swimming mainly take place in the lagoon and in the sea at Blouwildebeest Bay and Jutten Bay. Subsurface exercises and evaluation of new equipment are mostly executed in the vicinity of Donkergat Bay and Salamander Bay.

Sensitive ecological areas such as inner Riet Bay, the Geelbek area and the south-eastern extremity of the lagoon are used in a secondary role as command-and-control and observation points. Other training areas around the lagoon entrance are Saldanha Bay, Mykonos and the Langebaan/Leentjiesklip beaches. When the need for harbour exercises arises, the yacht basin at Mykonos, Saldanha harbour and the iron-ore jetty are explored. The appropriateness of specific areas for the diversity of training around DMTA is discussed further in Chapter 4.

As the salt marsh is a sheltered arm of the sea rather than an estuary, the *salinity* of the water remains more constant than it would otherwise. Summer salinity values approximate 39 ppt (parts per thousand) in the southern end of the lagoon and decrease progressively to 34.9 ppt in Saldanha Bay. The higher salinities in the south are due to the effects of evaporation. In winter the range is from 32 ppt in the far south of the lagoon, increasing to 34 ppt in Saldanha Bay. This seemingly abnormal condition is due to the dilution effect of winter rainfall (Day 1958). The variation in salinity does not significantly influence any subsurface activities presently undertaken by divers or submarines. As eighty per cent of diving training takes place at night, a controlled area is essential to minimise the possibilities of accidents or interference from commercial seagoing vessels and local fishermen.

Currents in the lagoon are vitally important to upcoming seaborne operators who fin from Donkergat Bay to Langebaan and vice versa. The influence of currents on such exercises is significant and operators must take the tides, stages of the moon, and wind strength and direction into consideration when determining their entry point so as to exit at a predetermined location on the other side of the lagoon. *Tidal flow* on either side of Schaapen Island reaches a maximum of five knots at spring tides, slowing towards the south (Day 1958). When the current is strong, swimmers must enter the water well upstream to reach the planned exit point on the opposite side. The ferries used for transport and training navigate specific channels in the lagoon but over the last ten years the incidence of vessels getting stuck or running onto sandbanks has increased. These waterways are influenced by the tidal flow because it directly affects *sedimentation rates*. The building of the breakwater between Marcus Island and the mainland in 1976 resulted in a change of the wave direction and current speed. The biggest effect of the breakwater on wave energy and circulation is in Small Bay, north-west of the iron-ore jetty where it causes an increase in the residence time of water in the bay and a consequent decrease in the availability of oxygen (Clark et al. 2012). Where current velocities have been decreased, accelerated sedimentation rates and invasive mussel-bank formation have led to the build-up of numerous sandbanks, even in the deeper channels. Progressive sailing training is also influenced by this sedimentation as the lagoon channels and ocean surrounding DMTA are negotiated for this activity.

Water temperatures influence the length of time operators can spend in the water, the equipment they use and the dietary supplements given to them when they are exposed to extreme cold conditions during long diving or swimming exercises. Surface temperatures fluctuate seasonally but the difference between the bay and the lagoon is less in the winter months. In winter the water temperature in the entire area is stable at around 14 ± 0.5°C. In summer the lagoon temperatures are affected the most and rise to 24°C in the south – clearly higher than that of Saldanha Bay (16-17°C). Temperatures also fluctuate locally according to water depth and tides (Day 1958).

Wave action influences swimming and boating activities and, depending on the experience of the operators, activities that can be executed are determined by wind speed according to the Beaufort scale. As a rule, most waterborne activities are postponed when the Beaufort sea state reaches 6 or higher. On the ocean side of Saldanha Bay, swells of up to nine metres have been measured. This can damage marine flora and erode the shoreline. Coastal-related training such as survival is terminated under such conditions. Shelter increases towards the interior of Saldanha Bay and at Schaapen Island wave action is markedly reduced. Waves are seldom higher than 0.6 m on the northern side of the island and even lower towards the sheltered Langebaan Lagoon (0.15 m). Schaapen Island causes a blocking effect to the tides and the *tidal range* of 1.4 m in the south of the lagoon is 0.3 m less than in Saldanha Bay. This blocking effect also causes a 40-minute time lag between low tide in Saldanha Bay and at the southern end of the lagoon (Day 1958). In the planning of exercises this time lag and the stage of tide changing are important when operators need to infiltrate and exfiltrate by finning or when executing the ‘mile swim’ around Meeuw Island.

2.3 GEOLOGY AND GEOMORPHOLOGY

Superficially, the geological nature of DMTA can be described as a granitic peninsula from which a shallow covering of Tertiary sands has been eroded. The most prominent geological features of the landscape surrounding DMTA are the granite outcrops, of which Vlaeberg (193 m) and Konstabelkop (189 m), in the Postberg Nature Reserve are the highest. At just above 100 m above sealevel the ridge line from the main gate to South Head (Figure 1.4) is the highest part of DMTA. Figure 2.3 shows that the elevation of DMTA ranges from sea level to just over 100 m. Large parts of DMTA have elevations of less than 20 m, making it vulnerable to sea-level rise and storm-surge damage. Regarding slope gradient (Figure 2.4), only a few areas have slopes of more than 45% (i.e. precipitous), while most of DMTA's terrain is level (<1%) or is slightly sloped (1-4%).

The geology was first described in detail by Visser & Schoch (1973) who listed the main geological features shown in Figure 2.5 as exposures of the Malmesbury Formation, Hoedjiespunt and Darling Granites and Saldanha Quartz Porphyry. Some of these granite outcrops, like Kamppunt (Siegfried 2008, Pers com) are small and unique within the constellation of Cape Granites. The surface area is largely covered by tertiary to recent sediments and includes conglomerate of limestone, sandstone, marble, gravel and sands. An active sediment track marks the north-western peninsular head, emphasising the dynamic landscape involved.

Geological research of these granites is continuing (Scheepers & Poujol 2002) by Stellenbosch University geologists. It was determined by study of the igneous rocks in the Langebaan area that there was a reduction in the timegap between the last phase of Cape Granite-related volcanism and the onset of the Klipheuwel and the Cape Super Group sedimentation. On the northern and southern shores of the mouth to Riet Bay, rocky features that once formed part of a volcano are evident. Traces of these volcanic activities are still visible on the eastern side of Riet Bay in the form of pumice fragments (Scheepers 2000, Pers com). This is one of the reasons why certain military activities, such as shooting and demolitions cannot be allowed in these parts of Riet Bay. A site of geomorphological importance is a karst-like sinkhole, not uncommon in calcareous strata that include limestone found in the Langebaan Formation, that appeared overnight between the northern and southern Donkergat infrastructure centres in July 2013 as depicted in Figure 2.6. The dimensions of the sinkhole were 2.8 m wide and 6.75 m deep when it opened. When measured in January 2014, the width was unchanged but the depth had decreased to 6.4 m. The possibility of a karst subsidence on DMTA is not farfetched as Tertiary Coastal Limestone is one of two extensive karst-host rock types in southern Africa, including the Langebaan Formation. These limestones occur discontinuously on land from Saldanha Bay along the coast to KwaZulu-Natal (Marker & Gamble 1987). Further investigation regarding this natural phenomenon remains to be done. At South Head where rock-climbing training takes place − with the southern face the most popular − the composition of the rock outcrop is suitable for mechanical climbing using pitons, friends and other mountaineering equipment. The climbing activities make no significant impact on the environment as the climbing equipment used is removed after exercises.

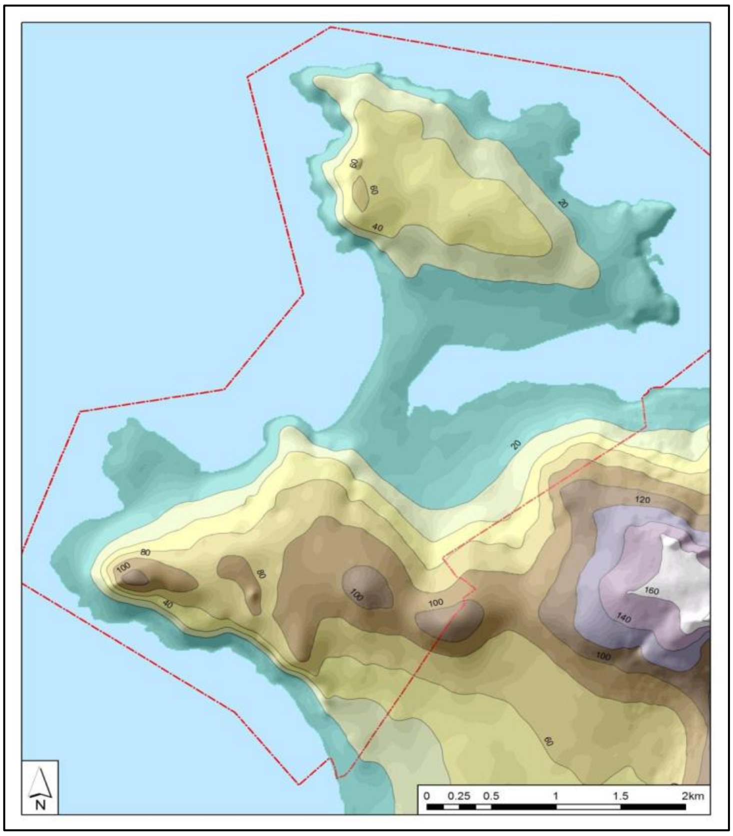


Figure 2.3 Terrain and elevation in DMTA

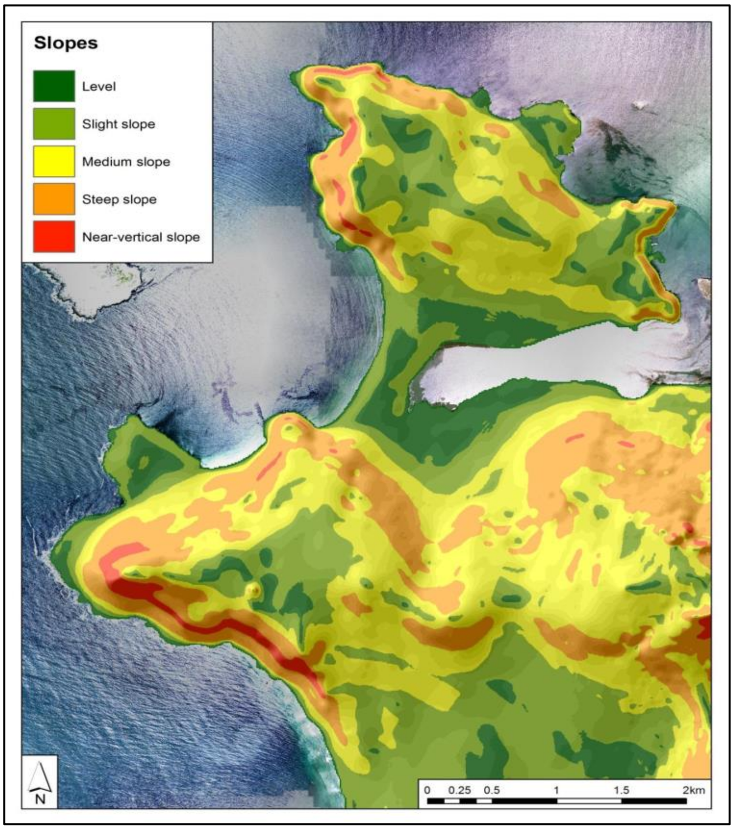
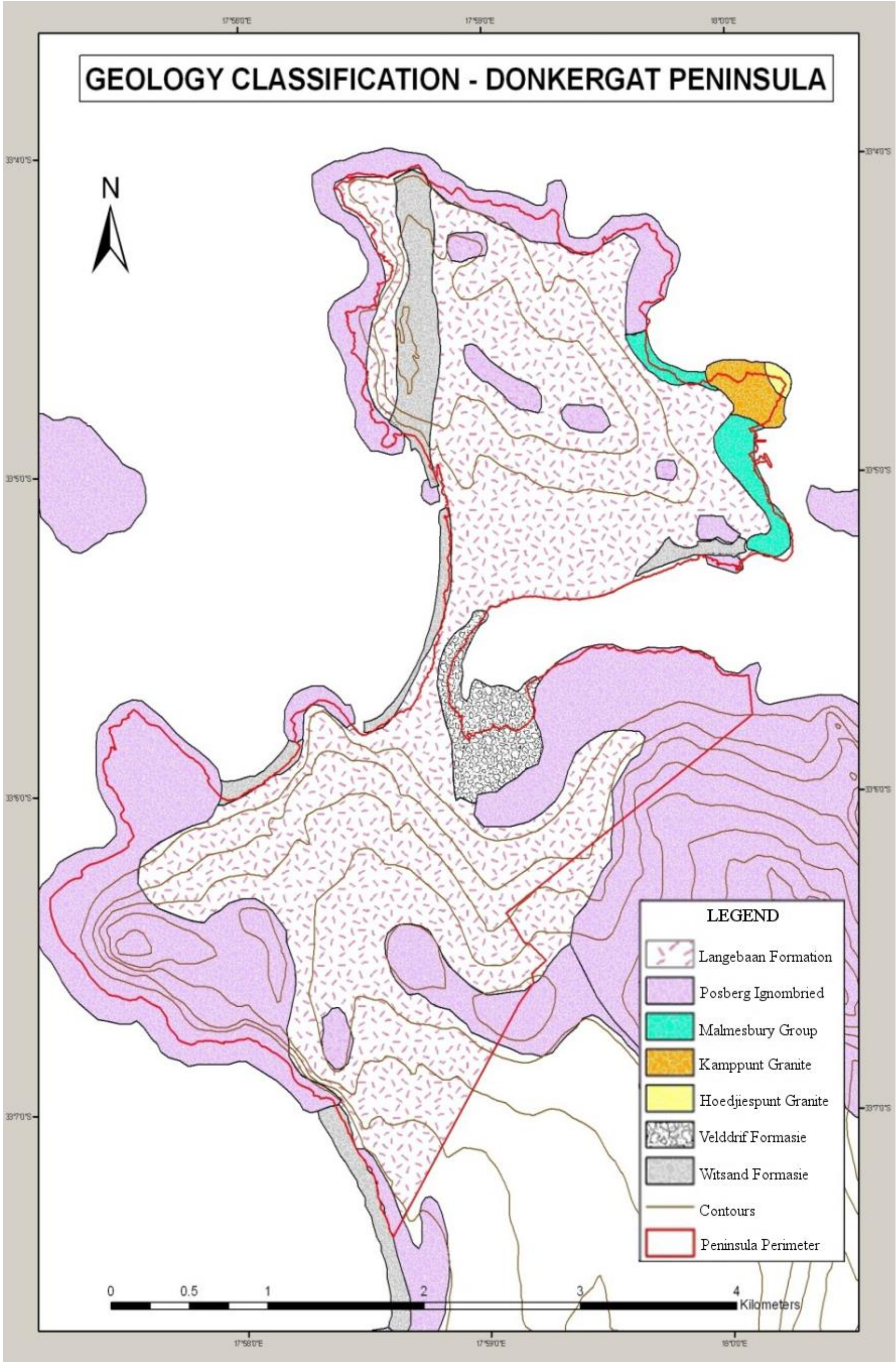


Figure 2.4 Slope gradient in DMTA



The geological composition of DMTA mainly consists of the Langebaan Formation, Postberg Ignimbrite, Malmesbury Group and Hoedjiespunt and Kamppunt granite. (Johnson 2004; Field confirmation by Siegfried (2008, Pers com)).

Figure 2.5 Geology of DMTA

To enhance communication networks, repeaters are placed on Vlaeberg and at times left for prolonged periods with solar energy as power source. All the sediments and the variety of vegetation hosted on and around them contribute to the formation of a variety of micro training habitats found on DMTA. The Meeuw Island shoreline is rocky with isolated coves where small sandy beaches (2-3 m) occur at places. The inner portion of the island is rocky, consisting of quartz granites (Johnson 2004).

This distinctive location with training areas that vary from dunes to rock faces originated during a geological era when the land was mostly below sealevel. Until about 13 Ma ago the present West Coast region was covered by 120 to 140 m of ocean above the present sea level. Because Saldanha Bay and adjacent areas were frequently subjected to fluctuations in sea level in geological history, its appearance changed through the ages (Erasmus 2005). With the prevailing sea level, land that was once submerged has become exposed and great topographical variations are exhibited. At Hugo’s Post for example, where most beach-landing techniques are practised, sea-terraces rich in mollusc shells form part of the existing dunes, testifying to higher sea level. The fluctuating sea level is the most important factor influencing the deposition of Tertiary sediments on the coastal margins of southern Africa (Hendey 1982) and it was central in the creation of the Donkergat peninsula and Langebaan Lagoon. These sea-level fluctuations with resulting regressions and transgressions of the shoreline and a change in the course of the Berg River were key elements contributing to the fossil abundance at the West Coast Fossil Park near Langebaanweg. An example is the early part of the Pliocene when the palaeo-Berg River entered the sea near present-day Langebaan and the transgression of the shoreline resulted in terrestrial and freshwater fossil deposition (Erasmus 2005). When the sea retreated, dunes were built up along the coast forming a barrier, but about 9 000 years ago the sealevel rose again and broke through the dunes between the rocky headlands that today flank the entrance of Saldanha Bay. The area behind the dune barrier was flooded, creating Langebaan Lagoon and the remaining dunes, today the Donkergat peninsula, separates the lagoon from the open sea (Branch 1983). The historical faunal fossil record is discussed in more detail later.

Because the Donkergat peninsula was submerged beneath the Atlantic most of the time, it lacks fossilised material and archaeological artefacts but a fossil record unparalleled in South Africa is found at Langebaanweg 15 km north-east of the lagoon. The fossils there and those found in the Prospect Hill Formation (Roberts & Brink 2002) provide evidence of a previous global climatological era. Paleontological riches have been found all around DMTA but more research on these must still be done on the peninsula itself. There are indications that there might be appreciable paleontological assets on the peninsula given the finding of a Mammoth’s (*Paleoloxodon*) molar tooth in the vicinity (Green 1970). The footprints of a modern *Homo sapiens sapiens*, well known as Eve’s footprints, dating some 115 000 years ago were discovered in 1995 by a geologist, Dr David Roberts, on the western shore of Langebaan Lagoon not far from DMTA (Avery & Booth 1997). Natural caves, eroded by wave action and suitable for investigation (Siegfried 2008, Pers com), occur on the western perimeter of Plankies Bay. Stalactites and stalagmites are being formed in these caves by water filtering through the Postberg ignimbrite. During March 2012 Cape horseshoe bats (*Rhinolophus capensis*) invaded one of the caves. The issue of this bat colony is revisited later given that their unexpected arrival forced a change in venue for coastal survival training.

Figure 2.6 Karst-like sinkhole on DMTA

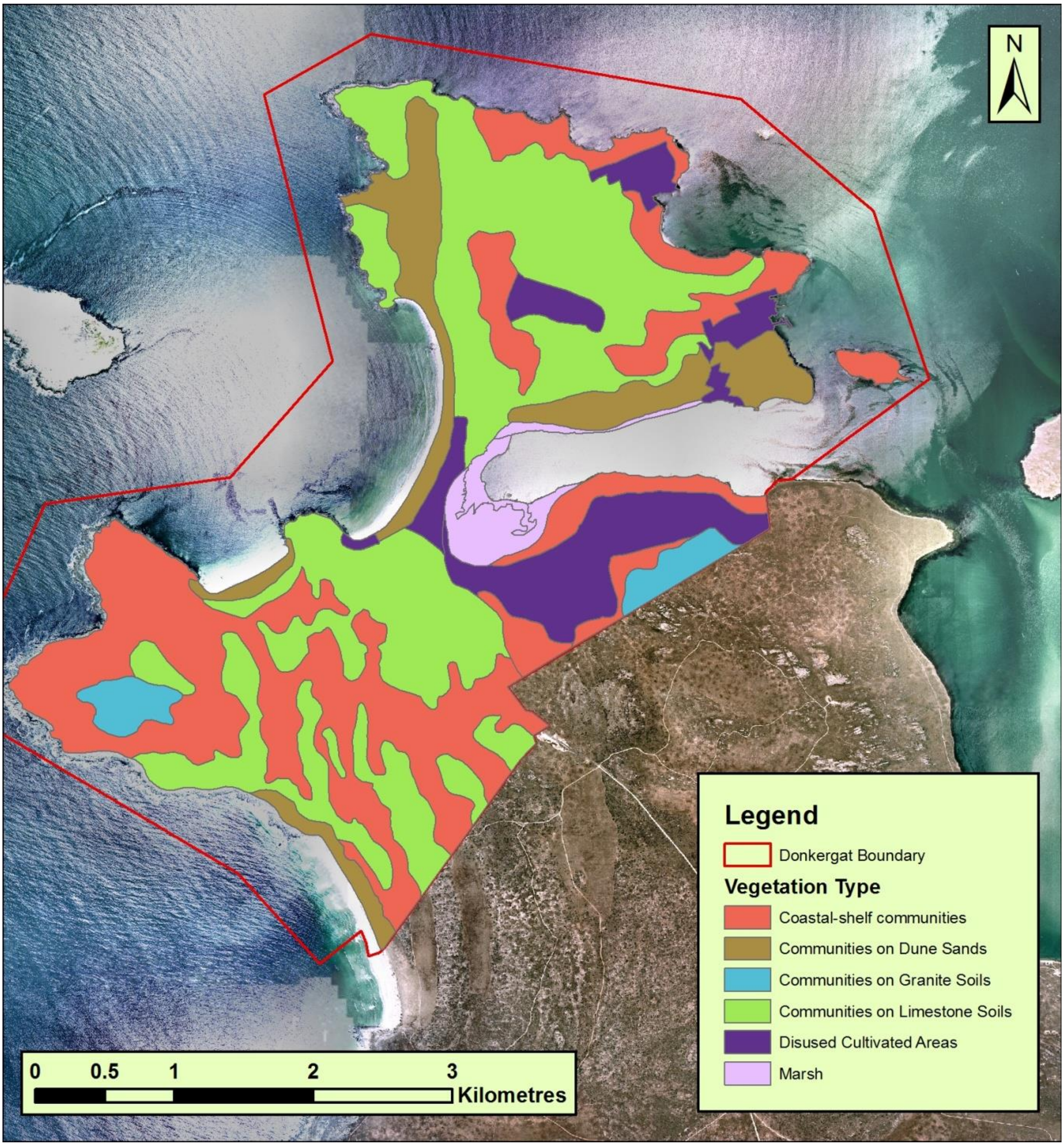
Geomorphology and vegetation on DMTA are interrelated as the limestone reefs (originating from seashells) influence the occurrence and nature of the groundwater in some areas. Rich phosphate deposits often occur around the granite hills that protrude from the sand, probably the result of massive quantities of guano once present there (Joubert 1990b) and these deposits quite likely contribute to the vegetation composition of these areas.

2.4 NATURAL TERRESTRIAL VEGETATION

The Langebaan floral community resides under the Cape Palaeotropic floral kingdom transition within the Fynbos biome, a geographic area extending roughly from 31 to 35°S and 18 to 27°E. The floral community, that includes the vegetation of DMTA (Figure 2.7), is distinct enough from true

Fynbos to warrant its own classification, namely the Langebaan Dune Strandveld (FS5) according to the SANBI vegetation index system (Mucina & Rutherford 2006).

The status of this vegetation is vulnerable and almost 30% is conserved in the West Coast National Park and in the Rocherpan, SAS Saldanha (Military Academy area), Cape Columbine and



DMTA is largely covered by strandveld vegetation, previously referred to as West Coast Strandveld (Acocks 1988) and currently as Langebaan Dune Strandveld (FS5) according to the SANBI classification (Mucina & Rutherford 2006).

Source: Adapted from Boucher & Jarman (1977)

Figure 2.7 Vegetation of DMTA and Meeuw Island

Yzerfontein nature reserves. Some 35% of this vegetation type has already been lost to or as a result of farming activities, holiday-resort development, pollution and urban sprawl, and broad stretches have been invaded by alien *Acacia* species (Joubert 1990b; Mucina & Rutherford 2006). West Coast plants are very inadaptable which makes them extremely vulnerable to disturbance (Joubert 1990b) and, according to Yssel (2000) (compiler of the WCNP management plan), the key contributors to the degradation of West Coast vegetation are urbanisation, development, sand and lime mining, invasion by alien woody plants, agriculture and uncontrolled use of dune systems by off-road vehicles and pedestrians.

DMTA, although included at large scale in the West Coast National Park vegetation community by the SANBI index, at smaller scale harbours unique floral features with distinct communities determined by local soil, rock and slope peculiarities and characteristics. The plant communities on DMTA shown in Figure 2.7 are associated with the typical soils occurring along the coastal shelf, on granites, limestone soils and dune sands (Boucher & Jarman 1977). The area that each vegetation composition dominates is shown in Table 2.1. Infrastructure such as buildings, roads and shooting ranges make up the 206 ha difference between 1178 ha (vegetation) and 1384 ha (total area).

Table 2.1 Vegetation composition of DMTA

Vegetation Type	Area (ha)	Percentage
Coastal shelf communities	410	34.8
Communities on granite soils	102	8.7
Communities on limestone soils	34	2.9
Communities on dune sands	462	39.2
Marsh communities	133	11.3
Disused cultivated areas	37	3.1
TOTAL	**1178**	**100.0**

The following examination of vegetation communities on DMTA is ordered according to the vegetation type domains shown in Figure 2.7. In the discussions the common names and confirmation of the distribution of the vegetation used were derived from Goldblatt & Manning (2000), Manning & Goldblatt (1996), Smith (1966) and Van Oudtshoorn (1994; 1999), although these sources are not referred to repeatedly. Scientific names, and Afrikaans common names by which most species are known locally, are used and some known English names are mentioned. Some plants are known by more than one name by the local residents as indicated in Appendix B which is an inventorised reference base for management purposes of the plants on record up to 2012 in DMTA. More than 120 plant species are listed by scientific as well as vernacular names. Many of these species are claimed to have outstanding medicinal and cultural value besides their crucial botanical value, hence the need for enhanced management strictures on landscape use in DMTA. The identification of the whole spectrum of plants and detailing of composition of the communities remain continuing management tasks on DMTA. The six vegetation communities shown in Figure 2.7 of which the area each occupies is stipulated in Table 2.1, are treated in detail next according where they occur, the dominant soil type, the defining genera, the average height of some plants and the sensitivity of the community to human disturbance.

2.4.1 Coastal-shelf communities

These communities occupy the second-largest (nearly 35%) area in DMTA. Two communities of dwarf shrubland are distinguished. First, *Atriplex-Zygophyllum* coastal-shelf dwarf shrubland faces north-west on the coastal boulder shelf and extends from the wave-splash zone inwards where it is exposed to salt spray and onshore winds. This community occurs on shallow, gravelly or sandy soil, sometimes having a high proportion of marine shells. These deciduous succulents form a dense mat-like cover about 5-10 cm tall, punctuated by clumps (varied forms of the same species), in the form of shrubs 50-100 cm high. The community's defining genera are *Artiplex* and *Zygophyllum* while the dominant species are *Artiplex semibaccata* (rankbrakbossie), *Drosanthenum floribundum* (persdouvygie), *Zygophyllum morgsana* (slaaibos), *Zygophyllum flexuosum* (spekbos), *Ruschia tecta* (regopvygie), and *Mesembryanthenum crystallinum* (ice plant).

Second, *Pelargonium-Muraltia* coastal-shelf, dwarf shrubland consists of low prostrate succulents and dwarf shrubs and occur below the 3-m contour on a mainly north-eastern aspect. This community is found on sandy soil which accumulates at the bottom of granite outcrops as along the southern shores of Riet Bay. The vegetation consists of low prostrate succulents about 15-50 cm tall, as well as a grassy element consisting mainly of *Ehrharta calycina* (polgras/gewone ehrharta/common ehrharta). The community-defining species are *Muraltia harveyana* (Saldanha-skilpadbos), *Pelargonium hirtum* (wortelblaarmalva) and *Ficinia nigrescens* (grasbiesie), while the dominant species are *Diosma hirsuta* (rooiboegoe), *Ehrharta calycina* and *Ruschia tecta*. These communities are sensitive to human and mechanical movement as the soil is gravelly, sandy and sometimes high concentrations of marine shells are present (Boucher & Jarman 1977). This substrate composition can lead to easy trampling and necessitates the correct management of game numbers. Military actions should be limited, preferably avoided, where coastal-shelf communities occur.

2.4.2 Communities on granite soils

These communities cover the second smallest area (nearly 9%) of the natural vegetation communities. The important community is *Ehrharta-Maurocenia* hillside, dense shrubland. It consists of an herbaceous (non-wooden) layer about 25-50 cm tall, a shrub layer with leathery-leafed evergreen shrubs and drought-deciduous shrubs 100-200 cm tall and a stratum of leathery-leafed, gnarled trees occurring in clumps 120-400 cm tall. The community occupies the south-eastern to south-western slopes of granite hillsides, occurring around the bases of granite rock domes where it prefers the relatively higher rainfall run-off and protection from the north and north-westerly winds. The soil tends to be shallow with a high organic content. The defining species are *Ehrharta erecta* (shade ehrharta) and *Maurocenia frangularia* (hotnotskersie) and the dominant species are *Rhus glauca* (taaiblaar), *Zygophyllum morgsana* and *Ehrharta erecta* (Boucher & Jarman 1977). Moll (1985) noted that DMTA is the most northern distribution of the hotnotskersie/hottentotskersie/Hottentot cherry which, in the Cape Peninsula is a common forest pioneer species. The community on granite soils is relatively robust and can withstand a fair amount of potentially-disturbing human and mechanical activity. Due to the nature of the outcrops these areas are not easily accessible by vehicle so that foot exercises will not have an appreciable detrimental effect on these communities.

2.4.3 Communities on limestone soils

This group occupies the smallest area (about 3%) of DMTA vegetation communities. The *Zygophyllum* limestone, evergreen shrubland stands grow in shallow, dark-brown sand on exposed limestone ridges or outcrops on hillsides. They face south-west, west to north-west or seawards and are exposed to onshore winds and salt spray from the Atlantic Ocean. The community has two strata, namely a 5-25-cm high dominantly *Rhus laevigata* (taaibos) and *Senicio sarcoides* (soetkopdikblaar) cluster and a strata of between 80 cm and 0.5 m dominated by *Zygophyllum* sp. The shrubs are diverse and comprise a mixture of evergreen and drought-deciduous succulents. The defining species here is *Zygophyllum morgsana*, while the dominant species are *Ehrharta calycina, Zygophyllum flexuosum, Ruschia tecta, Senicio sorcoides, Rhus laevigata, Lasiochloa longifolia* (haasgras) and *Festuca scabra* (Munnik-swenkgras/Munnik fescue). This vegetation has generally been heavily trampled (Boucher & Jarman 1977), and it is preferred grazing for indigenous antelope. Hence it should be protected against unnecessary military activities.

2.4.4 Communities on dune sands

Dune-sand communities occupy the largest (39%) area in DMTA. Two dune sand communities are evident. First, *Hermannia pinnata* littoral dune dwarf shrubland is limited to deep, sandy, calcareous and non-calcareous soils in the valleys and exposed ridges of dune systems running in a south-westerly direction on the seaside of Langebaan Lagoon. Two strata of this shrubland are sometimes distinguishable, the one consisting of dwarf succulent shrub (5-15 cm tall) and the other one of dwarf shrub and clumps of grasses (30-50 cm tall). The shrubs include evergreen, drought-deciduous succulents and annual types. The defining species is *Hermannia pinnata* (kwasblaar-kruippoproos) and the dominant species are *Ehrharta villosa* (doppiesgras/dune ehrharta), *Limonium peregrinum* (strandroos), *Ehrharta calycina* and *Ruschia tecta*. These areas are subject to heavy grazing (Boucher & Jarman 1977) and should be avoided as a general rule. This is especially applicable to all the dune ecosystems regarding any type of vehicle exercises.

Second, *Didelta* littoral dune, open grassland is found on the peninsula in the deep sand forming the crests of the dunes close to the sea. The species in this community are dune colonisers and are thus extremely hardy. Succulence and hairiness are common features of these dwarf shrubs and grasses, the shrubs sometimes being prostrate. These are also pioneer species whose root systems anchor the dunes and fertilise the sand when they die. The defining species is *Didelta carnosa* (seegousblom). The dominant species are *Eragrostis sp.* and *Senecio elegans* (veldcineraria) (Boucher & Jarman 1977). As with the dune, dwarf shrubland this vegetation should be protected against unnecessary military activities, especially vehicle exercises.

2.4.5 Marsh communities

Marsh communities cover the third largest (11%) area of natural vegetation on DMTA. The marsh area around Riet Bay is unique in its vegetation as it differs totally from the surrounding veld. This plant community occurs in the spongy wetland at the head of Riet Bay and is subject to tidal flow resulting at times that it becomes partially submerged in seawater. The defining species of this community is glasswort samphire (*Sarcocornia perennis*) which, like many of the species present, is halophytic (salt tolerant). The rank grass (strandkweek), *Spartina capensis* occurs in beds in the intertidal (littoral) zone of sand flats in the north-western corner. Marsh areas around Langebaan Lagoon have been disturbed considerably in the past by vehicles and domestic animals (Boucher & Jarman 1977). As Riet Bay is frequented by game and is the only marsh area enclosed in DMTA, no military activities should be allowed here. Aquatic plants are especially important in the lagoon ecosystem as their decayed remains enter the nutrient cycle of the wetland (Branch 1983).

Meeuw Island is vegetated with an *Artiplex-Zygophyllum* coastal-shelf community. This includes orange and gray lichens, *Albuca* sp. (Liliaceae), *Ferraria* sp. (Iridaceae), *Brachypodium distachyum* and *Bromus gussonei* (Poaceae), *Urtica urens* (Urticaceae), *Artiplex semibaccata, Chenolea diffusa, Chenopodium murale*, *Exomis microphylla* and *Sarcocornia* sp. (Chenopodiaceae), *Tetragonia decumbens* (Aizoaceae), *Disphyma crassifolium*, *Mesembryanthemum crystallinum* and *Prenia pallens* (Mesembryanthemaceae); representatives of the Legumninosae, *Acacia cyclops* (Mimosaceae), *Zygophyllum morgsana* (Zygophyllaceae), *Malva verticellata* (Malvaceae), *Ballota africana* (Lamiaceae), *Lycium afrum*, *L ferocissimum* and *Solanum guineense* (Solanaceae), *Cucumis myriocarpus* (Cucurbitaceae); and representatives of the Campanulaceae, *Matricaria sabulosa*, *Senecio vulgaris* and *Sonchus oleraceus* (Asteraceae) (Brooke & Crowe 1981). Because of the sensitive nature of coastal-shelf communities and the role the island plays as safe and breeding havens for birds, no military activities can be allowed on the island.

2.4.6 Disused cultivated areas

This category does not really qualify as a community of natural vegetation and covers about 3% of the area.The West Coast vegetation has a long history of human use when nomadic groups of Khoisan represented the first modern permanent human impacts through burning veld and concentrating livestock on regenerating vegetation, The European settlers introduced concentrated disturbance with their livestock as they were not nomadic and they created permanent destruction by laying vast areas of vegetation bare for agricultural purposes (Boucher 1982). The disturbed areas on DMTA were once cultivated primarily for wheat production but have been allowed to lie fallow for at least 40 years and definitely so since the military took over in 1978. The land is now colonised by *Euryops multifidus* (hanepootharpuisbos), which forms 100 cm high stands beneath which *Artiplex semibaccata* and *Oncosiphon suffruticosum* (strinkkruid/wurmbossie) occur to a height of about 10 cm. *Atriplex* was also identified by Boucher & Jarman (1977) as one of the species that makes up the understorey on old fallow lands. The field south of Riet Bay is one such area where cultivation has ceased and erosion in the dry season is rife. With the poor rainfall and oligotrophic (nutrient poor) soils, vegetation growth is slow, especially where the natural communities have been disturbed. Given their disturbed nature, these fields are candidates for sacrifice to enhanced human and military activity, of which the placement of the demolition range is an example.

Some vegetation communities are more sensitive to human disturbance than others so that they must be avoided during military practices. Three areas must be declared out of bounds with no military activity permitted there, namely Meeuw Island, Salamander Point and Riet Bay. These and some factors that can have destructive results on the DMTA vegetation are discussed next.

2.5 TERRESTRIAL VEGETATION SENSITIVITY

Because of the sensitivity of much of the vegetation, all types of military-training can not be executed all over DMTA. The three localities where no training can be executed are Meeuw Island, around Salamander Point which is the only place on the peninsula where the botterboom grows (see Figure 2.8) and around the perimeter of Riet Bay where glasswort samphire, better known locally as ‘seekoraal’, and sea grass beds occur. More information about sensitive vegetation systems such as those occurring between inland rocky outcrops will have to be obtained. But certainly, the latter two areas must remain out of bounds for operators on hiking exercises, quad-bikes or mountaineering activities. Compared to the factors identified by Yssel (2000) that are harmfull to the West Coast vegetation the main concern on DMTA is not related to economic development practices. Rather on DMTA the focus must be on overgrazing, especially at already disturbed areas, runaway veld fires, exotic tree and plant infestations and uncontrolled vehicle movement on the dunes and beaches.

During the summer months the vegetation on DMTA becomes extremely dry, especially due to the prevailing south-easter and other summer winds (Joubert 1990b). The opposite obtains during the wet winter months conditions. Fires are common along the West Coast during the dry months but none have occurred on DMTA since the establishment of the military base in 1978. Occasionally, fires break out during field-shooting exercises but immediate control is exercised by the firemaster and, morever wind strength and direction are taken into consideration when planning shooting or demolition activities. The most devastating fire in the broader region in recent years was during 2000 when a fire swept through from Yzerfontein to Hopefield, narrowly missing Postberg and DMTA. Between 99 000 and 282 000 angulate tortoises (*Chersina angulata*) perished in the flames (Baard 2000). Valuable lessons were learnt about combatting and preventing runaway fires on the West Coast. Smaller fires have occurred along the West Coast since 2000 but at some distance from the WCNP and DMTA, and without significant losses on farms neighbouring WCNP. The DMTA infrastructure fortunately has a natural fire break in the form of Riet Bay should a south-easterly-driven fire reach the peninsula.

Apart from the terrestrial plants in DMTA a variety of marine plants also occur along its shores. The next section gives an account of the marine flora.

2.6 MARINE FLORA

Unlike the terrestrial vegetation that is dominated by angiosperms, the marine plants are almost all algae and are commonly referred to as seaweeds. Colours vary more than those of their terrestrial counterparts, mainly because of brown and reddish pigments which often disguise the green colour produced by chlorophyll. Shelter from wave action is a critical determinant affecting the type and distribution of marine vegetation (Day 1958). Along the rocky shores facing the open sea the most noticeable seaweeds are the giant kelps like the split fan kelp (*Laminaria pallida*) and sea bamboo (*Ecklonia maxima*) which occur below the low-water mark. The rocks in the littoral zone remain largely uncovered due to wave action, except for patches of purple laver (*Porphyra capensis*) which inhabit the zone near the high-water mark. At the low-water mark, species such as branching red algae (*Laurencia* sp.), slippery orbits (*Aeodes orbitosa*) and robust hair weed (*Chaetomorpha robusta*) begin to emerge.

Sandy beaches such as at Plankies Bay lack a substratum suitable for the attachment of seaweeds so that no growth forms and only cast-up kelps and agarweed (*Gracilaria verrucosa*) are seen. Moderate protection from wave action as along the coast from Elands Point to Donkergat Bay is most suitable environment for intertidal colonisation so that this zone becomes overgrown by an expansion of the purple laver beds, hedgehog seaweed (*Nothogenia erinacea*) and sea lettuce (*Ulva* sp.) and near the sublittoral zone by tongueweed (*Gigartina radula*) with sea bamboo the most abundant plant. Sediments tend to cover the rocks where protection against wave action is high, hence the substratum becomes unfavourable for seaweeds. In these conditions the large kelps vanish completely and are replaced by agarweed, purple laver, *Chaetangium* sp. and *Aeodes* sp. that prefer the littoral-transition area (Day, 1958). Agarweed is a source of agar widely used in bacteriological and pharmaceutical work as well as in the manufacturing of glues, jelly and even ice cream. This commodity was harvested in Saldanha Bay since the advent of the Second World War and thrived up to 1973 when it earned revenue of about one million rand. Since 1974 the amount of cast-up weed diminished to almost nothing, bringing the industry to an end (Yssel 2000). The decline in the abundance of agarweed corresponded with the dredging of the bay. The construction of the breakwater between Marcus Island and the mainland (see Figure 1.4) and dredging that took place to build the iron-ore harbour resulted in most of the agar beds being silted over and eliminated (Branch 1983; Joubert 1990a). Some marine flora are therefore clearly sensitive to human activities and should be factored into planning for military actions.

Within Langebaan Lagoon, three distinct intertidal habitats, namely sea-grass beds, salt marshes and unvegetated sand flats, occur. The plants of these intertidal habitats are only found in the lagoon because they survive only in areas that are completely isolated from wave action. Sea-grass beds and salt marshes are important in the intertidal ecosystem as they improve habitat diversity, act as a key food source, stabilise sediments and provide protection against predators of juvenile fish and invertebrates. Aerial photographs of the lagoon show that sea-grass beds in the lagoon have declined in area by approximately 38% since the 1960s. Certain areas, such as Klein Oostewal near the lagoon entrance, showed a more drastic decline in sea-grass beds than other localities and this is matched by a decrease in the abundance in the macro-faunal invertebrate communities that occur with species associated with these plants. By contrast species that burrow in unvegetated sand increased in abundance (Clark et al. 2012). The diminishing sea-grass beds in the lagoon indicate an ecosystem shift mainly due to human disturbances such as trampling associated with bait collection. According to Clark et al. (2012), burrowing sand crustaceans have played an important supporting role in contrast to *Callinasa kraussi* and other sand-flat prawn species that turn over massive quantities of sediment and, once established in an area, effectively prevent sea grass from recolonising, thereby creating disturbed, new unvegetated habitats. The comparable burrowing prawn in the *Zostera* beds is *Upogebia africana* which is a filter feeder that makes permanent burrows in firm mud so not influencing the tubes and burrows of other members of the fauna as *Callinasa* and others does (Day 1958). This emphasises the importance of maintaining a natural area like Riet Bay in an undisturbed state and disallowing all military activities or bait collection there.

During coastal-survival courses, areas with sea-grass beds and salt marshes are left undisturbed. Plants that are used are mainly sea bamboo and sea lettuce learners use as ‘pressure cookers’ and as food sources respectively. The impact on the environment is minimal as these resources are abundant around the coastline of South Head. Survival training on DMTA is largely coast-orientated, but as the escape and evasion phase includes cross-country movement, information about the most common terrestrial animals and birds occurring in the area is included in the study material provided to learners. The animal life, especially the birds, is diverse on and around DMTA and the area offers a safe haven to numerous species. Available information on the faunal record is presented next because some structures and military actions have deleterious effects on animals, particularly birds. It will be noticed that there are still many informational shortcomings with several animal groups and vast potential for research opportunities as also mentioned elsewhere.

2.7 FAUNA

The Langebaan area boasts an interesting and rich stock of evidence of paleontological animal life even surpassing that which survives and remains in the natural environment today. Hence, this section begins with an overview of the paleontological history and development of the area as witnessed in its fossil record and it is followed by a detailed account of the contemporary occurrence of animals that would require consideration in the MIEM.

2.7.1 The faunal fossil record

The fossil records shows that the lagoon region was once teeming with animals, many species of which were lost as the fertile forests gradually gave way to arid Strandveld. Historically, early explorers and naturalists found a wealth of mammals and birds while the waters abounded with fish and cetaceans (whales and dolphins). The French naturalist Francois Le Vaillant described the skies above the lagoon as clouds of birds that were full of colour just over 200 years ago (Branch 1983). The Langebaanweg area is rich in mineral and fossil deposits that have long been of interest to scientists. In the early years Haughton (1932) described the field characteristics of these deposits and chemical and X-ray analyses of the phosphate composition were done by Frankel (1943). The first fossils were discovered in 1958 (Singer & Hooijer 1958) and since then the site has yielded a variety of remnants, notably the most important assemblage of Pliocene fossils yet recorded in the region (Hendey 1973). The diversity of fossils found at Langebaanweg has contributed to our knowledge on the evolution and correct systematic position of animals like the rodent subfamily *Otomyinae* (Pocock 1976) and it has yielded the largest find of early Pliocene vertebrates known anywhere in Africa (Grine & Hendey 1981). It is also the richest pre-Pleistocene bird-fossil locality in the world with ten thousand bones of 61 different taxa being found there (Rich 1980). Fossils of large herbivores have enabled scientists to visualise the nature of the vegetation of earlier times (Hendey 1973). By interpreting and correlating the succession of Late Tertiary deposits with sea-level changes, the Langebaanweg area can become a key to clarifying the Late Tertiary history of the coastal regions in South Africa (Hendey 1981). To give background to what led to the present faunal composition, fossil evidence of animal life in the region from the Miocene to the Holocene Epochs is described here.

- Miocene Epoch (23-5 m y BP)

The emergence of fossil remains begins in the Middle to Late Miocene Epoch some six to thirteen million years ago (m.y.a.). At this time the world climate was at its warmest and the Antarctic ice cap had largely melted, raising the sea level to some 140 m above the present. Only the highest coastal hills were not flooded and the islands that formed became inhabited by thousands of seabirds. The fossil record tells of an area covered in forests, marshes and tropical trees, such as palms. Evidence of fossil vertebrates is meagre but among those uncovered *Hipparion*, the ancestor of the modern horse, is possibly the most noteworthy (Hendey 1985).

- Pliocene Epoch (5-2.5 m y BP)

Most records of past life originate from the early Pliocene (4-5 m y a), a time of profound environmental change. The Antarctic ice cap had begun to reform, causing a drop in sea level. Wind systems changed, temperatures fell and rainfall diminished in the high latitudes. The extent of the forests shrank and grassland environments began to succeed them. Animal life, abundant at the time, adjusted to the changes. For instance, it is clear that the breeding-seabird community was very different, the fossil record showing species such as the albatross (*Diomedea sp.*), prion (*Pachyptila sp.*) and petrel species which today breed only in the sub-Antarctic islands. The relocation of such birds to more southern breeding grounds is more likely a consequence of the limited availability of areas suitable for breeding than changes in the sea temperature as once supposed (Hendey 1985).

Thirteen of the 14 existing African mammal orders were represented, but carnivores (meat eaters) were more numerous, among which the chief predators of the time were sabre-toothed cats. These cats could not strip meat from the bones of their prey (despite their ability to open their jaws to nearly 170°) as efficiently as modern cats, such as the lion (*Panthera leo*), so that scavengers such as hyena became abundant. Considering that the average lion weighs about 200 kg, the most spectacular fossilfound must certainly be that of a 750 kg African bear. Herbivores that are now extinct included a peccary (a wild pig of tropical America with no living descendants), two types of giant bush pig, various species of giraffe and the gomophore – an ancestral elephant. A musk-ox-like species no longer found in Africa and the boselphine, now restricted to India, are among those still living (Hendey 1982). Changes in sea level continued to occur as a result of the development of the ice caps and other climatic changes towards the end of the Pliocene. During times when the levels stayed relatively stable, the seawater erosion along the coastline formed rocky terraces when exposed by the dropping sea level.

- Pleistocene (2.5 m-11 700 y BP) and Holocene (11 700-present) Epochs

The fossils of this period at Langebaanweg dwindled causing the fossil search to shift further south to the farm Elandsfontein near the lagoon. Here, fossilised bones and Stone Age artefacts laid down in the mid-Pleistocene (500 000 y a) were exposed by wind. Indications are that the thinning of the vegetation that began in the Pliocene was continuing. The occurrence of fossils of modern-day species such as black rhinoceros (*Diceros bicornis*) and kudu (*Tragelaphus strepsiceros*) which prefer bush, and grassland species such as zebra (*Equus burchelli* and *Equus zebra*), white rhino (*Ceratotherium simum*), red hartebeest (*Alcelaphus buselaphus*), springbok (*Antidorcas marsupialis*) and reedbuck (*Redunca arundinum*) suggest this thinning of vegetation. Other Pliocene species, such as the sabre-tooth, bush pig and short-necked giraffe, became extinct about this time while some, like the giant hartebeest, giant buffalo and giant horse survived till more recently – between 10 000 and 20 000 years ago. The earliest human remains originated from the mid-Pleistocene, namely those of a *Homo sapiens* about 200 000 to 500 000 years old, called the Saldanha Man (Hendey 1985).

The last ice age (110 000-12 000 y a) followed and the sea level dropped to some 120 m below present. The islands currently occurring in the region probably became tracts of land linked to the mainland on which wildebeest (*Connochaetes gnu* and *taurinus*), hartebeest, bontebok (*Damaliscus dorcas dorcas*), blue antelope (*Hippotragus leucophaeus*), springbok, mountain reedbuck (*Redunca fulvorufula*), eland (*Taurotragus oryx*), kudu, zebra, elephant (*Loxodonta africana*), hippopotamus (*Hippopotamus amphibious*), rhinoceros and buffalo (*Syncerus caffer*) coexisted. Lions, hyenas and many smaller mammals are among the predators of the time (Hendey 1982; 1985).

Humans continued to live in the area throughout the late Pleistocene, leaving evidence of their hunter-gatherer habits in the form of shell middens (archaeological refuse heaps). About 12 000 years ago the sea level rose sharply by some 120 m to its present elevation, covering all but the most recent middens. From these, and others formed in the following Holocene, it appears that the movements of the Stone Age ancestors of the Khoisan were governed by the availability of food. Typical diets included shellfish, beached seals, whales, dolphins, seabirds, tortoises, a variety of mammals (even elephants) and plants. The decline in animal numbers, first brought about by climatic stresses, was intensified by man’s increasing inventiveness as a hunter-gatherer. The discovery of fire and the increased incidence with which veldfires then occurred caused the most environmental impact. This problem was aggravated by the arrival of the Khoi about 2 000 years ago who brought their domesticated cattle, grazing malpractices and even more frequent fires used to create grazing pastures (Hendey 1985).

Yet, most of the adverse environmental effects have occurred in the last 300 years following European settlement in the area. The previously unheard numbers of wild animals were hunted out, including all the remaining large mammals, eventually leaving the environment a ravaged legacy of the richness that once prevailed (Hendey 1985). The potential of Saldanha Bay as a strategic harbour and the area’s rich source of animal life have attracted human settlement since the early years of the colonial Cape settlement and it was only the area’s aridity and lack of fresh water that postponed large scale urban and industrial development. However, growing industrialisation, the virtue of fact of offering the country’s best location for a natural harbour, and the necessities of war have caused the impediments to be overcome and the area to develop into a harbour of national importance. Heavy industries like Namaqua Sands, Saldanha Steel and linked industries, further contribute to degradation of this part of the West Coast, so renowned for its natural beauty and attractiveness. Parts of this attraction are the terrestrial animals, birdlife and marine animals. These are discussed in the following subsections, beginning with terrestrial animals (and then birds) for which an inventory of animal species on record up to 2012 for DMTA appears as Appendix C.

2.7.2 Modern terrestrial life forms

The large predators reported by early explorers are no longer found in the region. Small elusive predators, like the caracal (*Felis caracal*) and water mongoose (*Atilax paludinosus*) now predominate on DMTA. Large indigenous vertebrate species that used to be a significant feature in the composition of the region's terrestrial life have disappeared, namely elephant, black rhinoceros and lion (Branch 1983; Hendey 1982). Some vertebrate species were re-introduced into the area by the owners of the Postberg Nature Reserve since its declaration in 1964, namely blue wildebeest, bontebok, eland, gemsbok (*Oryx gazella*), kudu, red hartebeest, springbok and zebra. Military-training activities adversely affect animals roaming the area through game becoming entangled in military devices or even getting hit when demolition charges are detonated.

Exotic- problem- and non-endemic animals are scarce on DMTA. Populations of the exotic European rabbit were established by the Dutch on some of the islands surrounding DMTA. Around DMTA rabbits now only exist on Jutten, Schaapen and Vondeling Islands, having either died out naturally or being eradicated from the other islands in the early part of the 20th century. The remaining populations face two problems, that is a short vegetation-growing season and water shortages in summer. On Schaapen Island, the albino stock has overcome the latter problem by feeding on marine algae, for example sea lettuce (*Ulva* spp) growing in the intertidal area (Cooper & Brooke 1981). Although classified as an invasive pest in Australia and Robben Island, these animals are scarce in Spain, Portugal and north-western Africa where they are endemic. This scarcity has caused the rabbits' main predator in their homelands, the critically endangered Iberian lynx (*Lynx pardinus*), to decline in numbers (Nel 2009). Blue wildebeest that are also not endemic to the area were introduced by the Oude Post Syndicate members. They do not pose any major ecological problems and have adapted well to the area, although some were removed by SANParks during 2011 as part of their management plan.

Alien animal invasions are not now a problem on DMTA but care must be taken to avoid inadvertent influxes of unwanted animals as happened on nearby Marcus Island (11 ha). Now no longer an island following construction of a causeway to the mainland, Marcus was subject to an influx of small mammals − grey mongoose (*Cynictis penicilata*), water mongoose, genets (*Genetta genetta*), porcupine (*Hystrix africaeaustralis*), bat-eared foxes (*Otocyon megalotis*), Cape foxes (*Vulpes chama*), meerkat (*Suricata suricata*), feral cats, house rats (*Rattus rattus*) and field mice which crossed unhindered via the causeway after it was completed in 1976. By the time a predator-proof fence was erected in 1982 these small predators had wreaked havoc on the bird populations and they are still a threat (Brooke & Crowe 1981). There is little information on the terrestrial invertebrate, amphibian and reptilian life on DMTA. The only available information pertaining to the military area applies to Meeuw Island which was faunistically and floristically surveyed from 1971 to 1981 by Brooke and Crowe (1981).

Except for the larger problem animals, a number of invasive invertebrate species have also been identified in the Saldanha Bay area. The Mediterranean mussel (*Mytilus galloprovincialis*) is one of 62 alien marine species that are believed to occur in Saldanha Bay and Langebaan Lagoon (Clark et al. 2012). Research on the ecological impact of some of the recently detected invasive species, such as the acorn barnacle (*Balanus glandula*) and European shore crab (*Carcinus maenas*), must still be initiated for Saldanha Bay. The presence and positive or negative influence of these invaders on DMTA and Meeuw Island must also still be investigated. The birdlife on and around DMTA is exceptional as the Langebaan waters are an important destination to vast numbers of migrating birds. Morever some scarce birds reside here. Because of the importance of the military area to the survival of some of these birds, a selection of birds is discussed in the next subsection.

2.7.3 Birdlife

Impacts on and conservation of birdlife in military-training grounds is always a priority concern especially so on DMTA due to its location bordering the Langebaan Lagoon Ramsar site which proliferates with migratory dynamics and species of global note. Consequently this aspect of the DMTA natural environment is covered in great detail and with particular reference to signal species that occur here and therefore demand exceptionally close management attention.

2.7.3.1 A multitude of species

Langebaan Lagoon offers widespread, diverse habitat for a large number of marine and coastal bird species and at least 53 use the area for feeding or breeding. Eleven of these species breed on the islands of Jutten, Malgas, Marcus and Schaapen (Clark et al. 2012). The lagoon provides key habitats, such as sheltered beaches, exposed rocky shores, islands, tidal sand marshes, sand flats and mudflats. Furthermore, this water system is a world famous place for its birdlife as it is an important wetland ecosystem forming a vital link in the seasonal migration route of the Palearctic migrant[1] waders which come south to avoid the Siberian and Greenland winters. A quarter of all the migrant

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[1] The Palearctic is one of the eight ecozones subdividing the Earth's surface and includes the terrestrial ecoregions of Europe, Asia north of the Himalaya foothills, northern Africa, and the northern and central parts of the Arabian Peninsula.

birds coming to South Africa visit the lagoon. These birds include the plovers (*Charadriidae*), turnstone, sandpipers, snipes, curlew and other *Scolopacidae*. As many as 55 000 birds can descend on the lagoon for five to six weeks during summer. While the majority of these birds use the lagoon as a ‘fuelling stop’ to rest and build reserves for the return leg of their journey, others use the region as their final destination and breeding ground, particularly on the islands (Branch 1983). During the year Langebaan Lagoon area harbours almost half of the world's total population of the swift tern (*Sterna bergii*); a quarter of the world’s population of cape gannets breeds on Malgas Island; 15% (±2 665 pairs) of the total population of crowned cormorant are found in and around Saldanha Bay; and 12% (±600 birds) of the African black oystercatcher (*Haematopus moquini*), endemic to southern Africa, breed in the lagoon region (Hockey 1985; Robinson 1990). Not all of these bird populations in the Saldanha Bay area are stable and their numbers are influenced by human, ecological and climatological factors. Diminishing sea-grass beds, for example, influence the abundance of certain wading birds. The terek sandpiper (*Xenus cinereus*) recorded a major crash in population numbers when there was a decline in sea-grass beds, which are their main food source. By comparison, waders not feeding on sea grass have maintained relatively stable numbers over time (Clark et al. 2012).

Despite the large numbers of waders, it is the larger birds, including pelicans (*Pelecanus onocrotalus*) and flamingos (*Phoenicopterus ruber* and *minor*), which make up about 90% of the avian biomass. The southern-ocean migrants visiting the lagoon are albatrosses (*Diomedeidae*), petrels and shearwaters (*Procellariidae*), but these are very rare. Numerous other species of bird are found besides the seabirds but unlike them, very few are migrants (Underhill 1990).

The only island enclosed in the military area, Meeuw Island, has been identified as a breeding ground for Cape (*Phalacrocorax capensis)* and crowned *(Phalacrocorax coronatus)* cormorant, blackheaded heron (*Ardea melanocephala*), sacred ibis, Egyptian goose (*Alopochen aegyptiacus*) African black oystercatcher, kelp (*Larus dominicanus*) and Hartlaub’s gull (*Larus hartlaubi)*, Caspian (*Sterna caspia*) and swift tern, as well as the Cape sparrow (*Passer melanurus*) (Brooke & Crowe 1981). More recently, of the fourteen seabirds breeding in southern Africa (Cooper, Williams & Britton 1984; Crawford, Dyer & Brooke 1994), crowned and whitebreasted cormorants and Hartlaub's gull (once from 1987 to 1993) were found breeding on the island. During the 17th century, cormorants must have been the most abundant as the island became known as *Isle aux Cormorans* (Island of Cormorants) as described by Director General de Flacourt on 14 October 1648 (Burman & Levin 1974). The role Meeuw Island fulfils as safe haven for birds is an important one to be investigated in more detail for it to be included in the area described as the Langebaan wetland of international importance (Cowan 1995).

According to the South African red data book for birds (Brooke 1984; Siegfried et al 1976), a number of birds occurring around DMTA, Langebaan Lagoon and Saldanha Bay are afforded red data status. Although some birds are not yet listed as red data species some require constant monitoring due to their variable populations. Nine species are listed as such in the Saldanha Bay and Langebaan Lagoon state-of-the-bay report (Clark et al. 2012). Consequently, they are discussed in more detail because military activities, such as demolition exercises, quite likely have negative influences on these populations. These birds are the African black oystercatcher, African penguin (*Spheniscus demersus*), bank cormorant (*Phalacrocorax neglectus*) Cape cormorant, Cape gannet (*Morus capensis*), Hartlaub's gull, kelp gull, swift tern and whitebreasted cormorant (*Phalacrocorax carbo*). Of these nine species, three–the African penguin, bank cormorant and Cape cormorant–are listed in the IUCN Red List of Endangered Species as 'endangered' with population trends decreasing (IUCN 2013). The African black oystercatcher is classified as 'near threatened' with population trend increasing and the Cape gannet 'vulnerable' with population trend decreasing. Hartlaub's gull, kelp gull, swift tern and whitebreasted cormorant presently enjoy the status of 'least concern' (IUCN 2013).

Crawford et al. (2008) found that although local factors may play a role in distributional changes of seabirds in South Africa, a decline in population sizes in the west was counterpointed by an increase of certain species in the east. This phenomenon of increased population sizes in the east of southern Africa was also recorded for eight of the nine birds identified by Clark et al. (2012), namely African penguins, bank cormorants, Cape cormorants, Cape gannets, crowned cormorants, Hartlaub's gulls, kelp gulls and swift terns. The consistent anticlockwise nature of the change in population sizes, the broad resemblance in their timing and their widespread occurrence suggest the influence of environmental change, perhaps forced by climate, and the consequent displacements of other South African marine resources (Crawford et al. 2008). It is thus imperative that local disturbances such as military activity and its management be informed by detailed knowledge about signal or distinct bird species under threat.

2.7.3.2 Distinctive species: African black oystercatcher

African black oystercatchers are abundant along the shores of DMTA where their numbers have increased most probably because vehicle movement on beaches has been restricted and staff members have been made aware of the birds' vulnerability, especially where their nesting sites are situated. This bird has been the subject of detailed study, with their biology, ecology and behaviour well recorded and described (Baker & Hockey 1984; Hockey 1981a; 1981b; 1982; 1983a; 1983b; 1984a; 1984b; Hockey & Branch 1984; Hockey & Underhill 1984; Summers & Cooper 1977). The maximum number of oystercatchers counted on the shores of the military area until 1999 was 220 birds on 28 September 1999. This survey was done by the author with assistance from unit members from the Plankies Bay border, clockwise around the military area to the border in Riet Bay. A count done 10 years later on 13 October 2009 recorded 305 birds in the same area. In the early 1980s the world population was approximately 4 800 birds (75% in South Africa of which 53% in the south-western Cape) but now the population probably exceeds 6 000 (Oystercatcher Conservation Programme s.d.). Threats to the conservation of this species are mainly human disturbances caused by competition for food (collection of bait organisms), use of off-road vehicles in the birds' habitat and introduced predators on islands (Hockey 1984b). Apart from restricting vehicle movement and the introduction of public awareness programmes, the invasion of the coastline by the alien Mediterranean mussel quite likely contributed to the growing numbers of oystercatchers. The abundance of the mussels has increased the food supply with possible improved bird-breeding success rates. In addition, the increase in depth and vertical extent of the mussel beds has expanded the available habitat for invertebrate species that occupy the environment between the shells, resulting in an increase in the intertidal biomass of the invaded areas (Hockey & Van Erkom Schurink 1992). Population growth of the oystercatchers has stabilised in recent years indicating that the carrying capacity of the islands, where 29% of these birds breed (Hockey 1984a), has been reached (Clark et al. 2012). Signboards indicating designated oystercatcher breeding sites at Jutten Bay should be erected to warn visitors who frequent the area and vehicle access to beaches must be restricted. These proposed oystercatcher protection measures are discussed later.

2.7.3.3 Distinctive species: African (jackass) penguin

The southern ocean's African (or jackass) penguins, endemic to southern Africa, were previously listed in the South African red data book for birds as vulnerable (Brooke 1984; Siegfried et al. 1976), but now they are classified as 'endangered' with population trends decreasing according to the IUCN Red List of Endangered Species (IUCN 2013). Only stragglers visit DMTA occasionally but breeding pairs do occur on the islands around the military area. Aspects of the biology, ecology, behaviour, population trends and conservation of African penguins have been well studied since the early 1970s and grave concerns about the conservation of this species has been expressed over the last 50 years (Broni 1983; 1985; Cooper 1980; Crawford et al. 1990; Duffy 1987; Frost, Siegfried & Cooper 1976; Hockey & Hallinan 1981; Jackson, Siegfried & Cooper 1976; La Cock, Duffy & Cooper 1987; Laugksch, Cooper & Walter 1988; Rand 1960; Randall 1989; Shelton et al. 1984; Wilson 1985). The national population of penguins has plummeted from an estimated two million to about 150 000 over the last 100 years, so accentuating the urgent need for effective conservation and management. Probable causes of this decline include oil spills, competition from commercial fisheries for food, egg harvesting, (stopped in 1967) and guano collection (Branch & Griffiths 1994).

According to penguin expert Dr Lorien Pichegru, in Harvey (2009), more recent evidence shows that penguin numbers along the South African coastline dropped by half from 54 000 birds in 2004 to 27 000 in 2009. In Saldanha Bay penguin numbers have declined sharply over the last few decades and according to Clark et al. (2012) annual counts of breeding pairs dropped from 2 049 in 1987 when monitoring began to 506 in 2010, a decrease of approximately 75%. The main reasons for the decline in Saldanha Bay is migration to other islands on the West Coast (particularly Robben Island and Dassen Island) and reduced availability of anchovy (*Engraulis encrasicolus*) as the main food source of the African penguin (Clark et al. 2012). A slight increase in numbers appeared again in 2011 (614 pairs) in Saldanha Bay but the overall trend in southern Africa shows no signs of recovery. Although only straggler birds are occasionally present on the peninsula, penguin carcasses, of which the intestines have been ripped out, are often found on the shores around DMTA. According to Dr Pichegru these mortalities are caused by seals that feed on the fish in the penguins' stomachs. Another reason for their declining numbers is predation of penguin eggs and chicks by seagulls, a practice which would be reduced around DMTA if demolition exercises are limited and charges restricted to the minimum amount (to be determined during upcoming experiments as discussed in Chapter 5). The shock-waves caused by large detonations scare adults away leaving the eggs and chicks exposed to scavenging gulls (Dyer 2005, Pers com). Because penguins have no definite breeding season, it is suggested that the regulation of using the minimum amount of explosives must be implemented throughout the year. In this way the military can make a worthwhile contribution to efforts to arrest the decline in the number of penguins in the Saldanha Bay area. Another positive conservation role the military fulfils is that 4SFR is part of the national oil-spill contingency plan which includes caring for oiled seabirds such as penguins. Caring for birds, such as the orphaned penguin chicks after the *Treasure* oil spill in June 2000, proved that these are worthwhile conservation interventions (Barham et al. 2008).

2.7.3.4 Distinctive species: Cormorants

The three species of cormorant especially significant on the DMTA are afforded separate discussion here.

- Bank cormorant

Bank cormorants are regularly seen around DMTA but do not nest on the peninsula or Meeuw Island in the military area. This bird is endemic to the Benguela system and the western Agulhas bank with large numbers occurring on Malgas Island. Although listed in the first South African red data book for birds (Siegfried et al. 1976), subsequent research indicated that it was not rare nor vulnerable (Brooke 1984) but later Crawford et al. (1999) noted that according to the IUCN criteria the bank cormorant merits classification as ‘vulnerable’. The newest IUCN classification for the bank cormorant is ‘endangered’ with the population trend decreasing (IUCN 2013). Crawford et al. (1999) reported a reduction in the number of breeding pairs at Robben Island and Malgas Island from 8 672 in 1978/80 to 4 888 in 1995/97. In the Saldanha Bay area breeding pairs dropped from a peak of more than 250 in 1991 to fewer than 50 in 2007. This decline seems to have stabilised and now there are about 60 breeding pairs in the bay (Clark et al. 2012). Low population levels of bank cormorants have always been a motive for careful monitoring as the declining numbers in Namibia many years ago gave reason for reassessment (Brooke 1984). The biology, ecology and behaviour of this cormorant are well known (Cooper 1981; 1985a; 1985b; 1986; 1987) and declines in numbers are mainly attributable to scarcity of prey (fish, crustaceans and cephalopods), increased egg and chick predation and persistent human disturbance (Clark et al. 2012). Crawford et al. (2008) found a decrease in bank cormorant numbers north of Cape Town but an increase eastwards to Cape Hangklip. This observation is consistent with a reduced abundance of West Coast rock lobsters (*Jasus lalandii*) in the north and an expansion of this resource to the east. Threats by human disturbance, including military activities such as demolitions, must be controlled in future.

- Cape cormorant

Cape cormorants are endemic to southern Africa and the most abundant seabird of the region. They occur in vast numbers on DMTA and Meeuw Island but do not breed on the peninsula nor on Meeuw Island in the military area. These cormorants breed on Jutten, Malgas and Schaapen Islands in Saldanha Bay and Vondeling Island south of Plankies Bay (see Figure 1.4). Breeding colonies of Cape cormorants vary in size annually and not all localities are used year after year (Clark et al. 2012). Numbers of this species have declined steadily from around 500 000 pairs in the 1970s to 120 000 pairs by the mid-1980s (Shelton et al. 1984). Although the biology, ecology and behaviour of the Cape cormorant have been studied (Berry 1988; Cooper et al. 1982), no clear long-term population trends are evident. The large fluctuations in population size over the years may be attributable to breeding failure and nest desertion − possibly due to human disturbances such as the demolitions executed on DMTA − and variations in the availability of food such as anchovy (Clark et al. 2012). Other external factors also influence the numbers of this species as Crawford et al. (2007a) found for their declining numbers in the Western Cape during the 1990s due to an outbreak of avian cholera caused by the bacterium *Pasteurella multocida*. The decrease in numbers during the 1990s in the northern coast of the Western Cape was followed by increases at some southern localities in the 2000s (Crawford et al. 2008). Crawford et al. (2007a) recorded the overall population of Cape cormorants along the southern African coast as 100 000 pairs in 2005/06.

- Whitebreasted cormorant

The whitebreasted cormorant can be differentiated into distinct marine and freshwater populations with the maritime component occurring along the entire southern African coastline (Clark et al. 2012). In the 1980s the coastal population was around 2 500 pairs with significant numbers breeding on Jutten and Marcus Islands (Shelton et al. 1984). During the same time period in the early 1980s, studies on the biology, ecology and behaviour of the coastal population were executed (Brooke et al. 1982) and in Saldanha Bay variable numbers of breeding pairs have been recorded since the 1970s. This population remained relatively constant since detail counts were initiated in 1991 (Clark et al. 2012). Whitebreasted cormorants are regular visitors to DMTA and in certain years breed on Meeuw Island in the military area. Between the 1990s and 2004 breeding populations shifted from Meeuw Island to Schaapen Island and back again with approximately 140 pairs nesting on Meeuw Island during the breeding season of 2011. Numbers have increased overall over the last two years and the species is not considered to be at risk (Clark et al. 2012). According to Clark et al. (2012), adult whitebreated cormorants have the tendency to desert their nests for extended periods when distressed, resulting in exposure of their eggs and chicks to predation. As these cormorants are more susceptible to disturbance than any other marine cormorant, human influences such as helicopter exercises in the vicinity of Meeuw Island, demolitions on land and in the underwater ranges and boating activities around the island should be limited. During the breeding season from September to December, when the whitebreasted cormorants are incubating eggs and breeding activities are at their peak (Harrison et al. 1997), there is a definite need to limit and probably prohibit military activities around Meeuw Island. ‘Mile fin’ swimmers taking shortcut walks across the island must be prohibited as visits to Meeuw Island are restricted to DEAT personnel for their research. Only during emergencies such as oil-pollution threats or rescue operations should access to this island be granted by the OC or the appointed responsible person. Because of the birds’ presence, all the islands in the Saldanha Bay area are already declared no-fly zones for all fixed-wing and rotary aircraft, and helicopters are not allowed to land on any island.

2.7.3.5 Distinctive species: Cape gannet

Cape gannets are not often found on DMTA but frequently carcasses of these birds, sometimes with signs that their intestines have been ripped out, wash ashore along the peninsula coastline. These gannet remains are mainly found at Jutten Bay and to a lesser extent along Blouwildebeest Bay (Figure 1.4). The distribution of Cape gannets is limited to the coast of Africa and the species only breeds on six offshore islands, one of which is Malgas Island (Clark et al. 2012). Detail studies regarding the distribution, population size, changes in movement patterns and populations, diet and conservation of this seabird have been executed in the past (Berruti & Colclough 1987; Crawford et al. 1983; Oatley 1988; Rand 1959). Research has shown that gannet numbers have been declining along the West Coast since the late 1990s when pelagic fish stocks, namely sardines (*Sardinops sagax*) and anchovies, became less abundant as a result of changes in ocean-circulation patterns (Clark et al. 2012; Crawford et al. 2007b). Population numbers can also be influenced by the breeding success of the gannets previously understood to be linked mostly to diet (Batchelor & Ross 1984; Berruti 1988). Additional factors affecting numbers are protection of nest sites from seals (Clark et al. 2012) and guano collection (Crawford & Cocrane 1990). Populations in Saldanha Bay have fluctuated over the years last showing a general decreasing trend. This is quite likely due to increased predation by Cape fur seals and great white pelicans that caused a 25% reduction in the gannet colony size at Malgas Island between 2001 and 2006. An example of the immense impact Cape fur seals can have on Cape gannet colonies is the attacks by these mammals on birds and nests that caused the abandonment of the entire Lambert's Bay gannet colony in 2005/2006 (Crawford et al. 2007b). As yet there have been no signs of positive change in population strength in the Saldanha Bay area (Clark et al. 2012). In the early 2000s Crawford et al. (2008) found that although local factors may have played a role in the distributional changes that resulted in a decrease in the numbers of Cape gannet in the Western Cape, that there was a simultaneous large increase in the Eastern Cape. This could have been due to an eastward shift in the distribution of sardine off South Africa in the 2000s (Crawford et al. 2007b).

2.7.3.6 Distinctive species: Gulls

Two species of gull are of special significance on the DMTA, Hartlaub's gull and kelp gull.

- Hartlaub's gull

Hartlaub's gulls are endemic to the Benguela system and the western Agulhas bank, the islands in Saldanha Bay being the most important breeding sites for this species in South Africa. These gulls occur in large numbers on DMTA and in certain years they breed on Meeuw Island in the military area. Unfortunately, these birds are the one species that regularly collide with the power lines on DMTA and many maimed Hartlaub's gulls have to be put down as a result of injuries sustained. Among the 50 gull species in the world, Hartlaub's gull is considered the tenth rarest (Clark et al. 2012). Their population size, distribution and conservation have been described by Williams et al. (1990). The numbers of Hartlaub's gulls vary widely from year to year with no obvious population trends shown since monitoring began in the Saldanha Bay area in 1987 (Clark et al. 2012).

Crawford et al. (2008) noted that there was a large eastward expansion in the breeding range of these gulls between 1995 and 2000 but this does not seem to have had any influence on the Saldanha population.

- Kelp gull

Kelp gulls are abundant along the shores of DMTA and they breed on Meeuw Island but, like the Hartaub's gull, they are prone to collision with power lines (illustrated in Figure 3.16). Their numbers increased in the Saldanha Bay area up to 2000 – most likely due to the accessibility of food in the form of the Mediterranean mussel. The feeding ecology and behaviour of kelp gulls have been described by Hockey (1980). In the early 1990s their population size was determined at around 11 200 pairs (Crawford, Cooper & Shelton 1982) and from then on numbers increased (Steele & Hockey 1990). However, since 2000 their numbers declined drastically due to predation by great white pelicans, an occurrence that was observed for the first time in the mid-1990s. This predation by pelicans was so severe that total breeding failure occurred on Jutten and Schaapen Islands in 2005 and 2006 and the impact of this phenomenon is still apparent (Clark et al. 2012). In comparison with Hartlaub's gull the kelp gull's eastward expansion during 2006 was less pronounced (Crawford et al. 2008).

2.7.3.7 Distinctive species: Swift tern

Swift terns, considered an endemic subspecies to South Africa, are a common sight on and around DMTA. They do not breed on Meeuw Island but they are also species subject to collisions with the power lines between Donkergat, Hugo's Post and Salamander (illustrated in Figure 3.28). Numbers in Saldanha bay have been inconsistent since the 1990s, with no obvious long-term trends and there is unease about no breeding pairs having been observed for the last four years. Crawford et al. (2008) noted that there was a marked increase in the proportion of swift terns that bred in the southern part of the Western Cape in the mid-2000s. Swift terns are subject to human disturbances and predation by kelp gulls, Hartlaub's gulls and sacred ibises. These factors should be monitored to establish whether there are any harmful effects (Clark et al. 2012). Jutten Island is the most important breeding site for these birds in Saldanha Bay (Clark et al. 2012) and being near the terrestrial demolition range (Figure 4.15), the experiments on the effect of explosive device detonation, (as described in Chapter 5), are of utmost importance to the breeding sites on the island. Birdlife management is imperative in the DMTA MIEM plan and needs special attention as discussed next.

2.7.4 Birdlife management on DMTA

The management of South Africa's seabird resources is shared by eight national or provincial authorities: the Department of Environmental Affairs and Tourism (DEAT), the four coastal provinces (Northern Cape, Western Cape, Eastern Cape and KwaZula Natal), SANParks, Robben Island Museum (RIM) and the SANDF. Various local authorities and private institutions such as Anchor Environmental Consultants (Clark et al. 2012) also provide input to seabird management. Although the responsibilities for managing seabird localities are generally well defined, seabird populations are not discrete, with varying degrees of interchange between colonies (Crawford et al. 2008). This necessitates a co-ordinated approach to their management and includes the co-operation of the military for research and bird conservation programmes on and around DMTA. Fourteen species of seabirds representing three orders and five families, breed in southern Africa and Crawford, Dyer & Brooke (1994) have examined nomadism in the breeding populations of 13 of these birds. They found that African penguins, bank cormorants, Cape gannets, whitebreasted cormorants and great white pelicans show strong devotion to specific breeding sites while Caspian terns (*Hydroprogne caspia*) change breeding localities at a low frequency and Cape cormorants, Hartlaub's gulls, roseate terns (*Sterna dougallii*) and swift terns at a higher frequency. At some localities, bank cormorants remain at the same breeding sites for long periods, whereas crowned cormorants, damara terns (*Sterna balaenarum*), Hartlaub's gulls, kelp gulls, roseate terns, swift terns and whitebreasted cormorants all change their breeding sites regularly. Where space is not a limiting factor, African penguins may also change their breeding localities.

Crawford, Dyer & Brooke (1994) found that the main reasons for restrictions on nomadism were strong attachment to traditional breeding sites, reluctance to roost at non-breeding localities and lack of appropriate substitute nesting sites. Among the causes of nomadism that they identified were excessive disturbance by humans and South African fur-seal attacks, as well as competition for breeding space which has influenced even the least nomadic of the species in changing their breeding locations. Frequently, nomadic species are likely to react to environmental cues that enable them either to lower cost of breeding or to enhance reproductive output. This makes the nomadic breeding trends of these birds useful indicators of ecological health. According to Crawford, Dyer & Brooke (1994), nomadic breeders also have the ability to establish new breeding colonies and make use of artificial structures to expand their breeding ranges, and probably also to expand their overall populations. From a conservation viewpoint, nomadic tendencies cause difficulties for the management of sensitive breeding localities and associated activities. By contrast, breeding species with strong commitment to traditional localities are more easily protected (Crawford, Dyer & Brooke 1994). In this content, the military can play a significant role in the conservation of the Meeuw Island and Riet Bay bird populations. Besides its terrestrial life forms, DMTA hosts a variety of marine animals that present challenging research opportunities, especially since the impact of numerous alien species that have established in the Langebaan waters still have to be investigated.

2.7.5 Marine life forms

South Africa occupies only two per cent of the world's surface area but its marine biological diversity is exceptionally high, with more than 11 000 species found in our waters. This is about 15 per cent of all global species, with more than 25 per cent of these marine species found only in South African waters (Steward 2006). The birdlife that exists in the Langebaan Lagoon area depends for its food on the extensive invertebrate biomass that thrives in this water system. About 550 invertebrate species, consisting mainly of molluscs, crustaceans and polychaetes, occur in the lagoon and annually provide the birds with an estimated 150 tons of food. The invertebrate diversity is facilitated by a large variety of habitats in the area, some of the species being adapted to rocky shores, others to the sandy beaches, Cape eelgrass (*Zostera capensis*) beds, mudflats, marshes, salt marshes and open water. This diversity also accounts for the numerous different bird species that occur which, by occupying the various niches, can avoid the limitations of interspecific competition for food and habitat requirements. This makes it possible for oystercatchers living off limpets and mussels, flamingos filtering organisms from the water and sanderlings, which pick out crabs and amphipods, to coexist (Branch 1983).

The distribution of the invertebrates is governed to a large extent by current velocity. Species richness is generally lowest in the channels flanking Schaapen Island, increasing towards the interior of the lagoon or on sandbanks. The currents bring phytoplankton, nutrients and gaseous exchange that support life within the lagoon, this being supplemented by plant material such as eelgrass growing in the lagoon itself. The plants are not eaten directly but are broken down by bacteria when they die so entering the food web in the form of detrital material. Unfortunately, the bathymetry of the lagoon directs the currents so that their influence on Riet Bay is diminished, resulting in low invertebrate biomass values (11g/m^2), though species richness (31 species/m^2) is average. The latter value is greater than that off Meeuw Island (23) where biomass is much higher but substantially less than the exceptional figure (56) at Salamander Point (Day 1958). In the years following the research done by Day (1958), major anthropogenic developments with severe environmental impacts were undertaken in Saldanha Bay. These developments, for example the construction of the Marcus-mainland breakwater in 1976, no doubt influenced Langebaan Lagoon's ecosystem as significant changes in its benthic invertebrate community were discovered. During the first state-of-the-bay survey in 1975, up to six species per sample, dominated by bivalves, were recorded compared to findings for 2004 to 2011 of fewer species, mostly crustaceans and particularly sand prawns (Clark et al. 2012). The species richness of the areas facing the open sea is lower than in the shelter of the lagoon and the former mainly host polychaetes and molluscs adapted to withstand the incessant wave action. Crayfish (West Coast rock lobster) that are harvested regularly during rock-lobster season from South Head to Plankies Bay by members of the unit are abundant in this area and feed off mussels, urchins and even barnacles amid the kelp beds (Branch & Griffiths 1994). The most important food source for crayfish is ribbed mussels (*Aulacomya ater*) and the availability of smaller specimens of this mollusc that are edible by the crustaceans determines their growth rate (Pollock & Beyers 1981).

The invasion by the Mediterranean mussel has adversely affected the waterways in the lagoon. These mussels were most likely introduced with ballast water discharged in the 1970s and they have diffused along the coast as far as Namibia and East London to become the most widely spread and abundant invasive marine organism in South Africa. Mediterranean mussels make their greatest impact in the mid-to-low shore of the intertidal zone where they have displaced native mussel and limpet species (Clark et al. 2012). The mussels establish themselves on sandbanks causing them to become even higher, to form dunes that make channels non-negotiable. Earlier the mussel banks were removed physically and a SANParks initiative allowed local residents to exploit this resource as a job creation project. This species is out of control and further investigation for commercial exploitation is needed (Hockey & Van Erkom Schurink 1992).

The area surrounding DMTA is rich in fish life, but it is mainly the pelagic species in the open sea which are the main food source for the larger island seabirds such as gannets, cormorants, pelicans and penguins. Commercial fishing off the West Coast and predation by vast numbers of Cape fur seals (*Arctocephalus pusillus*) are depleting the fish stocks, thereby depriving the birds of their food source and causing their populations to dwindle (Branch 1983; Branch & Griffiths 1994).

The lagoon supports one species of skate, *Raja clavata* (thornback skate), two species of stingray, *Dasyatis pastinaca* (blue stingray) and *Myliobatis aquila* (eagleray) which can on occasion be seen swimming near the surface, huge numbers of guitar fish (*Rhinobatos blochii*) and several smaller species of what is generally known as sand sharks. Sand prawns (*Callianassa krausii*) form the main diet of these fish, all of which are elasmobranches, i.e. possessing cartilaginous, as opposed to bony skeletons, characteristic of the teleosts. Kob (*Argyrosomus hololepidotus*), white steenbras (*Lithognatus lithognatus*) and white stumpnose (*Rhabdosargus globiceps*) are teleosts. Mullet (*Liza ramada*) are fished commercially using gill nets and significant catches are made at times.

Smaller teleosts such as dassie (*Diplodus sargus capensis*), steentjie (*Spondyliosoma emarginatum*) and white stumpnose are present and they contribute to the food supply of resident birds such as the cormorants. The teleosts tend to share the food preferences of the elasmobranches namely the crab, *Hymenosoma orbiculare* and isopods. On the West Coast *Clinus* species (klipfish) predominate in the rock pools. The marine mammals which frequent the area are Cape fur seals and a variety of cetaceans (whales and dolphins) of which the most significant are the southern right whale (*Balaena glacialis*) and common dolphin (*Delphinus delphis*) (Branch 1983; Branch & Griffiths 1994).

The marine environment of DMTA is an open biological system and conservation measures must be in keeping with those implemented at marine systems surrounding the military area. Measures governing exploitation and other protective processes applicable to military personnel must be the same as to those enforced on the public who exploit marine resources outside DMTA. Overuse and pollution of marine resources must be addressed on a larger scale than just the direct influences on DMTA. Proactive measures are especially important if infrastructural developments or new military actions are planned. For example, the development of the proposed breakwater at the Salamander boatpark must not be allowed to interfere with the natural functioning of the marine environment. To achieve this an environmental impact assessment must be executed and monitored by specialists who have relevant maritime experience. Besides the biological wealth found on and around DMTA, the area is rich in cultural-historic assets that must be given attention as conservation priorities.

2.8 CULTURAL-HISTORIC SIGNIFICANCE

In DMTA there are previously-farmed areas, war-related structures and installations and buildings that served the whaling industry that have been used by SF for training activities, while also preserving the natural terrain and maintaining structures that are unique and have substantial historical value. Eras of seal hunting, whaling and warfare each contributed cultural artefacts – mainly in the form of graves, wrecks, fortifications or ruins. Figures 2.8 and 2.9 show the location of some of these resources scattered around the peninsula coastline.

Photographic details of some of these resources are provided in the next chapter where management is addressed. Graveyards are present at Salamander Bay and Riet Bay. A single grave on Meeuw Island is that of the first European buried in Saldanha, a Mr L'Ecluse, who was put to rest in October 1648 by expedition members of the Director General of Madagascar, Etienne De Flacourt. He was found battered and bruised to death on Malgas (Malagas) Island, most probably when trapped by waves when he tried to retrieve birds he had bagged (Burman & Levin 1974). Green (1970) mentions that Camp Point on the northern side of Donkergat Bay, (Figure 1.4) was a burial

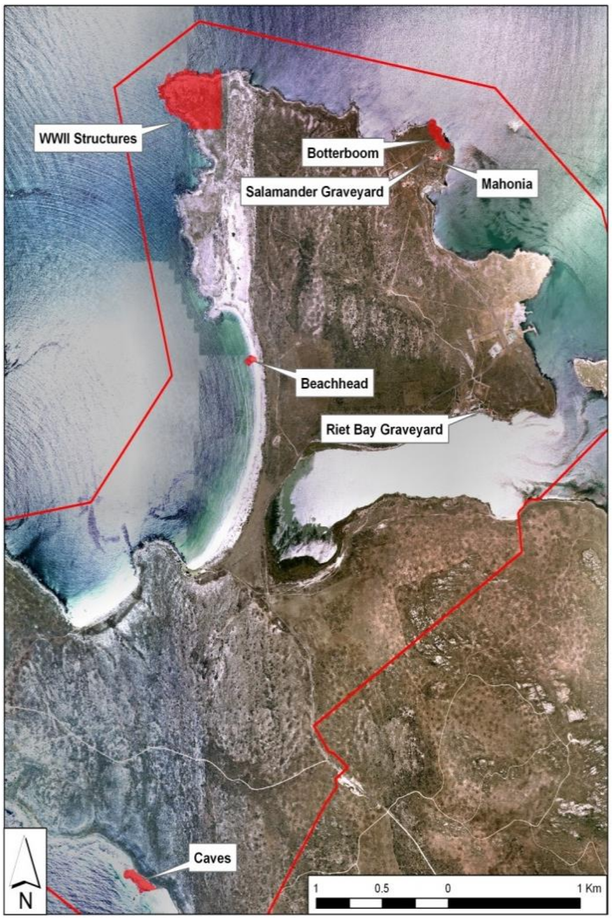


Figure 2.8 Cultural-historic heritage sites and the area of botterboom occurrence on DMTA

Figure 2.9 Cultural-historic heritage sites on DMTA

ground for smallpox victims but no remains of these graves could be found. Shipwrecks and structures from the whaling-era occur at Donkergat and in Salamander Bay and some of the wrecks at Donkergat are still used by SF for diving and swimming exercises. The WWII site is a naval gun battery situated at Elands Point that housed two twelve-pounder guns and formed part of the coastal-defence gun installations situated at Baviaanskop (two six-inch guns), Hoedjiespunt (two twelve-pounder guns) and Malgaskop (two six-inch guns). Two six-inch gun barrels the author found at Fort Wynyard in Cape Town in 2010 are permanently displayed at Hugo’s Post. Recently, a bridgehead, in the form of steel crosses (marine obstacles) that may have formed part of the battery defence, was discovered on the eastern side of Jutten Bay (location indicated on Figure 2.8).

A background history of DMTA, its ecological attributes and the significance of cultural-historic heritage features have been covered in this chapter. The impacts and relevance of the SF military activities and some implemented and suggested management practices are discussed in the next chapter to guide practical management actions for their incorporation into the MIEM plan.

CHAPTER 3 MILITARY IMPACTS, MANAGEMENT SOLUTIONS AND INTEGRATED ENVIRONMENTAL MANAGEMENT

Since DMTA was established in 1978 there has been unceasing pressure to incorporate the area into the larger West Coast National Park (Van Veelen 1997). Statements have been made that DMTA is one of the greatest sources of environmental disturbance in the area and that military activities have detrimental impacts on the ecology and ecotourism industry of the greater region. These accusations have not been qualified nor substantiated. Taking an unequivocal measure of environmentally harmful impacts, experienced as examples of real-world problems, together with ad hoc management measures implemented into consideration, the way towards a comprehensive understanding of environmental equilibrium may be paved. This chapter begins with a review of military activities and the infrastructure and means available on DMTA to accommodate this variety of events. This is followed by an overview of the appropriateness of environmental management legislation to military conduct in South Africa. The chapter continues by providing insights into the various forms of environmental impact by military activity on DMTA as they relate to infrastructure, cultural-historic heritage, ecological functioning and the accumulation of debris from military activity. In each case the relevance of management legislation is pointed out, management solutions are put forward and the degree of success that can be achieved is pointed out. The chapter concludes with a review of the status and considerations about a formal implementation of the official MIEM framework for DMTA.

3.1 MILITARY ACTIVITIES AND UTILITIES

To accommodate the diverse activities executed on DMTA, a variety of training areas, utilities and means are accessible for war-fighting training and preparations. These are classified into three categories namely urban-, indoor- and outdoor resources and they are listed with their specific uses during seaborne courses in Table 3.1. The urban means are listed separately as they are man-made structures positioned between the shooting ranges in the open area west of Salamander (Figure 1.6). Only the activities relating to the seaborne cycle and diving courses are listed and they must be interpreted against a frequency of each course being presented once every two years. Brief descriptions are given of the main activities involved in *waterborne*-, *airborne*- and *general training* to emphasise the intensity of military actions on DMTA. Environmental impacts that have occurred during the execution of these training ventures are cited.

Table 3.1 The utilisation of military resources during seaborne courses on DMTA

RESOURCE	MODULE 1	MODULE 2	MODULE 3	AD 1&2
URBAN				
Training bus	x		x	
Wire-fence obstacles	x		x	
Mahonia tower (sniping and fast roping)	x		x	
Shooting house	x		x	
Israeli shooting range	x	x	x	x
INDOOR				
Indoor shooting range	x		x	
Survival center	x		x	
Climbing wall	x		x	
Dive tank	x			x
OUTDOOR				
Swimming pool	x	x	x	x
Closed- and open-water diving areas	x			x
Survival and escape and evasion areas	x		x	
Old cultivated lands	x	x	x	x
Obstacle course	x		x	x
Blouwildebeest Bay shooting range	x	x	x	x
Classification range	x	x	x	x
Water demolition ranges				x
Field firing range	x	x	x	x
Pistol range	x	x	x	x
Rocky landings	x		x	x
Beaches	x	x	x	x

The old cultivated lands are suitable for parachuting but as this airborne activity is usually scheduled near airfields these areas are seldom used. Only when situations arise for parachuting to be done at DMTA, are these venues exploited. Given that the urban resources are situated west of the Salamander border shown in Figure 1.6, it is clear from Table 3.1 that most training takes place outdoors where impacts on the environment are inevitable. Although the beaches are not specified in Table 3.1 all beach areas are used in the courses. The most environmental damage inflicted during previous exercises has been at Jutten Bay and Plankies Bay. The uses of utilities shown in Table 3.1 are made clear in the following descriptions of the three training milieus.

3.1.1 Waterborne training

Waterborne training starts with basic swimming, mainly pool training, until a specific level of competency is achieved that fulfils the requirement for surface swimming (Module 1). In Module 1, learners practice their swimming skills while progressing to areas in the lagoon where the risk factor is low as in Donkergat Bay and Salamander Bay (Figure 1.4). To acclimatise the learners to more harsh conditions finning exercises are executed from Donkergat to Langebaan and vice versa. Conditions can become challenging in the lagoon if the sea current and prevailing wind are in opposite directions to one another. Learners begin their finning in only wet suits and progress to swimming first with battle jackets, then also with weapons and dressed in full gear, finally towing their bergens. Once the learners have gained enough confidence they progress to the open sea and do beach infiltrations, first at Jutten Bay and Wildebeest Bay and from there to Plankies Bay (Figure 1.4) where sea conditions can become extreme. During Module 1, learners are exposed to the underwater environment and confined spaces through snorkelling in a dive tank, underneath wrecks, the floating jetty and the permanent operational jetty. Vehicle movement on the beaches and disturbance of breeding birds are adverse environmental impacts when Module 1 is presented.

The *second phase of waterborne training* is training in handling all the different types of vessels at 4SFR, ranging from inflatables (F470 and Foursting) to hard-hull (Barracuda) and semi-ridged (Hurricane) boats in the Module 2 course. The module includes navigation, long hauls and surf work. The lagoon is well protected against the prevailing winds and extreme sea states so enabling learners to be trained progressively during both day and night conditions while progressing from small to larger craft before venturing to the open seas. Selected coxswains do the advanced operational coxswain course on the Wahoo boats and identified support personnel are trained in negotiating the ferry boats during the support coxswain course. During Module 2 severe disturbances of beaches occur when capsised boats must be recovered by tractors towing trailers.

The final phase of waterborne training to qualify as seaborne operators is Module 3 that focuses on *co-operation training.* As 4SFR deploy all over Africa, the capabilities to be delivered by sea, from a variety of naval vessels and air delivery with cargo aircraft, is essential. These joint tactics with the South African Navy (SAN) and South African Air Force (SAAF) are taught to operators during this module and involve air delivery of operators, equipment and boats into the lagoon, and the launching and recovering of boats from combat support ships (CSSs) mainly the SAS Drakensberg, frigate small guideds (FSGs), offshore patrol vessels (OPVs) (previously known as strike craft) and submarines. Training is initially executed in the calm waters of the lagoon before venturing to the open sea. During Module 3, operators are also exposed to deliver live firing from sea to land at the Wildebeest Bay shooting range (Figure 4.15). This is a unique training facility in South Africa where small-, medium- and heavy weapons, up to the 20 mm cannon and 40 mm AGL, can be fired from vessels at sea in the bay to land. During Module 3 the main detrimental environmental impact are disturbances of birds by low-flying helicopters, entanglement of game in devices and blinds left unattended at the Wildebeest Bay shooting range.

A few selected individuals progress to the *attack diver* level doing the AD1 and AD2 diving courses (see Table 3.1). Exercises start in the waters in Donkergat Bay and Salamander Bay (Figure 1.4) and later move to other bays (e.g. Jutten Bay) and harbour areas (e.g. Saldanha and Simon's Town). Diving activities do not influence the environment to any extent. The pro used in closed-circuit breathing apparatus for attack-diving is disposable through the existing waste management programme. Attack divers are taught to do underwater demolitions. The deep-water and shallow-water ranges, situated in the Salamander Bay area (Figure 4.15), were used for training divers in underwater demolitions until the beginning of 2013 when it was realised that demolitions could have damaging effects on the Salamander boat parks pillars embedded in the seabed. It was also realised that demolitions in a Ramsar site are undesirable so that alternative sites had to be investigated.

Sailing in waterborne training is no longer a formal course at DMTA and since 2005 the yacht deckhand course has been presented by the Sail Centre at Naval Base Simon's Town and civilian companies. This platform capability will be used from DMTA as the operational need arises in future. Boating and sailing activities do not have detrimental environmental impacts as long as crew members adhere to the regulations on garbage and sewage disposal and cleaning of bilges as laid down for all seagoing vessels.

3.1.2 Airborne training

Parachuting and freight drops are the most regularly executed *airborne training* activities. There are three airfields close to the Langebaan Lagoon, namely Langebaanweg 17.5 km, Saldanha 22.3 km and Somersveld 68.7 km by road. Flying time from the airstrips to the lagoon water-drop zones is between five minutes and half an hour. Land-to-air deliveries can be executed at all three airstrips. Working from platforms such as helicopters is essential for SF and this includes jumping from the aircraft into the water, fast roping, rappelling, hoisting and emergency (hot) extractions from land and moving vessels. The waters around DMTA are ideal for combined air- and water- work and the flight-free zone prohibits other aircraft from interfering when flying activities are in progress.

3.1.3 General training

General training involves land demolitions, sea- and coastal survival and mountaineering. Land demolition exercises are restricted just now awaiting results of tests to determine alternative demolition sites and the amounts of explosives to be detonated under specific environmental conditions. During survival exercises the impact on the fauna and flora is minimal and abalone (*Haliotis midae*), tortoises and birds, other than gulls and francolin, are not used. Because of the presence of bats in the Plankies Bay caves, these areas are avoided during survival training. Mountaineering is practised at the indoor climbing wall and rock formations in the South Head area (Figure 1.4). This landscape feature is ideal for mastering basic mountaineering skills and safety standards can be adhered because the training staff can be close by to control the climbers. Other institutions also make use of DMTA as their training area namely all water related training for South African Special Forces (SASF), (e.g. the small-boat coxswain course for the basic cycle members), SAN divers who use the area for onland and underwater demolitions and the South African Police Service (SAPS) Task Force that makes use of the shooting ranges and does survival training at South Head. Other activities include water-orientation retraining for members of 5 Spec Forces Regt, adventure training for school groups and foreign SF soldiers who participate in co-operation training during joint, multinational exercises.

3.2 LEGAL FRAMEWORKS FOR ENVIRONMENTAL MANAGEMENT IN SOUTH AFRICA

National legislation and regulations applicable to DMTA are essential for the compilation of the proposed MIEM plan. The fundamental legislation to guarantee conservation of natural resources and for enforcing environmentally-responsible conduct on DMTA and at other training facilities is briefly set out in this section.

The Environment Conservation Act, 1989 (Act no 73 of 1989) stipulates regulations under Section 21, namely identification of activities which may have a substantial detrimental effect on the environment as well as general regulations on environmental impact assessment (EIA). A more recent applicable act is the National Environmental Management Act, 1998 (Act no 107 of 1998). Provincial legislation contains municipal and local council EIA regulations on activities identified under Section 21. Other applicable laws are the National Water Act, 1998 (Act no 36 of 1998), the Physical Planning Act, 1991 (Act no 125 of 1991), the Land Survey Act, 1997 (Act no 8 of 1997) and the Development Facilitation Act, 1995 (Act no 67 of 1995). White Papers on minerals and mining policy (October 1998); integrated pollution and waste management (May 2000); and spatial planning and land use (July 2001) are appropriate. The Green Paper on development and planning (May 1999) and the Land Use Management Bill, 2001 have relevant directives. There are also specific DOD environmental policies and procedures that must be adhered to, for example the compulsory environmental impact studies prescribed by the Environment Conservation Act no 73 of 1989, CLOG/DFAC/R/401/1/3/13-B (7 June 1998).

The legal implications of non-compliance with these laws and regulations are severe and if specified activities are undertaken without written authorisation it can result in fines of R100 000 or imprisonment for 10 years. In addition, offenders are liable for the costs incurred or likely to be incurred in rehabilitating or preventing damage to the environment caused by such an unauthorised activity, as well as costs incurred during the investigation and prosecution of the offence. Failure to adhere to the provisions of the EIA regulations can result in a fine of R2 000 or to imprisonment for six months.

DMTA is unique for its fauna and flora and besides the importance of its ecological attributes it occupies a vital position in the structure of protected areas in South Africa, primarily because it is located adjacent to a water system that has international conservation status. According to the 2006 SANBI classification, the inland area accommodates Langebaan Strandveld predominantly interspersed with isolated Saldanha limestone patches with the dominant veld type being Langebaan dune strandveld (FS5), generally regarded to have a high conservation standing. DMTA's fauna is diverse and includes genetically-pure bontebok and the protected Cape horseshoe bat. DMTA is a breeding area for scarce marine animals like abalone and it accommodates vast numbers of scarce birds, such as the African black oystercatcher on the peninsula and the Bank cormorant at Meeuw Island. Meeuw Island is one of only 15 island eco-systems on the southern African coastline that has these delicate features. Four more, namely Malgas, Jutten, Meeuw and Schaapen Islands are also located in Saldanha Bay and Langebaan Lagoon. Due to poor management, some ecological problems having undesirable impacts on the fragile ecosystem of DMTA have accumulated over the years but they were immediately addressed when research started in 1997. The main ecological matters that are being attended to and receive continuous attention in the management of DMTA are examined next. The environmentally harmful impacts and the ways to mitigate them are the gist of the discussion.

3.3 MILITARY ACTIVITY IMPACT ON INFRASTRUCTURE

Infrastructure refers to man-made structures and facilities needed for the operation of DMTA, for example buildings, access routes, power supplies, training facilities and shooting ranges. Not all of the activities that impact DMTA environment are military. Dumping sites, roads, buildings, structures, fences, planted vegetation and landscape disturbances were all inherited from the whaling industry, the Second World War (fortifications) and the farming activities prevailing since the establishment of the Donkergat whaling station in 1909. The nature of the infrastructural impacts is reported at length next, followed by an account of suggested management solutions. Topics are illustrated with photographs.

3.3.1 Nature of infrastructural impacts

Infrastructural damage in DMTA involves two types namely that done to fixed heritage structures like shipwrecks and ruins from the war and whaling-eras and of disturbances such as dumping sites and road damage. These features pose environmental challenges such as the visual pollution and erosion evident in Figures 3.1 to 3.4. The examination that follows look at six different features.

First, *extraction excavations* were done at numerous sites on DMTA over the years for collecting sand, gravel, coal from dumps, seashell grit or for the construction of features such as shooting ranges. The excavation site (Figure 3.1) dating from the whaling-era is a fitting example. This excavation site created secondary problems by its use for dumping general waste and refuse. The site has become more extensive over time. The main whaling-era dump site faces south into the prevailing wind so that wind erosion is causing an environmental risk by extending the northern edge through blowout, while the other sides are caving in and physically damaging the surrounding natural vegetation (Figure 3.5). No comprehensive rehabilitation programme is in place although a cleaning-up operation was initiated in 2012 to remove the bulk of the refuse. North of Riet Bay on the road to the demolition range, a disturbed site where building materials such as sand and rock used to be stockpiled is now used as temporary storage space for vehicles, machinery and boat wrecks earmarked for disposal (Figure 3.6).

A rehabilitation plan for the site shown in Figure 3.1 is being formulated. Proposed solutions should meet the five principles set by the Guide to Environmental Compliance for Commanding Officers (SANDF 2003) as prescribed in the National Environmental Management Act, Act 107 of 1998 (South Africa 1998a), namely the:

- Best practicable environmental option – An option which provides the most benefit or causes least damage to the environment as a whole, at acceptable cost, because of the impact of a military activity.
- Cradle-to-grave principle – Implies that the organisation responsible for the management of hazardous material remains responsible for the waste from inception to final disposal.
- Duty of care – Indicates that the organisation is responsible for the fate of the generated waste in all circumstances and shall be responsible for ensuring that the waste is handled, stored, transported and disposed of according to legislative prescription and in an environmentally-sound and responsible manner. Passing waste on to another entity does not pass on the responsibilities and certain long-term responsibilities remain those of the producer of wastes.

During the whaling-era construction gravel was excavated from this site, west of Donkergat Bay.

Figure 3.1 Whaling-era excavation site used as a dump site

The road to South Head was built perpendicular to the steep hill to Operators Kop – an example of the unplanned layout of most of the access routes.

Figure 3.2 Erosion on DMTA gravel roads

Known as the 'kruithuis', this structure housed the explosives for harpoon guns during the whaling-era.

Figure 3.3 Ruins from the whaling-era used as training obstacles

This ship was sunk deliberately in 1991 after the military took over. In earlier years ships were deliberately sunk as part of harbour construction.

Figure 3.4 Wreck of the *Harvest Sirius* at Salamander

The site is expanding in a mainly northerly direction and was used to dump "US" boats, construction waste, waste ammunition containers, cartridges and equipment.

Figure 3.5 Erosion at the whaling-era excavation site

This disturbed area is used to hold "US" vehicles and boats to be disposed of through the SANDF logistical system.

Figure 3.6 Disturbed area north of Riet Bay

Note the bedrock laid bare by erosion down a too steep road gradient.

Figure 3.7 Deteriorating unplanned road above Plankies Bay

Exposed bedrock in an eroded road imprudently covered with building debris (shattered bricks, cement).

Figure 3.8 Crude rehabilitation of the Plankies Bay road

- Polluter pays principle – Implies that the person, company and/or organisation causing environmental pollution are liable for any costs involved in cleaning it up or rehabilitating its effects.

- Precautionary principle – Assumes the worst-case situation and makes provision for such a situation, especially where the nature and extent of risk is unknown. Since legislation is stricter and costs of treatment and disposal for hazardous waste are higher, the burden of proof shall always be on the generator of the waste (South Africa 1996b: 47).

Second, *roads* were constructed to link existing infrastructure and to gain access to new buildings, isolated localities such as the caves at Plankies Bay, Operators Kop, Blouwildebeest Bay shooting range, the demolition range, the water reservoirs, recreational sites and areas where security patrols must be deployed (Figure1.5).

There are 7,1 km of tarred roads, 8.1 km of main gravelled roads and 14.9 km gravelled service roads – some 30 km requiring to be serviced on DMTA . Environmental impact assessments were not performed before the roads were constructed but some disturbances, such as intensive erosion that has exposed the bedrock at places, have occurred as shown in Figure 3.7. When the roads became impassable due to over-use and erosion, crude and inefficient rehabilitation was done with building debris (Figure 3.8). Another environmental nuisance caused by existing roads is the establishment and distribution of undesirable endemic plants such as disseldoring (*Berkheya rigida*), as well as exotic species like spear thistle (*Cirsium vulgare*). Dissel, also known locally as brosdoring, threatens the natural vegetation as it disperses extremely rapidly over large areas if not controlled. By tolerating these road erosions and imprudent methods of repair, the military is not adhering to regulations. The DOD's policy (South Africa 1996a; 1996b) on the environment is consistent with national, such as the National Environmental Management Act (South Africa 1998a), international policy and other requirements for the "protection of the environment against disturbance, deterioration, poisoning or destruction as a result of human activity and structures."

Third, *disused cultivated areas* present as patches of disturbed veld that were once primarily used for wheat production but subsequently have been allowed to lie fallow for approximately 40 years. The level, sandy land south of Riet Bay (Figure 3.9) and adjoining Plankies Bay in Postberg (Figure 3.10) are areas which carry high volumes of spring flowers typical of disturbed veld. They are prone to erosion in the dry season and places where – even after 30 years of being fallow – valuable West Coast thicket has not been rehabilitated. This experience emphasises the folly of disturbing normal veld conditions in a relatively arid region – restoration is a highly problematical and slow process. The area south of Riet Bay has been colonised by *Euryops multifidus* (hanepootharpuisbos), which forms 100 cm high stands beneath which *Artiplex semibaccata* and *Oncosiphon suffruticosum* (strinkkruid/wurmbossie) occur at a height of about 10 cm. With the low rainfall and oligotrophic (nutrient poor) soils, growth is slow, especially where plant communities have been disturbed by practices such as agriculture.

Fourth, *fences* were not maintained between the time of establishment of the base and 2011, resulting in numerous game mortalities as evidenced in Figure 3.11. A wide range of animals – from big game such as eland (*Taurotragus oryx*) to small animals such as the angulate tortoise – have died as a result of fence deterioration. A contingency plan for fence safeguarding and maintenance was initiated in 2011 to minimise game mortalities. By not maintaining a basic feature of DMTA, such as fence lines, the military fails to observe environmental laws and policies as prescribed by government.

Fifth, *water-troughs and drinking points* constructed for game keeping are sets of structures that have not been maintained and simply allowed to deteriorate. Over time the structures started to leak and eventually collapse (Figures 3.12, 3.13 and 3.15). Birds make use of these water-supply points to bathe and drink but sometimes they drown in the troughs so contaminating the water (Figure 3.14).This trough shown in Figure 3.15 illustrate the degree of deterioration reached before it was upgraded for use by game. During the dry season, antelope concentrate in the DMTA area and trampling around water-supply points is severe. In the absence of regular bird-safeguarding, trough maintenance and game rotation plans, these events intensify to problematic proportions. Mitigation of these problems is being investigated and related experiments are being done.

Six, e*lectricity transmission lines* stretch from the Donkergat headquarters area to Salamander and Hugo's Post. These are not ESKOM lines but power-distribution networks maintained by the Department of Public Works (DPW). The line routes were not properly planned and they cause numerous bird collisions. The lines north of Riet Bay and west of Stink Bay (Figure 1.4) are especially the cause of injuries and mortalities to a variety of birds. Figure 3.16 illustrates a recorded instance of this problem.

Although not the responsibility of 4SFR, the deaths and injuries of birds colliding with power lines are a grave concern and more effective safeguarding methods are being researched and implemented. The long duration of deteriorated border fencing in DMTA and the present condition of troughs and power lines contravene the DOD’s policy (South Africa 1996a; 1996b) on protection of the environment that demands as priority: “the protection of species and habitats and the conservation of biodiversity and natural resources.”

The Duckitt wheat fields established on the Riet Bay area after the Second World War.

Figure 3.9 Disturbed area where wheat was cultivated south of Riet Bay

Previously-cultivated lands lying bare for more than 40 years, proving how long it takes for natural vegetation to establish after disturbance had occurred.

Figure 3.10 Previously-cultivated areas north-east of Plankies Bay, Postberg

Game attempting to cross the fence gets entangled and at times sustains serious injuries due to the limp fence. Injuries sometimes lead to mortalities.

Figure 3.11 Mortality of springbuck south of Riet Bay

Poor maintenance leave the trough cracked through the centre section, rendering it dysfunctional.

Figure 3.12 Deteriorating water-trough at Blouwildebeest Bay

This poorly planned watering point is leaky due to poor maintenance and the high evaporation rate necessitates constant refilling.

Figure 3.13 Deteriorating watering point, DMTA

Trough frequented by most antelope especially during the dry season when game concentrate in the Riet Bay area.

Figure 3.14 Decomposing sacred ibis (*Threskiornis aethiopicus*) in trough west of Riet Bay

Deteriorated water-trough west of Riet Bay. Evidence of neglected watering points.

Figure 3.15 Water-trough west of Riet Bay before repair

Most birds, such as this kelp gull, are not killed by impact, but they fracture their wings resulting in them having to be put down.

Figure 3.16 Injured kelp gull found under power lines north of Riet Bay

3.3.2 Suggested management solutions: Infrastructure

The problems sketched above have not gone unnoticed and a range of mitigating or preventive management measures have been instituted or experimented with. The six examples of solutions described here concur with the like-numbered problem elements described in the previous section (extraction excavations, roads, disused cultivated areas, fencing, water dispensing points, electricity transmission lines).

The need for *excavation and dumping sites* exists on all military-training areas but the sacrificed areas must of course be limited to the minimum in both number and area. These sites should be proactively located, planned, designed and encamped. The use of existing excavations as on DMTA, should be avoided since access may be problematic and space management of equipment and waste content may be restricting. The Donkergat site (Figure 3.5), almost beyond salvaging, was the subject of a major clean-up operation initiated during 2012 (Figure 3.17). The effort involved heavy machinery such as front-end loaders and trucks equipped with cranes. Rehabilitation of this area, consisting mainly of recontouring followed by revegetation is under planning scrutiny now and will commence once all the waste has been removed.

As a rule of waste management and to minimise further piling up of unwanted material and equipment, all waste material should be routinely transported to the municipal refuse dump in Langebaan and unserviceable equipment disposed of from time to time. Screening criteria for new waste-site locations should include road accessibility, size of the dump to suit equipment, environmental sensitivity, migration routes of animals, visual pollution and fire hazard. Identifying redundant equipment and disposing it regularly should be included in the site-maintenance cycle.

Experimentation to rehabilitate disturbed areas was carried out at a dumping site north of Riet Bay from 1997 to 2007 (Figures 3.18 and 3.19). This area was extremely disturbed when the dune between Riet Bay and the hinterland was levelled to accommodate an incinerator and to increase the manoeuvrability of vehicles (Figure 3.18). Rehabilitation entailed the removal of all waste, closing up excavations and reconstruction of the dune with a front-end loader. The gap in the dune was built up and planted with natural vegetation from the surrounding area. This venture was the initiative of the author and the base environmental manager, who also operated the machinery. As the scene in Figure 3.19 attests, the project was successful and can be replicated at other disturbed areas. Research to determine the rate of growth of a man-made excavation used as waste site is being done at the existing whaling-era quarry west of Donkergat. Progression of erosion from the original excavation edge is being monitored by placing marker poles along the edge at ten-year

Rehabilitation of this disturbed area is an envisaged environmental management project.

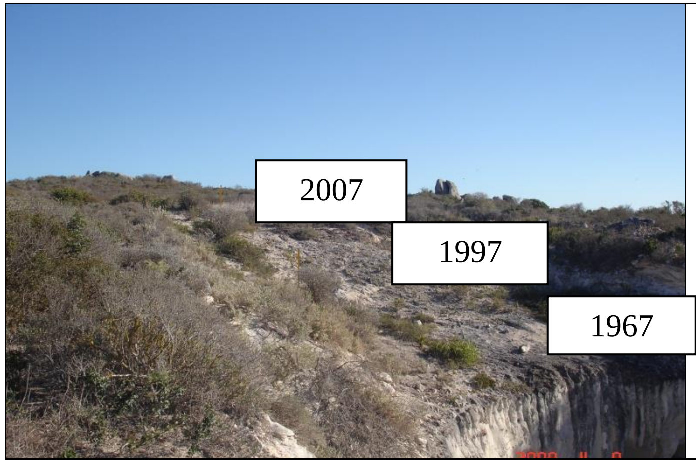
Figure 3.17 Cleaning of the Donkergat waste site in June 2012

Damage to the environment caused by excavations, incinerating activities and indiscriminate dumping of waste.

Figure 3.18 Disturbed area north of Riet Bay, July 1998

Rehabilitated disturbed area by means of simple dune reconstruction, removal of waste, establishing of plants and isolation of the area.

Figure 3.19 Rehabilitated area north of Riet Bay, October 2007



Monitoring of erosion extending in a northerly direction caused by the prevailing south-easterly wind.

Figure 3.20 Erosion expansion at the Donkergat waste site intervals to record the rate and direction of deterioration. Figure 3.20 demonstrates how the edge of the excavation has expanded westward since 1967 through 1997 to 2007. Although not all inherited ecological disturbances can be rehabilitated, programmes for limiting environmental risks, such as vegetation and landscape disturbances experienced at the expanding Donketgat dump site, must be formulated and implemented continually.

Experimentation with and monitoring of the efficacy of various *road maintenance* methods is being conducted by applying construction waste and refuse coal from whaling-era deposits (Figures 3.21 and 3.22) to fill gullies and holes in roadways. Discarded coal is recouped from one of several already disturbed whaling-era dump sites and compacted into holes and gullies. The coal-tamping method was more successful than in places where the underlying road surface consisted of soft topsoil and building debris and sand were used for rehabilitation. There are other coal refuse sites on DMTA that can be exploited for this repair material, for example as at Salamander and Camp Point, but care will have to be taken when excavating these deposits not to damage artefacts still present in some of them.

The management plan for existing roads prescribes the immediate repair of surface damage and maintenance of water run-offs. Roads must be limited in sensitive areas and if they are not logistically essential, closed down. Experimental closing of certain access routes and monitoring of their rate of rehabilitation to the natural state without mechanical interference are being conducted at Jutten Point (Figures 1.4 & 3.23). Results show a discouragingly low rate of natural rehabilitation, especially when surreptitious use of paths continues despite regulation closings. Further monitoring action specifies that all roads must be evaluated to determine their logistical necessity and susceptibility to damage. According to these criteria, access to certain roads must be prohibited. It is essential that a comprehensive road maintenance and management plan that addresses rehabilitation, water run-offs and closing of certain access routes be formulated and a method to control undesirable vegetation adjacent to roads must also be formulated and implemented.

As for *previously cultivated areas*, scientific observations of seasonal migration patterns and concentration areas of game determined the need for a water-trough exchange schedule to encourage an even distribution of game over DMTA. To promote this endeavour, an extra water-trough was built at South Head (Figure 3.24) because game did not freely frequent this area and no disturbed patches of land occur in this vicinity. By taking the annual migration cycle of the ungulates into consideration, the supply of water is now alternated between troughs to distribute the game evenly over the area during the dry season. This measure is designed to minimise trampling in specific areas, as in the disturbed agricultural fields. A game-canalising system is also incorporated into the game distribution plan as discussed under Section 3.5. The new water-trough at South Head, the two north and west of Riet Bay and the one at the urban shooting range in the Salamander area are maintained on a weekly basis. The watering points at Blouwildebeest Bay and near the reservoir (Figure 3.13) must be upgraded and included in the watering-point alternating programme.

A *fence maintenance* contingency plan must include routine repairs to damaged fences on a weekly basis and removal of redundant stretches of fencing. Figure 3.25 shows part of the fence taken down between the main gate and Plankies Bay. The new fence is rigid with large openings at the bottom to allow passage of small animals. Migration gaps for larger game were sited where erosion danger is low. Noticeboards are displayed as prescribed. Game that are habitually liable to jump fences, such as eland and kudu (*Tragelaphus strepsiceros*) (Bothma 1995), tend to do so along the main border fence from Perlemoen Point (Figure 1.4), south of the Riet Bay Mouth, to Plankies Bay, resulting in severe damage to the top wires and injury to the game. Experiments to increase the visibility of the fence to the animals are continuing and include the use of silver, aluminium squares and the tying of elongated silver-painted wooden strips to the fence. Correct spacing and height must still be researched. A contingency plan for fence maintenance must be compiled and implemented continually.

A more effective safeguarding method to limit bird-collision mortalities on *electricity supply lines* is continually being researched and implemented. Although the polyvinyl chloride (PVC) pigtails the author experimented with on ESKOM power lines in the Free State, were fitted to DMTA power lines, bird mortalities persisted. In addition to the pigtails, orange reflecting perspex squares (50x50 mm) were fitted between the pigtails (Figures 3.26 and 3.27). The idea for non-static diverters came from noticing rotating devices used on rooftops to scare away birds. The elongated bird-flight diverter (Figure 3.31) seems to be the most effective and is based on the same principle as the Firefly HW Bird Flapper/Diverter manufactured by P&R Technologies, Inc. (P&R Technologies 2014). The Firefly has more than one colour, a possibility that should be investigated further. Bird mortalities declined by approximately 50% after installation of the new diverters, but still occurred (Figures 3.28 and 3.29). The effectiveness of other diverter dimensions, namely two 55x55-mm squares, fitted at 90° angles to each other (Figure 3.30) and an elongated 110x50-mm diverter (Figure 3.31) was investigated. Both diverters were designed to rotate on a swivel during windy conditions.

Although the recommendations about the six problem elements described in the previous section were not based on rigorous scientific enquiry, practical methods applicable to MIEM were obtained.

Coal refuse dumps consist of used coal and other by-products of furnaces that melted whale blubber for oil production.

Figure 3.21 Use of the whaling-era coaldump at Donkergat

When levelled the coal binds the topsoil and after rains blends into the environment.

Figure 3.22 Road repair with refuse coal on the road to South Head

Closing selected access routes can be effective but rehabilitation is slow.

Figure 3.23 Closing of a road at Jutten Point

Absence of water necessitated a truck-filled reservoir on the trough. Supply duration is two weeks in summer and more than a month in winter.

Figure 3.24 New water-trough at South Head

The new fence is rigid with openings to allow passage of small and large animals.

Figure 3.25 Construction of fence from main gate to Plankies Bay

The 50x50 mm squares were cut from perspex sheets and cable tied to the line.

Figure 3.26 The 50x50 mm bird-flight diverter

The pvc pigtails shift due to wind action and cluster together which reduces their efficiency. When fitting the new diverters the pigtails are secured with cable ties.

Figure 3.27 Newly invented bird-flight diverter fitted between PVC pigtails

Swift terns were killed or injured by power lines despite fitting of the new diverters. Langebaan Lagoon is an important haven for these birds and hosts 50% of the population (Robinson 1990).

Figure 3.28 Mortality of swift tern after fitting of new diverters to power lines

Although a healthy population of black oystercatchers resides at Donkergat, these birds are near-threatened globally and in South Africa (Barnes 2000; Birdlife International 2000).

Figure 3.29 Mortality of black oystercatcher after fitting of new diverters

During evaluations the results showed that the swivels did not last long due to too much rotation during windy conditions.

Figure 3.30 Newly developed 55x55 mm three-dimensional bird-flight diverter evaluated at DMTA

These diverters proved to be longer lasting and were fitted to the transmission lines during spring 2013.

Figure 3.31 Newly developed elongated 110x55 mm bird-flight diverter

All the inherited ecological disturbances cannot be rehabilitated but reactive monitoring and mitigation programmes for limiting the environmental risks can be implemented. A comprehensive road-maintenance and management plan that makes provision for varying degrees of intensity, depending on the dry- and wet seasons, must be formulated. Once all the watering points are functional the water alternating programme must be implemented, especially during the dry season when hoof pressure on agriculturally disturbed fields is rife. A contingency plan for fence maintenance must be implemented but research must still ascertain the type of game fence that will be the most suitable in the long term as the new fences are already showing signs of decay.

3.4 MILITARY ACTIVITY IMPACT ON CULTURAL-HISTORIC HERITAGE

DMTA has a rich history dating from precolonial times, through the more recent whaling era to the Second World War. The South African Heritage and Resource Agency (SAHRA) is aware of these heritage sites in DMTA and has confirmed the applicability and relevance of the National Heritage Resources Act (Act 25 of 1999) to the area. Although these sites are not maintained by SAHRA, they are worthy of attention in DMTA history and should be managed as such. Article 34(1) of the Act states: “No person may alter or demolish any structure or part of a structure which is older than 60 years without a permit issued by the relevant provincial heritage resources authority” (South Africa 1999: 58). The act demands accountability by the managers of DMTA where it stipulates that “Every generation has a moral responsibility to act as a trustee of the natural and cultural heritage for succeeding generations’’(South Africa 1999: 16). The stipulations about the management of graves are specifically ordained by military regulations in South Africa (SANDF 2003).

Two categories of heritage resources in the Western Cape are applicable to DMTA, namely indigenous which includes palaeontological, geological and archaeological heritage and government that involves five eras, that is the Dutch East India Company (1652-1795), transitional British and Dutch occupation (1796-1814), British colony (1814-1910), Union of South Africa (1911-1961) and Republic of South Africa (1961-) (Western Cape Department of Environmental Affairs and Development Planning 2005). DMTA has four categories of protected sites, namely human burial sites older than 60 years, archaeological and palaeontological sites, shipwrecks and associated remains older than 70 years and structures older than 60 years.

Two graveyards in the area have graves marked from as long ago as 1882 and a diversity people were buried here, even members of the Royal Navy in 1902. A number of shipwrecks are found around DMTA, most of them from the whaling-era when they were scuttled to form harbour walls. According to legend on one foggy night six vessels were scuttled in Salamander Bay to make insurance claims, but there are few remnants of these vessels submerged in the Bay. During 1942 the area was occupied by the SADF and a coastal battery was set up at Elands Point. After the war a Mr Duckitt leased some parts of the area, mainly for recreation and farming. In 1978 the SADF reclaimed the peninsula and in 1983 it was restored to SADF occupation in entirety. With the initial takeover, especially of Riet Bay in 1993, concerns were raised that the military would misuse the asset and disturb the fragile ecosystem (*Cape Times* 1983a; 1983b). The then minister of defence, General Magnus Malan, responded by allowing public access to Riet Bay on a permit basis (*Cape Times* 1983c), but the decree never realised. At no stage was cultural heritage on DMTA a conservation priority, resulting in sites being left to the elements to deteriorate and to damage induced by military activity, visitors and developers. These problems and the solutions to redress them are considered in this section. Again photographic evidence is provided.

3.4.1 Nature of heritage impacts

The most prominent historical buildings on DMTA are the remains of the Second World War battery at Elands Point and structures from the whaling-era. Some of these heritage sites were and are still used for training purposes by SF (recall Figure 3.3) and some structures have been seriously damaged during military exercises (Figures 3.32 and 3.33). The graveyards at Salamander and north of Riet Bay have historical value, so contributing to the heritage value of DMTA. The gravesites, tombstones and graves were not maintained for many years and their being left unattended resulted in regrettable deterioration of the structures (Figures 3.34 and 3.35).

Shipwrecks are cultural-historic asset that beg management. The wreck of the *Harvest Sirius*, a 405-ton fishing vessel shown in Figure 3.4, was scuttled at the request of the military in Salamander Bay in 1991 without consideration of all the implications. It is now a navigational hazard and visual pollutant at the entrance to the new Salamander boat park. When construction of the boat park (Figure 3.36) began in 2009, shipwrecks from the whaling-era were found to be obstructing the building of the new harbour wall. This was not catered for in the EIA approved for the building of the boat park so that while building was underway officials from SAHRA had to inspect the wrecks to grant permission for sections to be removed (Figure 3.37). Artefacts and whalebones were found and salvaged without the necessary permission and permits (Figure 3.38). Article 34 (1) of the Heritage Resources Act clearly states that “all material from shipwrecks older than 60 years, automatically become the property of the state and may not be removed from their original site without a permit” (South Africa 1999: 58). As part of the construction process whaleen was dredged and pumped into Salamander Bay causing short-term pollution of the bay and adjacent lagoon. The correct procedure would have been to chemically analyse the whaleen and, if contaminated, to dispose the sludge at Vissershok near Cape Town. The EIA that was executed for the boat park did not adhere to all the NEMA regulations. Apart from being a transgression of the NEMA by not executing EIAs correctly and timeously, post hoc measures that are time consuming and often unsuccessful were required. This approach also delayed the date of completion as construction was interrupted on 11 June 2010 owing to pressure from Langebaan residents (Yeld 2010a; 2010b). Work only resumed on 24 January 2011 costing the government vast amounts of money in penalties and continued payment of the contractor while awaiting approval. Work could only continue once the regulations laid down by the NEMA were adhered to.

The harbour wall was eventually built beyond its planned length and now stretches up to the wreck of the *Emily Faithful*, an 822-ton English, iron sailing schooner from 1868 that was always a cultural-historic landmark at Salamander (Figure 3.39). After completion of the harbour wall the contractors filled the bow of the ship with stones as shown in Figure 3.39. This was done without permission, but the damage is irreversible and the wreck is now largely obscured from view. This contravenes the prescriptions in Article 27 (18) of the Act that addresses the defacing of a heritage site. Rocks excavated from the harbour-wall building site were dumped around the half-finished 1930 whale-flensing platform and some of the columns were damaged (Figure 3.40). Article 34 (1) of the Act that prohibits the damaging of structures older than 60 years is applicable in this case.

A factor that contributed to this debate is that the Department of Public Works (DPW) was unaware of or simply disregarded the legal requirements of EIAs that had changed on 1 July 2006. The new law requires a full EIA to be carried out and an environmental management plan (EMP) to be drafted (Molteno & Snijman 2009). This necessitates careful scrutinising of the EIA regulations (South Africa 2006) published under the NEMA (South Africa 1998). The Salamander boat park development required a full environmental assessment and intensive interaction between authorities, subject specialists and stakeholders. It is a prerequisite that EIAs and rehabilitation measures should be undertaken and applied to counter, as far as possible, any detrimental impacts of developments, military operations and other military activities, on the environment. Regulations that must be adhered to involve national, provincial and general legislation and it is essential that for any future projects, inputs must be obtained from the local community before commencement of work on new ventures.

3.4.2 Suggested management solutions: Heritage

Although all the graves at Salamander were photographed, the inscriptions documented and the records kept at the 4SFR Registry, the present level of information recording of heritage on DTMA is inadequate. The detail of the inscriptions of the five out of nine graves that have tombstones at the Riet Bay cemetery must still be captured. These graves are not as old as the 12 at Salamander (1812-1965) and dates of those recovered so far range between 1918 and 1937. Consequently infrastructural developments and all routine military activities are taking place with inadequate consideration given to potential impacts. A priority is the construction of a spatially-intelligent database. All heritage sites should be recorded in a proper information system and a classification of the conservation status of artefacts must be implemented. Structures should be classified according to their potential to be physically conserved and rehabilitated and those to be left as they are. The first class includes the graveyards and WWII battery and the second the shipwrecks, whaling station remains and WWII beachhead. Once all the heritage assets have been recorded and classified the information must be reviewed by SAHRA and if necessary be inspected for accuracy for inclusion in a heritage registry required by Section 30 of the National Heritage Resources Act (South Africa 1999). A preservation plan for heritage sites must include regular cleaning in and around structures and inspections by SAHRA. Training on and around these sites and the number of visiting groups should be minimised and controlled. The graveyards must be maintained and graves, like those shown in Figures 3.34 and 3.35, should be whitewashed once a year. Although some of the grave structures are deteriorating rapidly, SAHRA guidelines are to let them be and only to keep the area around them clean. No structural repairs, such as re-erection of fallen tombstones, may be done but requests to implement basic preservation methods must be submitted to SAHRA as these can be sanctioned according to the aforesaid Act that stipulates: “Desirable changes may include: changes to prevent further deterioration” (South Africa 1999).

Due to ignorance, training did take place in the past at the Elands Point gun battery and damage was inflicted. To renovate the area, sandbags and targets were removed and the hole detonated through the wall of the WWII-battery structure (Figures 3.32 and 3.33) was repaired by experimentally filling it on the inside with original building material and plastering the outside with a strong cement mixture (Figures 3.41 and 3.42). Smaller bullet holes were left intact because they are fairly inconspicuous and patching would have resulted in further visual disturbance. Information on graveyards, the WWII battery and whaling history already recorded are being systematically documented and made available to key military personnel on the base and to the public (Marx 2007; 2008).

A preservation plan for heritage sites must be formulated and implemented so that before new developments, such as the Salamander boat park are initiated, comprehensive EIAs are fully informed through the DMTA documentation, the management plans and the appointed environmentalist. Results and input must be made available for public scrutiny and officials from

Structures of the Elands Point battery were used as targets for training exercises.

Figure 3.32 WW II structure used as a target at Elands Point

The wall was damaged by detonation of a 'platter charge'.

Figure 3.33 Close-up view of military damage to a WWII structure

Headstone inscriptions are still visible, unique and valuable to foreign visitors and the local community associated with the previous eras.

Figure 3.34 Untended graveyard at Salamander

Weeds cover the graves and some tombstones are toppled over. Descendants of the deceased still visit the sites occasionally. At this gravesite inscriptions must still be documented.

Figure 3.35 Graveyard north of Riet Bay

SA Special Forces identified the requirement for the construction of a new boat park in 1989; official starting date of the contract was 01 April 2009.

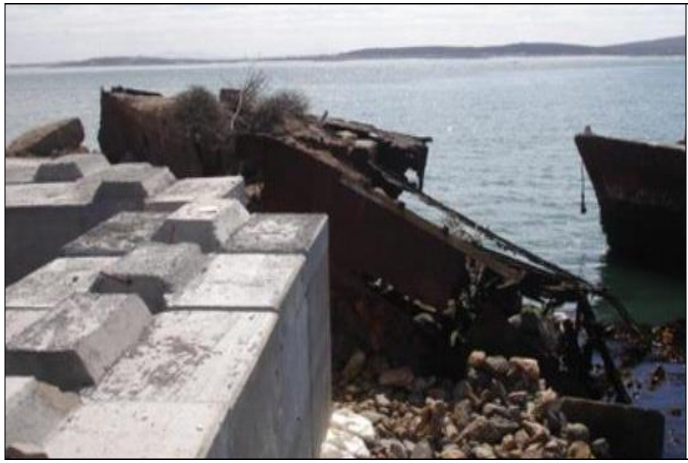
Figure 3.36 Construction of the new boat park at Salamander

As the shipwrecks could not be identified and were scattered over the lagoon floor, SAHRA granted permission to remove the wreckage to complete the construction of the harbour wall.

Figure 3.37 Parts of shipwrecks recovered from the Salamander construction site

Top left: cannonball and type of bollard. Top right: chain and parts of ships motor. Centre: harpoon. Bottom left: plaque found on motor and machine-gun belt. Front: piece of whalebone

Figure 3.38 Some of the artefacts recovered from Salamander Bay



The serene beauty of the wreck is influenced by the wall and piling of rocks against the bow. It was later totally damaged when it was stone-filled.

Figure 3.39 Harbour wall stretching to the wreck of the *Emily Faithful*


Figure 3.40 Damaged 1930 flensing-platform pillars, Salamander

The columns were part of the planned construction for the extension of the Salamander whaling station, a venture left uncompleted.


Figure 3.41 Restoration of the wall of a WWII structure wall at Elands Point

Original building material fitted into the interior of the damaged wall to create some authenticity.


Figure 3.42 Repaired WWII structure at Elands Point

Cement mixed with the minimum amount of building sand was used to plaster the damaged wall on the outside of the structure. The picture was taken the day after repairs were done.

the regional facilities interface manager (RFIM) [1] should get involved from the start and inspect development sites regularly. Possible impacts on the ecology must be predicted by environmentalists stationed at DMTA enabling proactive mitigation measures. Because military activities have detrimental effects on the environment it is vital that the ecologically-harmful impacts that stem from military activities must be investigated. The situation in DMTA is considered next

3.5 ECOLOGICAL IMPACTS OF MILITARY ACTIVITY

Ecological impacts mainly result from human negligence and irresponsibility and they are rectifiable through addressing the issues with proper management and enforcing applicable legislation. The nature of the ecological impacts experienced on DMTA is explored first and the section is concluded with proposed management measures to address these impacts. Photographic evidence is given.

3.5.1 Nature of ecological impacts

The ecological impacts on DMTA are grouped as the effects of uncontrolled game movements that pose threats to floral and faunal health; poor state of seagoing training vessels; the challenges related to sewage disposal; and issues of occupational health and safety (OHS) experienced from time to time. These four environmental issues are discussed in turn.

Uncontrolled game movements through poorly or unplanned gaps in fence lines result in trampling of sensitive vegetation on already disturbed areas. Figure 3.43 illustrates this problem. Environmental harm such as irreversible damage to the natural vegetation through severe hoof erosion results. As with unplanned roads, this damage to natural vegetation allows the establishment of invasive and insidious pioneer plants to flourish on disturbed areas. A system of game canalising management was designed and implemented. However, because the ecological management of the neighbouring WCNP and Oude Post/Postberg Nature Reserve is not continuously science-based in the absence of permanent scientific staff for these areas, this institutional weakness results in poor management with serious consequences, like game that perish from starvation during dry seasons (Figure 3.44).

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[1] The RFIM, based at Youngsfield, Cape Town is the regional military unit where environmental affairs responsible for the Western Cape is situated. The RFIM personnel are responsible for regular staff visits and inspections and to give guidelines for developments. A previous request for EIAs on shipwreck rehabilitation has been submitted to the regional RFIM, yet no avail.

Unserviceable seagoing vessels used for hostage-release training are poorly maintained and not professionally preserved. Such neglect poses serious environmental threats as exemplified by one such vessel that sank without warning, causing serious oil and other fluid pollution. A replacement ship was purchased, but in the absence of a maintenance plan the potential repetition of the incident required its early disposal (Figures 3.45 and 3.46). No funds were budgeted to maintain the vessel and the SAN was unwilling to invest money in a cleaning operation to obtain permission from DEAT to prepare the ship as a submarine or frigate target – the most suitable solution at that time. Because bilges are not cleaned properly before the vessels are handed over to the Defence Force, dangerous gasses that pose an OHS hazard to personnel build up over time in closed compartments and ships' holds.

Sewage on DMTA is deposited in five septic tanks. These are emptied on a regular basis by a private company with the brief to dispose of it at the municipal sewage works. However, the company economises on the number of service trips to and from DMTA by frequently releasing raw sewage in the veld some 300 m north of Riet Bay (Figures 3.47 and 3.48). This is a serious offence according to the Waste Bill (South Africa 2007) and can result in severe penalties. The real danger exists that some of the spillage will filter through the sandy soils into the sensitive Riet Bay ecosystem, possibly resulting in contamination of the water. Riet Bay is a shallow, sheltered water-body with a unique floral composition used as a safe haven and breeding area by a number of animals. It is mandatory that the bay be given the utmost protection against pollution, damage and disturbance.

The potential *OHS hazards* posed by the training vessels and the dumping of sewage in the veld directly contravene the DOD's policy (South Africa 1996a; 1996b) on the management of environmental integrity. This policy is consistent with national and international procedures and includes the maintenance and improvement of environmental status which contributes to the quality of life of South African citizens and the provision of healthy working environments for personnel (South Africa 1993).

3.5.2 Suggested management solutions: Ecology

Game must be distributed more evenly over the available grazing area to minimise trampling in the vicinity of the troughs now in use. Survey results suggest that a game-canalising system in conjunction with a water-trough rotation plan that addresses uncontrolled game movement are having the desired effect. During January 2008 the gaps in the fence south of Riet Bay were closed, so preventing the animals from moving through the trampled areas, (cf. Figures 3.43 and 3.49).

Intensive veld disturbance caused by game migrating between DMTA and Postberg.

Figure 3.43 Movement of game through fence openings causing trampling and erosion of veld south of Riet Bay

One of five gemsbok shot in January/February 2004. The animals were so frail they could barely stay upright. Not all the animals dying of starvation could be located and culled as some were too weak and collapsed.

Figure 3.44 Starving gemsbok (*Oryx gazelle*) culled on DMTA

The training vessel Lupin, *the predecessor of the* Seahorse, *sank without warning and caused a minor oil spill as the bilges had not been completely drained.*

Figure 3.45 The *Seahorse* training vessel anchored outside Stink Bay

Corroded decks such as these pose a major OHS hazard to soldiers using the training platform.

Figure 3.46 The deteriorating deck of the *Seahorse* training vessel

Sewage was illegally discarded in the area that slopes down to Riet Bay.

Figure 3.47 Truck ready to discard sewage north of Riet Bay

Apart from possible contamination of the bay, this practice is unhygienic, contravenes the Waste Act and emits a foul smell in the area.

Figure 3.48 Raw sewage being pumped into the veld

Gaps for game to move through were located at already disturbed areas resulting in deterioration of the vegetation.

Figure 3.49 Disturbed area caused by hoof erosion before closure of gates in May 2008, south of Riet Bay

In conjunction with the culling programme the changing of the gap location in the new fence lessens the impact of hoof erosion.

Figure 3.50 The same disturbed area (Figure 3.49) in August 2008 after the gaps had been closed for three months

During May 2008 just before the rainy season – the area had been badly disturbed as is shown in Figure 3.49. To reach the Riet Bay trough (Figure 3.14) the game had to pass to the north-east at Perlemoen Point or to the south-west where the fence meets the tarred road. Initially, the game wandered along the fence and some attempted to cross the obstacles but, after about three weeks, the animals adapted their daily migration patterns and started making use of the provided openings. As shown in Figure 3.50, canalising of game to restrict hoof erosion has direct beneficial effects on trampled veld. Research on the closure and opening of troughs are continuing and will be finalised once all the watering points are functional.

There was a suggestion that the existing fence be replaced with a two metre rigid 'veld fence'. A selection of these fences with varying opening sizes is available on the market and they are widely used on game farms (Bothma 1995). A request for such fencing was granted and the old fence was replaced in 2009 (Figures 3.51 and 3.52). The new fence has mesh blocks with dimensions of 300x200 mm at the bottom and 300x80 mm at the top. The fence was erected with the bigger openings at the bottom as this configuration allows small animals, such as tortoises that suffered a high mortality rate when struggling to negotiate the old fence, to traverse at ground level while the small openings at the top make the obstacle more visible to bigger game. The new migration gaps are located at places where hoof erosion has minimum impact on the vegetation. To prevent unauthorised human entry to military terrain, and in accordance with the SAAO GS3/77 Volume VII (SAA 1997) regulations, noticeboards have been erected at the road entrances to the reserve and at the migration gaps to notify the public that the area beyond the fence is a military terrain to which access is prohibited.

Proposals made by the SANDF since 1997, especially about the reduction of game, have only been considered in decision making by SANParks since 2008. Inputs from the shareholders in the neighbouring Postberg Nature Reserve were ignored but should be taken into account to maintain good relations, especially since most of the game was introduced by them. The shareholders have supported the SANDF proposals made about issues such as game reduction and adjustment of sex ratios. The implementation of the carrying capacities proposed in the DMTA environmental management plan must be done by SANParks in DMTA, WCNP and Postberg Nature Reserve. This management plan for DMTA must be updated regularly and co-ordinated with that for the WCNP. Game management, especially the reduction programme, only received attention ten years (since 1997) after recommendations had been made by the military to SANParks. This resulted in the culling of old animals and relocation of antelope, especially eland. The first group of 97 were moved during May 2008. Of these, 47 were transported to the Addo Elephant National Park in the Eastern Cape and 50 to Mooimaak in the WCNP (some 30 km away).

The new fence was designed to have the bigger openings at the bottom to let smaller animals through and the smaller openings at the top to enhance visibility for larger animals.

Figure 3.51 New fence stretching from Perlemoen Point to Plankies Bay

Gaps made at localities where erosion will be minimal as shown here where the surface is rocky and there is no water run-off. Information boards are displayed at the gaps.

Figure 3.52 New fence with migration gap

The device in which the gemsbok got entangled is the remains of an illumination mortar that is kept airborne for a period by means of parachute.

Figure 3.53 Gemsbok entangled in an illumination mortar parachute

The animal had to be put down as the wires from the illumination device severed the lower-leg sinews.

Figure 3.54 Close-up of injuries sustained by gemsbok

Unfortunately, the animals transferred to Mooimaak were left unmarked, making it impossible to determine if some returned to their original roaming grounds. This has indeed happened on previous occasions when some eland even swam across the lagoon back to Donkergat. Following the 2008 reduction, selective culling of old and injured animals continued, but the carrying capacity continued to be exceeded. New recommendations followed in 2011 resulting in approximately 150 eland, 200 ostriches and other animals being removed during the winter of 2012. These animals were relocated to a variety of venues and following good rains the veld recovered significantly. As the condition of the veld deteriorates rapidly during dry conditions and when the south-easter blows relentlessly, annual reduction of game must remain a management priority. Another consequence of extremely dry conditions is that some game tend to feed on poisonous plants during these times. During the summer of 2011/12 a number of bontebok died in the WCNP, Postberg Nature Reserve and on DMTA. Autopsies by the state veterinarian found remnants of a plant from the genus *Cotyledon* in the intestines of these animals. A recurrence of this can only be prevented if game numbers are kept to the determined carrying capacity of the veld.

Training vessels such as the *Seahorse* have limited lifespans and it is unfeasible to maintain them. Bird nests must regularly be removed from these ships as it cause lice that contaminate the ship and the guano accumulating on the deck. Risks to OHS are deteriorating decks that constitute unsafe stepping areas and the dangerous build-up of gas from asbestos and diesel in the holds of ships. Visual pollution created by the presence of *Lupin* and *Seahorse* between Langebaan and Donkergat can lead to dispute between the public and the military. Based on the infrequent use of this training aid during a year it is unfeasible to replace this vessel. Exercises can be performed on static vessels available in Saldanha Bay or Simon’s Town harbour. Training actions that include boarding while vessels are underway can be negotiated with the SAN and private ship companies.

Sewage shall not be disposed of on DMTA under any circumstances. It is stipulated in the contracts of sewage-removal companies that dumping must be done at designated sewage plants. These regulations must be reflected in the relevant environmental documentation and the unit standing orders. The management plan should stipulate the seriousness of and severe penalties for such misconduct and also the importance of specifying relevant regulations in the contracts with private companies responsible for sewage removal. For general guidelines the Outeniqua sensitive coastal area extension to the Environment Conservation Act (South Africa 1998b) and Waste Bill (South Africa 2007) can be consulted. Added to the adverse effects caused by misconduct in DMTA are the impacts of military action residue resulting from irresponsibility and negligence. These residues must be seriously addressed as expounded in the next section.

3.6 IMPACTS THROUGH MILITARY-ACTION RESIDUE

Military units must accept the responsibility of stewardship for the environment under its control and within which it operates. The handling of environmental matters should take place within the parameters of international, national and regional agreements, legislation and regulations and should support national environmental objectives as well as the military mission. The emphasis on environmental management should be on integrating environmental considerations into all military planning and activities which could impact on the environment. SF and military activities on DMTA are diverse and have a variety of undesirable influences on the environment, mainly because there is a lack of control and an absence of an efficient maintenance programme. Some of these deleterious impacts are caused by negligence or by not adhering to (even ignoring) standing orders on sweeping and cleaning of shooting ranges after exercises; lack of building maintenance; vehicle manoeuvres on beaches; and indiscreet detonation of explosive devices. These problems and transgressions highlight similar management challenges at other military-training areas and the suggested solutions to address them. This section examines the residues of military action and their resolution. Photographs illustrate the text.

3.6.1 The nature of military action residue

Refuse left at shooting ranges and in training areas causes game to unintentionally become entangled in illumination devices, netting and parachutes (Figures 3.53 to 3.55). After training exercises at ranges such as Blouwildebeest Bay, the terrain is sometimes not cleaned properly so that containers, targets and hastily-built temporary structures pollute beaches and the hinterland (Figure 3.56). Debris left for years at training areas poses dangers for animals to get entangled in wires and netting and sustain injuries by corroded containers. No shooting range management and maintenance plan is yet in place and clean-up operations are disregarded. Prefabricated buildings erected as lecture rooms have not been maintained, causing structures to collapse and becoming OHS hazards and forms of visual pollution (Figure 3.57). The main reason for these maintenance related challenges is that no comprehensive and applicable terrain management plan exists.

In the vicinity of Elands Point, dunes, beaches and secondary roads are used for motorcycle off-road training (Figures 3.58 to 3.60). Severe erosion of sensitive dune systems emerges in some training areas where natural sediment tracks lead from coastal dune fields and extend uphill into natural vegetation. This is a dynamic natural feature that allows the natural transportation of beach sediment into dune fields. The process is thus essential for the maintenance of coastline equilibrium. Examples of adverse economic and ecological results from such disruptions occur elsewhere along the Cape coast.

The animal could not be captured to remove the parachute. It was observed for two weeks wandering around with the decoration and then most probably got rid of it herself.

Figure 3.55 Bontebok (*Damaliscus dorcas dorcas*) with horns entwined in an illumination mortar parachute

The only shooting range allowing live firing from sea to land. Targets on the beach and hinterland are used to enable operators to practise shooting skills.

Figure 3.56 Used targets and structures left for years at Blouwildebeest Bay shooting range

Prefabricated buildings erected as temporary classrooms. Without proper maintenance collapse of the sidewalls started to occur.

Figure 3.57 Deteriorating prefabricated structure at DMTA shooting range

This damage was caused during training exercises on 26 August 2009. The tracks on the beach shown in Figure 3.59 were made on the same day.

Figure 3.58 Damage by motorcycles on dunes next to a sediment tract east of Elands Point

Damage inflicted at one of the most important African black oystercatcher breeding sites on the peninsula.

Figure 3.59 Quad-bike tracks on the Jutten Bay beach

The sediment track stretches uphill from the beach. Sand is deposited by prevailing southerly winds.

Figure 3.60 Sediment tract next to off-road training area at Elands Point

Noticeable disturbance on the heavy-weapons range already classified as sacrificed.

Figure 3.61 Marked area inside the heavy-weapons range

Negligible influence of shooting activities on the vegetation just outside the heavy-weapons range.

Figure 3.62 Marked area outside the heavy-weapons range

Off-road vehicles also directly influence the breeding success of African black oystercatchers when vehicles scare the mature birds off their nests, exposing the eggs and chicks to predation by gulls or other animals or resulting in the eggs becoming putrid. The tracks shown in Figure 3.59 are directly next to six oystercatcher breeding sites. This vehicle activity on beaches directly contradicts national law set down in the National Environmental Management: Integrated Coastal Management Act (South Africa 2009).

Terrestrial, inland explosions on the DMTA demolition range disturb birds, some of which have variable population trends, especially during their breeding seasons. This disturbance has serious consequences for the breeding success of the birds (Dyer 2005, Pers com). Affected birds mainly belong to the Pelecanidae (e.g. great white pelican), Sulidae (e.g. Cape gannet) and Phalacrocaracidae (e.g. cormorants) families. Shock-waves created by explosions on the DMTA demolition range are propagated to the neighbouring islands as far as Marcus Island in Saldanha. When the shock-waves reaches the islands the breeding birds abandon their nests to allow opportunistic gulls to prey on the eggs and nestlings, thus influencing the breeding success of the colonies. Complaints have been received on numerous occasions from Langebaan residents about plaster falling off the walls in their homes and dogs and horses running away when big detonations are initiated (Richards 2013, Pers com; Weslander 2002; 2008; 2011a; 2011b; 2013; Yeld 2010a; 2010b). In response articles were published to inform the public about the beneficial environmental contributions the military are making on DMTA (Marx 2013; Weslander 2008). After completion of the Salamander boat park, underwater demolition practices raised concern that they might have a damaging effect on the submerged structures. This activity was never taken into consideration when the EIA was conducted.

It is clear that the environmentally harmful impacts caused by military activities came about because the SF do not adhere to basic environmental regulations and policies stipulated by government in the South African White Paper on Defence (South Africa 1996b), the NEMA (South Africa 1998a), the National Heritage Resources Act (South Africa 1999), the comprehensive Department of Defence policy statement on defence facilities and environmental management (South African National Defence Force 2000), regulations in terms of chapter 5 of the National Environmental Management Act (EIA Regulations R 385-387) (South Africa 2006), the Waste Bill (South Africa 2007) and the Integrated Coastal Management Coastal Protection Zone and Coastal Set-back Regulations (Overberg District) (South Africa 2009).

3.6.2 Suggested management solutions: Military residue

Management of military residue largely entails the proper maintenance of facilities and equipment and the routine clean-up of spent materials. The content of dump sites must be limited to the bare minimum by prioritisation of the unserviceable paraphernalia to be so stored. Generally these sites must be fenced off to prevent access by game.

To ensure sustained clean-up operations at *shooting ranges and training areas*, a designated section that addresses the removal of used targets, discarded pyrotechnic devices, ammunition shells and containers, must be formulated in the management plan. This management plan for continuous clean-up operations at shooting ranges and training areas must include prescriptions for thorough sweeping of the sacrificed and the surrounding areas. Illumination devices dropped by parachute must be counted during firing and be accounted for at the conclusion of exercises. At the end of every shooting exercise the ranges must be cleaned and all cartridges deposited in containers. Once full, the containers must be returned to the ammunition stores for recycling of the brass. Facilities for disposal of shooting range waste must be inaccessible to unauthorised visitors and game. Ammunition with cables or parachute attachments must not be left in the open but preferably be stored in containers for disposal. Major clean-up operations, as called for at the excavation site shown in Figure 3.1, can be avoided if proper control is executed after completion of military exercises. All targets must be removed and stored at dedicated places for reuse or disposal. Blinds and misfires should be destroyed as soon as possible by qualified personnel. Research on the military impacts on vegetation is being conducted at the heavy-weapons and demolition ranges. Rectangular experimental impact areas (10x10 m) have been marked inside and outside the disturbed areas (Figures 3.61 to 3.64) where the vegetation composition and effects of disturbance are being monitored as part of a long term project.

A *terrain management plan* that addresses the demolishing of existing structures such as unused prefabricated buildings must be compiled and institutions identified to which building material can be donated (Figure 3.65). The terrain management plans should be part of the unit standing orders for implementation by the terrain manager and his team.

Designated areas already available for 4x4 recreational purposes at private locations outside DMTA must be used for *off-road vehicle training*. Instead of risking any further disturbance of dunes on DMTA, as shown in Figures 3.58 and 3.59, venues managed by civilian adventure groups were identified for such activities. Many such facilities are available along the West Coast and they

Inside the demolition range the area is noticeably disturbed and classified as sacrificed.

Figure 3.63 Marked experimental impact area inside the demolition range

Just outside the demolition range perimeter the vegetation is not disturbed.

Figure 3.64 Marked experimental impact area outside the demolition range

Material from the demolished prefabricated buildings can be reused. Those shown here were donated to schools for the construction of classrooms.

Figure 3.65 Demolishing and removal of prefabricated buildings provide a variety of off-road challenges. An example is the Melkbos 4x4 facility near Duynefontein on the R27 to Cape Town. Training with four-wheeler motorcycles, light delivery vehicles and other SF vehicles can be done there. The cost for using the facilities is minimal as most owners see the use of their courses by SASF as publicity for their businesses and opportunities to have their facilities professionally evaluated. Of course, the use of classified operational vehicles will require security measures to be enforced. Beach landings done at Blouwildebeest, Jutten, Plankies and Stink Bays generally have no undesirable effects on the dunes. Vehicles should be allowed on the beach only during emergencies such as oil spills, search-and-rescue operations and boat or casualty recoveries. In the past the damaged dunes were left as they were with some staying in a disturbed state for many years. Immediate rehabilitation of the dunes is essential if signs of disturbance reappear.

The *effect of demolitions on breeding birds* was tested using different sized charges. Crude tests carried out on warm cloudless days during November 2009 indicated that charges up to three kilograms have minimal effect on the birds of Meeuw Island, which is the nearest to the demolition range. Thorough research must be done with seismographic recordings to determine the exact amount of explosives that can be used without generating shock-waves that disturb the breeding colonies on all the surrounding islands. The effect of prevailing weather conditions on the intensity of shock-waves must be investigated. To determine an appropriate window period for demolition exercises, the breeding seasons given in *The Atlas of southern African birds* (Harrison et al. 1997) were applied and additional information on the birds breeding on the surrounding islands was obtained from DEAT research personnel. The regular surveys conducted by DEAT indicate that the key months for seabirds on islands are February-March when swift tern breed (incubate) and September-December when kelp gull, cormorant (cape, crowned and whitebreasted) are incubating eggs or brooding their chicks. Cape gannets incubate eggs and hatch chicks during the latter period. Several species of shorebirds − sacred ibis, cattle and little egret and blackheaded and grey heron − breed on the islands throughout the year. African black oystercatchers start to breed in November and their chicks leave the nests by the end of January.

Bank cormorants that recently showed a decline in numbers breed mainly in winter from April to October. The breeding seasons of these named birds and the suggested window period for demolitions are given in Table 3.2. The peak breeding season of all the birds must be taken into account when scheduling demolition exercises and minimum amounts of explosives detonated as there are constantly breeding activities on the islands (Dyer 2005, Pers com).

Table 3.2 Planning of demolitions to make allowances for the sensitivity of island-breeding birds and Cetaceans

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vulnerable birdlife: Incubating and breeding												
African black oystercatcher	**X**										**X**	**X**
Bank cormorant				**X**	**X**	**X**	**X**	**X**	**X**	**X**		
Cape cormorant									**X**	**X**	**X**	**X**
Crowned cormorant									**X**	**X**	**X**	**X**
Cape gannet									**X**	**X**	**X**	**X**
Kelp gull									**X**	**X**	**X**	**X**
Swift tern		**X**	**X**									
Whitebreasted cormorant									**X**	**X**	**X**	**X**
Vulnerable marine mammals: Present around DMTA												
Whales					**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Demolition window period	**z**	**z**	**yy** **zz**	**yy** **zz**	**y**	**y**	**y**	**y**				

X *Breeding birds and whales present*; **y** (minimum) **yy** (maximum) *Demolitions at the terrestrial ranges*; **z** (minimum) **zz** (maximum) *Demolitions at the underwater ranges*

Alternatively, since breeding activities continue throughout the year with the variety of avifauna involved, charges should be detonated in intervals and be kept to a minimum at all times. Until 2012 the maximum amount of explosives allowed to be detonated as a solitary charge was 100 kg. This is an unrealistic mass and it was lessened considerably on the author’s advice. The maximum amount of explosives to be detonated on DMTA in a single charge was stipulated as 3 kg in the unit standing orders in July 2012. Detonations of such maximum amounts of explosives must be restricted from mid-March to mid-April (Table 3.2). Fixed charges of more than 3 kg must be elevated above ground level to lessen the impact of the shock-waves but such enhanced detonations must only be permitted if absolutely necessary for operational purposes. A further experiment with explosives is briefly discussed in Chapter 5. During land demolitions game occasionally get hit by shrapnel from detonations. This can be avoided by chasing all the game out of the exercise area before detonations begin.

The *underwater demolition* ranges are situated in Stink Bay where access can be relatively easily controlled from land or sea. Two underwater demolition ranges, namely deep and shallow ranges are available to divers in Stink Bay. The boundaries of the ranges stretch into the lagoon and past Salamander Point to the north and Camp Point (Figure 1.4) to the south as shown in Figure 4.15. Table 3.2 indicates that underwater demolition activities be scheduled from January to April with large detonations only being allowed during March and April. Even if the locations of these underwater ranges are changed, as to be proposed, the window periods must remain the same till further research indicates otherwise. Subsurface explosions at these ranges affect sea life – mainly fatalities of fish that die when shock-waves rupture their swim bladders, the hydrostatic organ in bony fish that regulates buoyancy (Wikipedia 2014a). Most of these casualties float to the surface and become carrion for seabirds. A situation must be avoided as happened during the construction of the Saldanha Breakwater when explosives were detonated too close in succession and scavenging birds were killed by secondary blasts (Branch 1983). Precautionary measures must be implemented by patrolling an affected area to ensure that no birds are still feeding on the dead fish when further detonations are initiated.

Complaints about the effect of land demolitions on whales have been received in the past as the public was under the impression that whales are disturbed by these actions (Weslander 2000). To determine the effect of detonations on whales, an experiment was conducted by detonating 12 charges of up to five kilograms at intervals of 15 minutes at the land demolition range while whales were present in Jutten Bay. It did not appear as if the shock-waves had any harmful effect on the mammals as they carried on with normal swimming activities, did not seem to be disturbed and stayed in the bay. Todd et al. (1996) investigated the effect of underwater borehole charges on Humpback whales (*Megaptera novaeangliae*) in Trinity Bay, Newfoundland. Charges of up to 248 kg were detonated in delayed sequence of a few milliseconds, the entire charge lasting two to three seconds. The depth of the boreholes ranged from 3 to 10 m in water ranging from 0 to 15 m deep. The whales showed little behavioural reaction to the detonations regarding decreased residency, overall movements or general behaviour. Yet public opinion and other concerned parties regard underwater demolitions as having effects on marine mammals (Footprint 2000; Weslander 2000; Yelverton 1981).Thus, until more is proven of the effects of detonations on marine animals care must be taken when whales frequent areas around the underwater demolition ranges. Regarding Salamander Bay in the interim no demolitions should take place if whales are present in the area during the whaling season (May to December) (Table 3.2) and the same rule applies for dolphins. Experimentation with underwater bubble curtains able to absorb shock-waves has been done and can be implemented to diminish the impact on underwater wildlife and the Salamander boat park structures (Damon et al. 1974; Richmond & Jones 1974; Würsig, Greene & Jefferson 2000; Yelverton 1981). Noises emanating from cargo ships, such as the iron-ore carriers traversing Saldanha Bay, may also have an influence on marine animals. Marine mammals, fish and even some invertebrates use sound to find food and mates, to avoid predators and to communicate. The degree to which man-made noise affects whale-made noise has been studied for northern right whales (*Eubalaena glacialis*) in the port of Boston and showed that on a normal day, the area's whales could hear one another but this has reduced to only 10 to 20% of the natural range through noise. This caused the whales to be unable to communicate and to find each other (Allen 2011). A research programme on DMTA can investigate the effect on marine animals by high- and low pitch noise created by the new Hurricane- and Wahoo boats respectively. Apart from all these impacts and residues caused mainly by military activities, there are certain undesirable ecological implications of applying unsound management principles. The next section discusses some generic environmental management recommendations and priorities to handle and counter the incidence and effects of environmentally detrimental states of affairs.

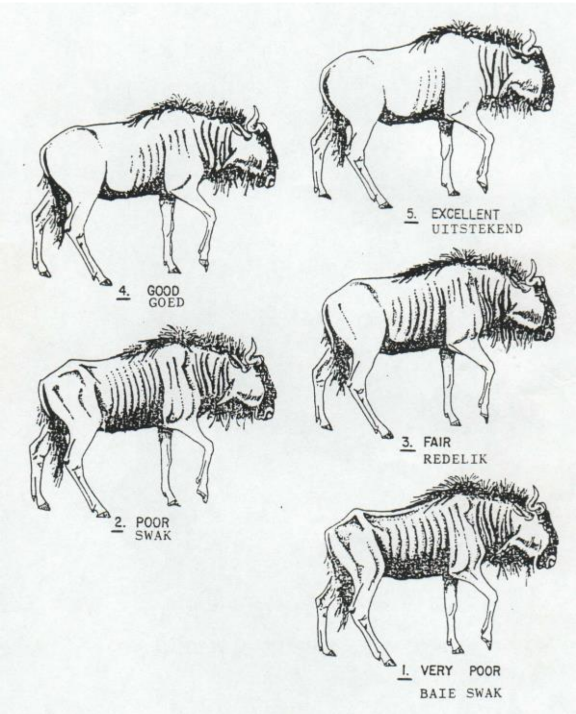
3.7 GENERIC ENVIRONMENTAL MANAGEMENT RECOMMENDATIONS AND PRIORITIES

Some management practices must be highlighted, namely those concerned with game management; exotic and problem plants and animals; and water-quality actions such as oil spills and monitoring of trace metals in Donkergat Bay and Salamander Bay. Because the game in the area roam freely between the WCNP, Postberg Nature Reserve and DMTA, the management is a SANParks responsibility. Recommendations about the game have been made to SANParks because overstocking is a challenge that needs continuous attention. Exotic or historically non-endemic plants and animals − some of which pose invasive problems − that occur in the vicinity of DMTA are briefly discussed. Research on the water quality around DMTA is a priority and some findings of surveys on the topic are highlighted.

3.7.1 Game management

Game in DMTA was and still is not managed scientifically and the reduction programme and the proposals should be implemented on a continuous basis. The SANDF can only make recommendations regarding game management and cannot act independently to control game numbers. DMTA comprises 1 384 ha and is shown in relation to its surroundings in Figure 1.4 with the adjacent Postberg Nature reserve (previously Oude Post) 1 851 ha adding to a total of 3 184 ha available to game as gaps in the dividing fence allow animals to roam freely between the two land parcels. Excluding the beaches and rocky outcrops, unfeasible for grazing, approximately 2 800 ha can be roamed on by most ungulates. The carrying capacity of 5.5 animal units (AU) per 100 hectare (1 AU per 18 ha) (Bothma 1995) must be strictly adhered to if serious hoof erosion experienced during the previous dry cycle is to be prevented. Judged by the numbers present during the February-March 2007 game counts, the 2 800 ha area was overstocked by 120.7 AUs. This approximate 54 000 kg of excess game. Some eland and ostriches were culled and relocated but to enable selective reduction the programme must be a continuing process. The 2010 surveys again showed excess game of 133.9 AUs or 60 270 kg. The game reduction programme proposed must take place annualy, take sex ratios into consideration and a predetermined number of male animals should be removed through selective culling.

The condition of game is associated with available grazing which is determined by the rainfall in the Langebaan Dune Strandveld vegetation area. During monthly game counts, the condition of game is determined according to the Berry scale shown in Figure 3.66 and recorded in code format. Average annual rainfall varies considerably, for example in 1962, 388 mm were measured at Cape Columbine and three years later (in 1965), only 166 mm (South African Weather Service 2009). A dry year was experienced in 2003 and eland (an exceptionally hardy species) condition averaged only a median value of three to four on the Berry scale. After the good rains and the reduction of the number of eland, the condition of the game improved to an average of four to five during 2010.



According to the Berry scale method, five condition classes are classified, namely:

- Class 1 Very poor
- Class 2 Poor
- Class 3 Fair
- Class 4 Good
- Class 5 Excellent

Figure 3.66 The Berry scale for indicating the condition of game

Median values below three per species are certain indicators of environmental stress experienced by game and a high probability of overstocking as determined by the AU/ha ratio.

3.7.2 Exotic and problem plants and animals

An alien vertebrate species present in Saldanha Bay is a population of the exotic European rabbit that was established on islands by the Dutch – most probably during the late 17th century (Cooper, Hockey & Brooke 1985; Skinner & Smithers 1990). In the Saldanha area the rabbits still occur on Jutten, Schaapen and Vondeling Islands, having either died out or been eradicated from other islands in the early part of the 20th century. The European rabbits, restricted to Schaapen Island, do not pose a potential threat to the endemic rabbits occurring in the surrounding areas, including DMTA.

Bouwildebeest (*Connochaetus taurinus*), a species not historically endemic to the area (Skead 1980), were introduced by the Postberg Consortium, adapted well and now have aesthetic value on DMTA. Other terrestrial mammals that occur on DMTA which is outside their historical distribution range or their previous occurrence here is doubted, are Cape mountain zebra, bontebok, kudu and springbok (Skead 1980). All these animals have adapted well to the area and if well managed according to scientific principles they can be accommodated in DMTA. The presence of historically non-endemic species, such as the blouwildebeest, is of lesser importance to vegetation preservation than to adhere to the prescribed carrying capacity of the Langebaan Dune Strandveld. Although feral animals are not now a problem on DMTA, they should be eradicated as soon as spotted on the peninsula.

Cape fur seals, now officially called the South African fur seal (Envirofacts 2014) are the main problem animals in the area. Their range is restricted to islands and the mainland coast between the fishing grounds of northern Namibia and Algoa Bay on the south-eastern coast of South Africa. There are 25 known breeding and ten non-breeding localities along the South African and Namibian coasts, the largest at Kleinzee near Port Nolloth (Envirofacts 2014). Fur seals consume large amounts of fish annually and as the numbers of their main predator, the great white shark (*Carcharodon carcharias*), is declining, the seal population is increasing to the extent that in 1990 there were already approximately two million fur seals on the south coast of Africa (CITES 2001). The average weight of a seal is 227 kg and they eat 6% to 8% of their body weight in fish per day. A colony of 10 000 seals will consume a total of 159 090 kg per day or more than 1.1 million kg of fish per week (Capelinks.com 2010). Undersize crayfish returned to the ocean by commercial fishermen while sorting their catch are consumed by 'vulturine' seals. Island-breeding birds lose many chicks on their first-time water ventures to predating seals. The seals attack the chicks from below surface and rip out their intestines in a search for fish. Approximately 10 000 Cape gannets (*Morus capensis*) fell prey to seal predation during the 2005/06 breeding season in the waters around Malgas Island (Bonthuys 2006).

Alien plant species occurring on DMTA that need constant attention are *Acacia cyclops* (rooikrans) that is eradicated immediately when spotted and *Myoporum tenuifolium* (manatoka) that is removed on a continuous basis outside the built-up areas. The eradication of problem plants is a monthly venture as stipulated in the base environmental management plan in Appendix D. Disseldoring, although endemic to the West Coast, and the exotic spear thistle, both flourish on disturbed areas such as along roads and if not controlled by physical removal they can invade large areas in a short time (recall 3.2.1). Inside the perimeters of DMTA's built-up areas, some exotic trees planted by previous residents and the military do occur but they are tolerated as they provide shade and have historical and esthetical value. These exotic species do not pose any fire hazard and are trimmed regularly.

Although no significant veld fires have occurred on DMTA since establishment of the base, precautions must always be taken by ensuring that fire-fighting equipment is available when live firing is in progress and extra care taken in windy conditions. The fire in 2000 taught the lesson that the only prevention mechanism for runaway veld fires is the lighting of firebreaks at areas where the fire will be canalised. Normal-width (20 to 100 m) firebreaks are not effective in strong wind conditions as the wind-driven flames leap over them, as well as over gravel or tarred roads. A fire on its way to DMTA from the south must be stopped between the ocean at Tsaarsbank Gate and Kraal Bay (see Figure 1.4).

3.7.3 Water quality actions

4SFR has a designated role in the national oilspill contingency plan. Basic guidelines stipulate that all sightings of oil spills at sea, oil washed up on the beach or islands and the presence of polluted birds must be reported to the officer commanding. The type of response from the unit and other involved parties depends on the severity of the oil spill classified as light, moderate or major. In the case of a light spill, the unit will collect the oiled birds and transport them to SANParks or the South African Foundation for the Conservation of Coastal Birds (SANCCOB). Cleaning operations of beaches and other allocated tasks will be done in conjunction with DEAT if necessary. In the case of a moderate or major spill, the response is to form part of the broad coastal oilspill contingency plan available on internal file 4SFR/B/401/1/13/12. Prevention and cleaning-up operations will be done under the supervision and in conjunction with the South African Marine Safety Authority (SAMSA), Strategic Fuel Fund (SFF), Saldanha port control, the responsible local authorities and relevant nature-conservation bodies. The areas of responsibility of the unit are Meeuw Island, Riet Bay and the rest of DMTA from Riet Bay to Storm Bay (Figure 1.4), South Head and Plankies Bay. (See Appendix D for the annual management plans of objectives for 2013).

Clark et al. (2012) recorded an increase in the trace metals cadmium (Cd), copper (Cu) and lead (Pb), especially in the Donkergat Bay and Salamander Bay areas. Cadmium is toxic to marine animals at consumption levels above 1.2 mg per kg sediment. In 2011 it reached 2.09 parts per million (ppm) in Donkergat Bay and Salamander Bay which is higher than Cd in the surrounding waters where levels were between zero and 1.0 ppm (Clark et al. 2012). As cadmium bioaccumulates, it is a vital concern for the marine environment and the human consumption of marine organisms. The high Cd concentration in Salamander Bay is attributable to the recent dredging activities for the construction of the new boat park (Clark et al. 2012). The high concentrations in Donkergat Bay cannot just now be explained. Copper becomes highly toxic to marine organisms if concentrations rise anywhere above 34 mg per kg sediment. In 2011 it was 40.75 ppm in a small part of Salamander Bay, much higher than the surrounding waters where 0.0 to 5.0 ppm Cu were recorded. This high concentration of copper is probably a result of industrial discharges when the new boat park was constructed (Clark et al. 2012). Lead is a persistent compound that becomes toxic to aquatic organisms and mammals with concentrations above 47 mg/kg considered to be harmful. Higher than average concentrations of Pb were detected in Donkergat Bay and Salamander Bay but the reasons for this phenomenon are unknown. Changes in the concentrations of these trace metals will be closely monitored in collaboration with the survey teams of the Saldanha Bay and Langebaan Lagoon state-of-the-bay report. Access to the military area will be granted to their research personnel and assistance given when needed.

It is evident from the foregoing exposition that the relationship between the state of the environment in 4SFR and the variety of training activities in DMTA is indeed complex. Given South Africa’s stringent national environmental legislation, environmental compliance is becoming an increasingly important issue. The unit is committed to providing operations-ready operators with the right equipment at any place at the right time. This mission must be accomplished with the application of military integrated environmental management in the use, management and developments associated with the environment under 4SFR's control.

3.8 MILITARY INTEGRATED ENVIRONMENTAL MANAGEMENT

Proposals for a MIEM plan for DMTA is the gist of this study. In this section background to the MIEM is sketched from the international and national commitment of the SANDF, before suggestions are made for applying at the local level of DMTA.

3.8.1 The international MIEM

A consideration of MIEM for SANDF properties, including DMTA, requires reflection on international environmental laws. South Africa has signed and ratified virtually all the current environmental conventions and protocols (South Africa 2001) and in some instances even played a leading role in the implementation and development of these international legal tools. Some important agreements that South Africa has ratified and that are applicable to a military area such as DMTA are the Bonn Convention on Migratory Species (CMS), the Convention on Biological Diversity (CBD), the Convention on Wetlands of International Importance especially as Waterfowl Habitat and the UNESCO World Heritage Convention (WHC). Additional international conventions, treaties, agreements and protocols relating to the core business and the environmental responsibility of the DOD are listed in South Africa (2001). These agreements are only part of international law and have limited application in South Africa if not ratified by Parliament, formulated in other legal tools, applied during assessments (DEAT 2005; World Bank 1996) or considered when drafting MIEM plans.

Global examples of lack of government support hampering the implementation of environmentally friendly military training practices abound. In Poland, training areas are reportedly devastated by heavy military equipment, toxic combat substances, and combat simulations, requiring financial and human resources and dedicated effort and planning for renovation (Borucka & Mikosz 2012). Magagula (2014) reports similar problems for the Grahamstown Military Institution (GMI) where 6 South African Infantry Battalion (6 SAI Bn) is stationed. He deduces that the inability of the South African government to adhere to international legislation and treaties can be attributed to its struggle to provide basic needs such as drinking water and sanitation to the national population. This dilemma to deal effectively with environmental problems and enforcing regulations in the face of urgent human welfare priorities (Glazewski 1993) is a longstanding challenge.

With reference to land use planning, the concept of environmentally friendly management systems applied by entrepreneurs during project planning originated in Britain in the latter part of the nineteenth century. Its inception accelerated after World War II as the fundamental elements of town and country planning were adopted and implemented (Smith et al. 2011). The development of planning tools was mainly land orientated, unlike the MIEM and SDSS proposed for DMTA here, which integrate both land and maritime attributes to ensure coherence in the formulation of temporal and spatial objectives. The proposed system operationalises the Smith et al. (2011: 297) dictum that “integration can be approached in two contexts. The first relates to that of spatial planning frameworks per se and involves the integration of land and sea use planning systems. The second involves the operation of these systems within the wider context of environmental management”. Nevertheless, international spatial planning models involving both land and sea that are now evolving mostly proves land use planning systems are generally much more developed than sea use planning systems (Smith et al. 2011). In South Africa NEMA is well instituted for terrestrial appliance and generally utilised, but the Integrated Coastal Management Act (ICMA) still requires full deployment, compelling Taljaard et al. (2012: 48) to state that “the practice of incorporating spatial planning and zoning of the coastal marine environment in the existing spatial planning processes, particularly at the local level, is not yet common in South Africa”. While maritime spatial planning (MSP) has not been definitely adopted as a process within South Africa’s integrated coastal management (ICM) existing legislation supports this process. Taljaard & van Niekerk (2013: 78) states emphatically that “the ICMA is viewed as the most suitable legal route to embed a statutory mechanism for multi-use MSP in the coastal marine environment, provided that strong links are established with other spatial planning processes (for example conservation, fisheries and land-based spatial planning)” – a highly significant observation for environmental planning on DMTA.

In Europe, MSP programmes, utilised for maritime developments, are mainly applied in the core region of North West Europe (Smith et al. 2011). This system still suffers shortcomings regarding clear governance baselines, but after years of a primarily sectorial approach towards maritime matters, governments now begin to recognise the necessity for an integrated governance framework. The new Integrated Maritime Policy of the European Union exemplifies this shift in policy and decision making (Olsen, Olsen & Schaefer 2011). This developing policy landscape for MSP involves four main domains, namely: environmental legislation, legislation on marine renewable energy, fisheries regulations and the integrated maritime policy, but they are still weakly linked for the development of ecosystem-based and integrated marine spatial planning in Europe (Qiu & Jones 2013). In South Africa a universally integrated approach is being adopted and developed that can lead to the formulation of definite criteria for establishing baselines towards streamlining authorisation processes and to identify obstructive and success factors for the implementation of MIEM. Taljaard et al. (2012) highlights the challenge of a sector-based approach in South Africa, regardless of realising the importance of cooperative governance for realising truly integrated coastal management (ICM) implementation. Using the justification for existing coastal management unit boundaries, such as the embayment of Saldanha Bay and Langebaan Lagoon, these authors proposed a prototype ICM implementation model that can be applied in the planning of new projects at DMTA or other localities along the SA coast. This model encapsulates the Coastal Policy, ICMA and other environmental legislation that support the concept of an overarching vision and objectives for the coastal marine environment of SA, as well as the concept of spatial planning (Taljaard et al. 2012).

Until the 1980s, the concern in South Africa with the identification and management of environmental phenomena and issues was mainly the responsibility of the then provincial nature conservation departments, the National Parks Board, numerous non-governmental ‘green’ movements and diverse pressure groups. Since then, environmental matters have become internationally institutionalised as integral parts of sustainable-development doctrines and hence part of governance as reflected and entrenched in the Constitution of the Republic of South Africa, Act no 108 (South Africa 1996a). Commanding officers in the SANDF have been made directly accountable for the environment under their command (SANDF 2003) and set guidelines for the inventories of natural resources have been formulated according to the USA model initiated at the USA/RSA Integrated Range Management (IRM) Workshop in 2000/01 (ESWG 2001). The Corporate Environmental Policy Statement approved by the Plenary Defence Staff Council on 17 September 2001 (SANDF 2003) states that: "The Department of Defence shall, in compliance with the environmental obligations placed upon it by the constitution, national and international regulatory provisions and within the constraints imposed from time to time by nature of its business, protect the environment through proactive measures of military integrated environmental management” (South Africa 2001: 16).

The United States of America is the prime example of experiencing major environmental challenges in the military environment for which they had to pioneer programmes to address MIEM. This must be appreciated because the US Department of Defence manages more than 5500 military installations that occupy approximately 12 million ha of land used for various military training programmes (Howard et al. 2013). Being responsible for such vast areas of land, the US military developed an environment-friendly approach and applicable management tools. Unlike the USA, most African countries still have to develop this ‘new’ environmentally-friendly attitude which, due to ignorance, dictatorship, exploitation and widespread poverty, poses major challenges. In 1989 the USA established the Centre for Hazardous Substance Research (CHSR) at Kansas State University and after years of progress and partnership with various agencies, including the US Environmental Protection Agency (USEPA), the Urban Operations Laboratory (UOL) resulted in 2001. The function of UOL is to support dynamic military needs through practical environmental assessments, software tool design and technology development (Saulters et al. 2009). In the USA military, environmental programmes are administered through four primary focus areas, namely conservation, restoration, compliance and pollution prevention. All four of these focus areas have been encapsulated in the DMTA MIEM proposal and the resulting plan for a spatial decision support system. Pollution is a major problem in the USA and in 2003 a US government report revealed that over 15 million acres in the US are contaminated by military munitions and estimates showed that clean-up costs will be between $8 and $35 billion and that it will take longer than 75 years to address this issue. Although not as extreme on DMTA as in the USA, pollution through munitions such as blinds and misfires is a matter of great concern on SASF training areas such as Madimbo bordering the Kruger National Park. The MIEM plan and incorporated SDSS tool developed for DMTA is modelled on the UOL design of the Environmental Knowledge and Assessment Tool (EKAT) programme (Saulters et al. 2009).

UOL developed a web-based toolkit (www.ekat-tool.com) with some key modules and capabilities of EKAT being environmental screening; the National Environmental Policy Act (NEPA), which assists military users in meeting federally-mandated requirements; and EmisCalc that allows users to estimate actual air pollutant emissions. The EKAT Wizard feature is set up in a question-and-answer format to guide users and help them determine which assessments, tools and other EKAT resources can best help address their requirements (Saulters et al. 2009). These principles are applied in the MIEM model and SDSS programme proposed for DMTA.

3.8.2 National framework and status of MIEM implementation in the SANDF

According to the White Paper on Defence, the Minister of Defence, as well as the Chief of the SANDF “is responsible for ensuring the exercise of proper ecological and environmental management and control of military properties" (South Africa 1996b: 190-191). Legal environmental compliance not only refers to compliance with national and international environmental legislation, but also includes provincial and local legislative provisions for which the duty rests with the commanding officer (CO) of a unit. Within the transformed structure of the DOD, the responsibility and accountability for compliance with environmental legislation and MIEM implementation is a dual process due to the roles of the respective structures for support and force preparation, as shown in Table 3.3. In the left column of the table are the main categories of military use of allocated areas and in the right column the key environmental concerns are named that are discussed in detail in Appendix D. All the concerns are subject to legislation on waste management and water- and energy efficiency. The latter two still have to be researched to offer an effective management system that can be applied practically on DMTA.

Except for national legislation, the SANDF prescribes specific regulations in the Corporate Environmental Policy Statement for Defence (South Africa 2001) stating in the environmental implementation plan (EIP) that the military "must accept responsibility for sustainable use of the environment entrusted to it; minimise the adverse impacts of its operations on the environment by

Table 3.3 Accountability under environmental legislation of DOD-controlled property

MILITARY USE OF LAND AND FACILITIES BY FORCE STRUCTURE ELEMENTS (FSEs)	ENVIRONMENTAL CONCERN
Planning of operations and training activities	Environmental management of bases
Force preparation	Ecological management
Execution of military activities and operations	Environmental education and training
	Included in the above: Integrated waste management, water- and energy efficiency

means of a programme of continual improvement; promote open communication on military related environmental issues to all interested and affected parties and to train and motivate its members to regard environmental considerations as an integral and vital element of their day-to-day activities'' (South Africa 2001: 16). The purpose of the EIP is to co-ordinate and harmonise environmental policies, plans, programmes and decisions of the national departments that exercise functions that affect the environment (South Africa 2001). The concept of the compilation of detail EIPs to ensure long-term continuation of environmentally-sound range management practices seems feasible on paper, but in practice the challenge lies in the availability and appointment of skilled environmental managers, an applicable MIEM plan and a useable tool such as the SDSS, that can be applied by the ground-level user.

3.8.3 MIEM implementation at DMTA

It has become clear that since 1978 the impacts of military activities have gone unjustly unnoticed and that the consequence of this covert nature of activities and facilities on DMTA is that the DOD environmental services responsibilities were not adhered to and remained unknown to the broader army and general public. This situation also developed at other SF training areas and it is in contrast with the Environmental Services mission to ensure environmentally-sustainable management of military activities and facilities. It is understandable that SASF did to a large extent not adhere to this mission as it is not an ordinary army institution and many of its activities are classified as secret and executed as such. SF is however still accountable to government and civil society and obliged to reduce its impact on the environment through implementing a sound environmental management system (EMS). Furthermore, the responsibility and accountability of COs of military bases or units (SANDF 2003; South Africa 1996b) is to ensure that “the planning and execution of military activities will take account of the environmental implications and not jeopardise the long-term potential of land and other natural resources” (SANDF 2003: 1). In an organisation such as SF it is, however, unrealistic for COs to take direct responsibility for the whole spectrum of areas where training and operational preparation take place and detrimental effects on the environment can result. While activities are executed on DMTA, the OC can be held accountable to a certain extent but operators from 4SFR undergo training in places as far as Madimbo or even in neighbouring countries.

The three environmental themes listed in Table 3.3, and the examples given in Appendix D, must be developed and implemented on DMTA and other SF training facilities, but the emphasis must be to generate a ‘mind switch’ in SF personnel towards the implementation of sound environmental practices. This can be introduced through lectures on applicable, authentic subjects and practical involvement such as beach-cleaning operations, rehabilitation of penguins during oil spills and game- or bird surveys. To further initiate this and make it the responsibility of every planner, the onset must be to incorporate MIEM into the prescribed unit order format for everyday activities. For every activity, be it a demonstration, exercise or vehicle movement, an order is compiled and approved, but nowhere is provision made for MIEM. MIEM must be compulsory as an additional appendix with the signals, medical plan and other appendices that form part of any order. Taking a shooting exercise as example, the MIEM plan must stipulate the most suitable locality for the exercise; areas to avoid; access routes to be taken; the person responsible for the MIEM; the authorities to contact if flares or explosives are to be used; parking area for vehicles (to provide drip trays); the maximum amount of explosives that can be detonated; the collection sites for spent cartridges; the area that must be swept for mortar parachutes; the procedure for disposing waste; the fire-fighting plan and equipment needed; and the indication method for blinds. Similar aspects can be listed for all the different training or rehearsal activities and be made available as practical templates from which operators can work. In order to determine suitable routes, choose the appropriate training area, identify sensitive places to avoid, ascertain whether explosives can be detonated and the amount of explosives allowed, a system must be available that assists exercise commanders while compiling orders and taking variables such as environmental factors, the time of year and meteorology into consideration. The SDSS developed in the next chapter is suggested as the useable tool the exercise commanders require.

CHAPTER 4 SPATIAL DECISION SUPPORT SYSTEM FOR MIEM ON DMTA

The fourth objective of this research was to develop a spatial decision support system (SDSS) for managing the sensitive environmental resources of DMTA by means of an efficient application of military integrated management (MIEM) as an advanced management concept that entails the integration of military operational and universal environmental prerogatives in a site-specific procedure. Hence, this chapter provides details on a hierarchy of developments and concepts that are prerequisite to understanding a spatial application in a range of key aspects in the military context. It commences with an overview of geospatial technology applications in the military and drafts a suggested framework for such an application within the military command hierarchy. A stepwise exposition is then given of the implementation principles, followed by the actual construction and design of a comprehensive spatial decision support system (SDSS) on DMTA as the core of the chapter's material. The concept of an SDSS running off a geographical information system is finally demonstrated for DMTA and the chapter concludes with application test results and some suggestions for future refinement.

4.1 GEOSPATIAL TECHNOLOGIES FOR THE MILITARY

A range of technologies with spatial or locational awareness have been developed chiefly for and by military expertise and to serve peculiar military needs. By nature much about military activity plays out in locations and deploys over spaces, so it is small wonder that geographical information technology (GIT) has become applied in this sphere. This section explores the comprehensive geospatial technology of SDSS and geographical information systems (GIS) as a particular technology in SDSS. The section concludes with an overview of GIS application examples in military context.

4.1.1 Spatial decision support systems

SDSS are decision support systems (DSS) with a spatial component. DSS were developed in the 1960s to aid decision making when problems are neither well-structured nor unambiguous. These problems are referred to in the literature as ill-structured or semi-structured (Ascough et al. 2001; Densham 1991; Goodchild & Densham 1990), i.e. they cannot be solved with an algorithm or a predefined sequence of operations. To solve such problems, predictive analysis is often required to present decision makers with different scenarios to explore the possible effects of their decisions. This type of interactive exploration enables a decision maker to develop a better understanding of a given problem. DSS are therefore not meant to provide solutions, but rather to support decisions in complex environments like the military.

DSS distinguish themselves from other information systems in that they require a database management system, analytical modelling capabilities, analysis procedures, and a user interface with display and report generators. DSS often use expert systems to interpret and analyse data. Expert systems are software programs that mathematically analyse subject-specific knowledge in the form of context-specific rules to solve problems.

In addition to the capabilities of DSS, SDSS should include a geographical database, mechanisms for spatial data input, representation of spatial relations and structures, spatial analysis functions and various output forms including maps (Ascough et al. 2001). SDSS can therefore be created by extending existing DSS to handle spatial data.

Geographical Information Systems (GIS) comprise many of the key features of an SDSS. When the sub-systems of a GIS (i.e. input, storage, management and analysis, and output) are compared to those of a SDSS, many similarities are evident, although a GIS cannot be regarded as a SDSS on its own as it lacks the interactivity and automation required for scenario generation. However, thanks to GIS’s capability to handle spatial data, GIS and DSS are often combined to create SDSS (Agrell, Stam & Fischer 2004). Such GIS/DSS implementations save development time as they make use of existing software, obviating development input.

Another approach to developing SDSS is to modify and customise GIS to incorporate the functionality of DSS (Basson 2005; Bester 2004; Mlisa 2007; Van Niekerk 1997; Varma, Ferguson & Wild 2000). Most modern GIS allow developers to extend their functionality through programming. This approach has a cost benefit as no DSS licensing costs are applicable, although, as with the GIS/DSS approach, the user must still own a copy of the GIS software in order to use the system. In many cases users are managers or decision makers for whom the GIS software must be purchased especially to run the SDSS. This can be very expensive and, because these SDSS (and users) rarely use the full GIS functionality, it is highly inefficient.

Some GIS developers offer component-based software development tools that allow spatial functionality to be incorporated in other non-GIS software. With these tool kits, GIS functions (components) can be seamlessly embedded in existing applications such as spreadsheets, digital atlases, and routing systems. A programmer can also create an entirely new SDSS (or even GIS) containing only the functionality that is needed for a specific application (Longley et al. 2002). This lowers the implementation cost per user as the developer purchases a tool kit once and pays a small licensing fee for each deployment (ESRI 2002). However, the procedure requires additional development time and resources and is only viable when the number of users is large.

Because SDSS are designed for specific applications, like the military, many of the operations can be automated to perform typical or routine screening or modelling tasks. This reduces the need for user input, which limits the chances of human error. The software can also be developed to be highly user-friendly as the user interfaces can be simplified to include only the functions that are necessary for the specific task. The user can also be directed through the process and adequately informed about the available options, thereby reducing the possibility of error – which can be catastrophic in the military environment.

The ease of use and increased integrity of SDSS make spatial analysis more accessible to users with very little or even no GIS skills and therefore the military in particular. Unfortunately, the higher level of sophistication of SDSS comes at a price. Even if an organization is willing to invest in the development of a SDSS, the GIS licensing costs that are often involved impede its deployment. While prohibitive to small entities, this factor should, however, not be a serious impediment to a large institution like the military in South Africa and, in fact, such systems are licenced and running in dedicated units.

4.1.2 Geographical Information Systems

To comprehend and appreciate the inherent value of GIS adoption, basic knowledge about the technology itself is indispensable, and also a grasp of the innovative application possibilities (like spatial modelling) is requisite. This section imparts the technical basics on GIS and multi-criteria evaluation as one of its application modes practically employed further on in the chapter, and consequently forming an indispensable reference source to follow the procedures applied.

4.1.2.1 GIS: The technology

Because of the diverse applications of GIS there is no generally accepted definition for the technology. Opinions about what is essential for a system to be called a GIS differ according to each user’s needs. Most users agree, however, that GISs are special computer systems for the capture, storage, query, analysis, modelling and display of geographically referenced data (Chang

2006; Clarke 2003; DeMers 2005). But the single most important property which truly differentiates GIS from other spatial systems, such as Computer-aided design (CAD), is its ability to innovatively generate and analyse spatial data (Clarke 2003). Spatial analysis is defined by Longley et al. (2002: 278) as "the process by which we turn raw spatial data into useful information…[to]…add value, support decisions, and reveal patterns and anomalies that are not immediately obvious."

In order to conduct spatial analysis, a spatial database is required. Geographical data are expensive to collect and capture and can be the most expensive component of a GIS. Fortunately GIS is maturing and more data are becoming available. Many governments, including that of South Africa, have made state-owned data freely accessible to the public through legislation such as the Promotion of Access to Information Act (Act 2 of 2000) (South Africa 2000).

For a GIS to operate, a computer system is required. Initial GISs ran on bulky mainframes, which were later replaced by UNIX workstations and since the mid-1990s workstations have made way for personal (micro) computers running Microsoft (MS) Windows. Today, nearly three quarters of GIS professionals use MS Windows, while only one quarter use UNIX-based systems (GISjobs.com 2006). This trend is continuing, primarily because of the affordability and computing power of modern personal computers.

Besides hardware, a GIS also requires specialised software to process spatial data. GIS software became considerably more affordable during the 1990s, mainly due to greater demand and technological advances. More than three quarters of GIS professionals currently use either ArcView or ArcGIS developed by ESRI, while Autodesk, Intergraph and other GIS software developers compete for the remaining market share (GISjobs.com 2006). The drop in prices, together with advances in providing user-friendly interfaces, are perceived to be the major reasons why GIS software sales grew exponentially since 1995 (Longley et al. 2002).

Undoubtedly the most important and least valued component of GIS is the people (operators), also called 'brainware' (Chang 2006), who use and manage these systems. GIS is often regarded as a set of spatial tools (Clarke 2003) and it is the highly trained GIS operator's function to choose the correct set of tools for a specific application and to use these tools in the correct order and manner to achieve the desired results. A GIS installation is inoperable without human operator and spatially aware decision-making input.

The number of GIS users, estimated in 2000 to have been about three million worldwide, is rapidly increasing (Longley et al. 2002). GIS has become more accessible mainly owing to the lower costs of GIS software and hardware and the advent of intuitive, user-friendly desktop GIS. With these systems, users can perform many spatial tasks with little GIS training, thus enabling many managers, scientists and decision makers to perform routine queries and analyses themselves instead of relying on dedicated GIS staff. This has opened a solid new market for GIS, resulting in large increases in system implementation.

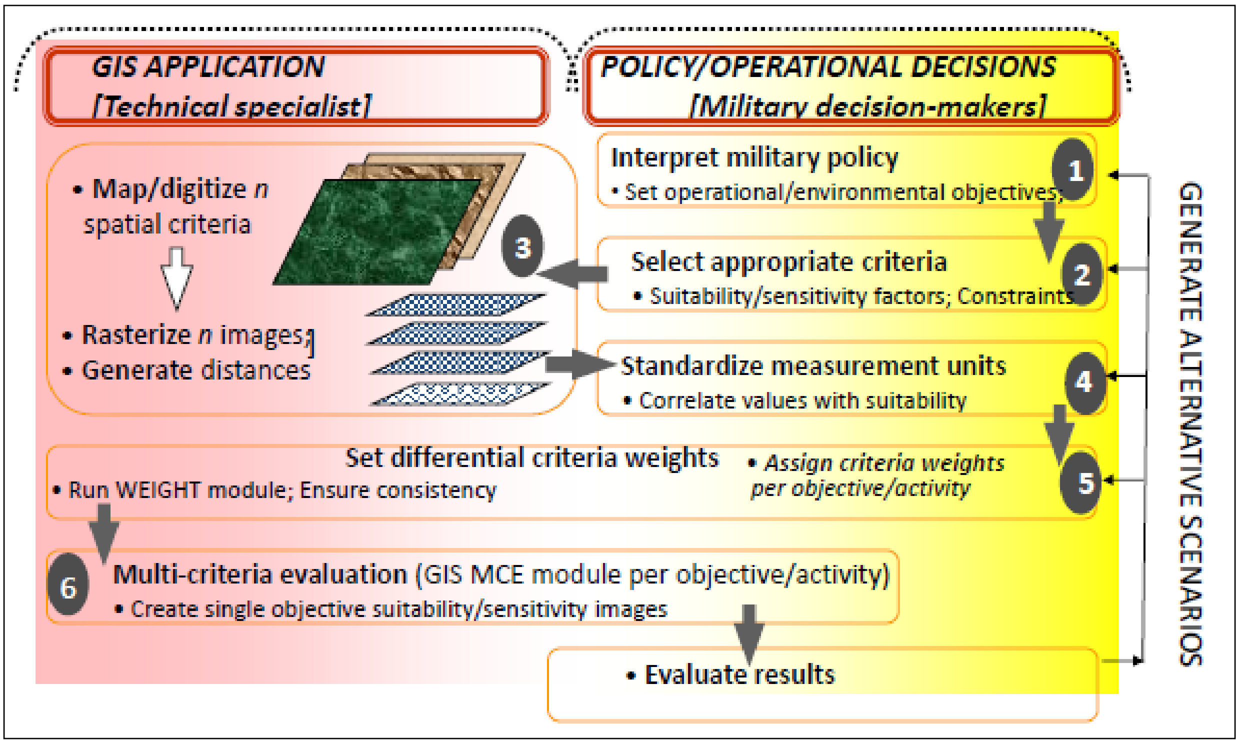
Increasing numbers of users, resulting from better access to GIS, is certainly good for the industry, but off-the-shelf desktop GIS cannot ensure that unskilled users choose the appropriate procedures ('tools') for a specific task or that they use appropriate procedures correctly. Such failings can lead to meaningless results or errors which might remain undetected by the casual user. One way to ensure that GIS users, including the military, use the technology appropriately is to dedicate a GIS application for a specific task only – the military application offering a prime example of a specialised application. The term 'specialised GIS' is somewhat ambiguous as GIS is by nature not specialised (i.e. can be used for many purposes), but it signifies that some operations are automated in such a way that there is little room for error. When GIS is customised to perform a combination of automated operations, they are often called spatial decision support systems (SDSS).

4.1.2.2 Multi-criteria spatial analysis in GIS: The concept

The procedural description addressed further on in this chapter specifies two modes of GIS decision-support application, namely simple cumulative Boolean overlaying to provide 'hard' operational rules for the conduct of activities (as demonstrated in the previous section), compared with the multiple-criteria evaluation (MCE) technique that allows more subtle suitability measurement along a sliding numerical scale of intensity/suitability/sensitivity. The two techniques are briefly overviewed here for the sake of methodological clarity on the applications developed and demonstrated further on.

This subsection has a dual purpose: it principally structures the actual procedural steps followed in this study, but at the same time participants in the public decision-making process deemed ideal for their respective purposes are indicated – all technical and judgmental decisions were taken by a consultative team of military participants.

As illustrated in Figure 4.1, the first step is to define the particular suitability objectives to be set for the targeted planning area - i.e., the military activity types to be permitted. These objectives will, of course, differ from setting to setting and should be based on locally negotiated consensus while also being in line with regional or national planning guidelines. Typically this step will entail the



Source: Adapted from Van der Merwe (1997)

Figure 4.1 Stepwise procedure for conducting MCE in GIS

formulation and testing of various experimental scenarios and viewing and debating of realistically displayed graphic results.

The second step is to define adequate and appropriate criteria through which the suitability/allowability of land parcels for each objective may be measured. Both the factors which enhance a land parcel's viability for a particular activity and the constraints to all or some activities must be stipulated. These criteria or factors need to be of a spatial nature so that their locational distributions may be digitally mapped (on GIS) as a third step. Typically digitising will take place in vector format, so that subsequent rasterisation (prior to, or after transfer to an appropriate raster based platform like IDRISI or GRID in ArcGIS) will have to be done. Since, at this point, each criterion map is still uniquely feature coded, the fourth step entails the standardization of all criteria/factors to a common measurement scale.

While the first two steps require consultation among participants, the third step is purely technical. Step 4 is also rather technical in nature, but since the standardised value range replacing the unique variable codes must correlate with suitability rating, some judgement is involved. For Step 5 the participants will be called upon to rate the relative importance of each objective by applying a system of differential criteria weights for each – once more through joint consultation. Weight values of criteria range from 0 to 1 and should be specified so that their sum is 1. Deciding on which weights to allocate to each criterion becomes more difficult as the number of criteria increases. Fortunately, a method called the analytical hierarchy process (AHP) supports this task (Saaty & Vargas 1991). AHP employs a pair wise comparison of criteria to arrive at a scale of preferences. Complex unstructured problems are broken down into their component parts, which are then arranged into hierarchical order. The relative importance of each pair of criteria is subjectively judged and numerical values (see Table 4.1) are assigned accordingly. These values are placed in a comparison matrix and evaluated.

Table 4.1 Scale of analytical hierarchy process (AHP) comparisons

NUMERICAL RATING	**QUALITATIVE DESCRIPTION**
1	Equal importance
3	Moderate importance
5	Strong or essential importance
7	Very strong or demonstrated importance
9	Extreme importance
2, 4, 6, 8	Intermediate values
Reciprocals	Inverse comparison

Source: Adapted from Saaty & Vargas (1991)

Because comparison matrixes are created by human reasoning, they can contain inconsistencies. For instance, criterion A may be regarded as more important than criterion B, while B might be considered more important than criterion C. An inconsistency will occur if criterion C has been defined as being more important than criterion A (Marinoni 2004). To guard against such inconsistencies, Saaty (1977) introduced a consistency ratio (CR) which can be calculated from the principle eigenvector of the comparison matrix. A comparison matrix is considered inconsistent when its CR value is 0.1 or more. Several software packages that facilitate the AHP process are available.

During the ultimate step (Step 6) of the MCE process, the constraints and criteria weights are applied to the factors in a single procedure to produce separate image-maps of suitability for each operational activity objective. The method combines criterion values (in each individual raster image cell) mathematically in the GIS MCE module to form single potential images. This last step is largely instrumental and is performed by technical GIS experts once more, although a judgmental element is involved when participants weigh the different objectives in order of priority in the final step. The final MCE process allows the incorporation of Boolean imagery as ‘constraints’ disallowing activities in particular areas according to absolute no-go rules, by the multiplication action in the formula rendering all 0-values unfit for the particular activity.

4.1.2.3 Multi-criteria spatial analysis: Overlay calculations mechanism

Boolean overlaying employs simple arithmetical combination of overlays containing Boolean values (0 or 1) in each cell and where 0 indicates that the feature captured in the value layer (e.g. soil type, slope, distance) falls within acceptable limits (value 1) or falls outside the limits of acceptability (value 0) for a given activity. As such a single Boolean layer can serve to indicate where a particular activity can or cannot take place. Should more variables/factors/layers need to be considered, these layers can be combined in GIS using simple combinatory operators (+, -, x, /) to combine criterion values (in each individual raster image cell) mathematically in the GIS OVERLAY module to form single images via a linear combination formula (Equation 1).

$$P = \sum x_i \qquad \text{Equation 1}$$

where P is the resulting value; and

x_i is the criterion score of factor i, repeated for j factors.

Multiplication is the most common operator used to combine subsequent layers cumulatively, because it ensures that the resultant image will contain Boolean (0,1) values only and that, should a value of 0 be present in any cell on any of the combinatory layers, the final value will be zero. This procedure allows for simplified rule formulation and unyielding results layers to be produced, leaving virtually no leeway for decision-making by field personnel having to make operational decisions.

The second decision-making mode allows multiple contributing data layers to generate more realistic decisions from ordinal image layer cell values previously classified to produce a suitability or sensitivity rating inherent in the original raw values for the particular activity being influenced by or impacted on. These contributing criteria are also not simply overlain cumulatively, but the criteria are differentially weighted and then mathematically combined to generate a graded value range denoting a cell's suitability or sensitivity for the activity.

In MCE, factors, constraints and weights are combined using weighted linear combination (WLC). This essentially involves calculating a suitability value for a particular land usage by employing Equation 2.

$$S = \sum w_i \, x_i \times \prod c_j \qquad \text{Equation 2}$$

where S is the sensitivity value;

w_i is the weight of factor i;

x_i is the criterion score of factor i;

c_j is the Boolean criterion score of constraint j; and

$\prod$ is the product of criteria.

In contrast to the high-risk Boolean intersect (AND) and union (OR) operations, WLC produces a risk-averse (Eastman 2000) and full trade-off solution (Mahini & Gholamalifard 2006). The result of MCE is a set of maps showing the level of sensitivity for each criterion analysed and as shown combined in Figure 4.2. Graduated shades are often used to help visualise increasing suitability as

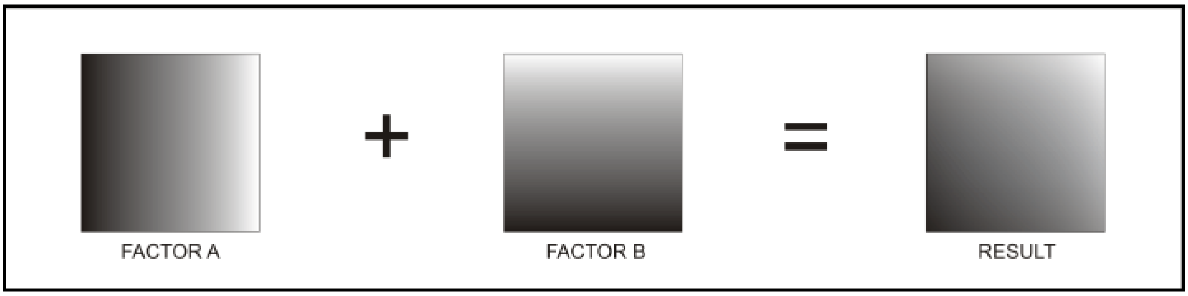


Figure 4.2 Graduated shades used to visualise sensitivity levels of factors and the combined result

graphically demonstrated here. These results of a simple MCE involve two factors (A and B) of equal weight.

4.1.3 GIS application history in the military

A perfunctory search of the global literature using Google Scholar and also the Google Advanced Search browsers was conducted, using a consciously limited set of keywords in strict combination with the words 'military', 'geographical information system' or 'GIS': Military GIS/Application/Environmental management/Integrated/Operational/Military terrain/multiple criteria. The exercise identified a fairly limited range of sources, demonstrating that perhaps the military is somewhat lagging in its adoption of the technology. Several explanations can be provided to account for this state of affairs: 1) The nature of military applications is clandestine and therefore not freely discussed or published in the public domain; 2) Military applications tend to be proprietary and less likely to have been developed on well-known commercial software platforms (Macleod 1998). Browsers, as employed here, are geared to pick up published scholarly products and not operational system discussions and confidential system reports. Recognising these constraints in the literature search, a number of general comments and conclusions based on the literature store can be justified.

A distinctive temporal and origin/locational or national trend in the source origins can be discerned. While fairly specific or focussed application issues had emanated from Western countries earlier on, the first general texts dealing with geospatial application in the military had surfaced very recently. Examples are Singer et al. (2012), Loechel, Mihelcic & Pickl (2012) and Rehak (2010) in Canada. The second trend is the apparent acceleration in 'open' source generation to the public domain from eastern countries, albeit more often dealing with rather specific application issues as demonstrated by Chen et al. (2011), Ding, Wu & Ding (2010), Jha, Karri & Kang (2010), Jun et al.(2011), Kang, Jha & Karri (2010), and Luo et al. (2011). It seems safe to claim that GIS adoption and the unchaining of its potential to military applications worldwide has entered a more prolific and overt development phase.

Of special interest to this research was the extent to which spatial multi-criteria analysis/ assessment/evaluation using GIS in military applications had been reported. Mendoza, Anderson & Gertner (2002a; 2002b) (military land condition assessment), Singer et al. (2012) (environmental condition assessment) and Tuvesson (2011) (roadside bomb detection in Afghanistan) all report on operational applications of this most sophisticated decision-support tool in various operational conditions.

It must further be noted that most sources encountered on GIS in the military had what is here termed operational military management applications as focus. Transportation related operational issues like vehicle use patterns during field training (Ayers, Anderson & Wu 2005), operational surveillance, and reconnaissance intelligence (Cameron 2005; Liao, Sun & Wang 2003; Tuvesson 2011) and transportation path planning (Chen et al. 2011; Jha, Karri & Kang 2010; Kang, Jha & Karri 2010; Luo et al. 2011; Rehak 2010) receive growing attention. Others deal with less specific issues like enhancing situational awareness (Kleiner et al. 2007; Loechel, Mihelcic & Pickl 2012) and information system integration (Kettani & Maamar 1997; Macleod 1998).

The focus of this dissertation has been on GIS in *military environmental management*, a discipline receiving much less attention when combining the search with geospatial technology application.

Godschalk (1998) is the definitive source on specifying how ‘green soldiering’ is to be achieved through MIEM application in the SANDF. Other sources encountered were much more specific in terms of analysing and handling environmental management goals such as land use and conservation assessments on (British) military lands (Andersen, Thompson & Boykin 2004; Doxford & Hill 1998), while Ferro (2012) compared the environmental management system (EMS) strategies and policies for military activities in the American, Canadian, Brazilian and NATO armies.

An encouraging trend is detected in terms of how integrated operational/environmental military management is becoming a focus in a number of studies – exactly what this research aims to accomplish as well. DeFraites (2007) offers insight from the military medical field in how to build operational situational awareness through simulation in geographic information systems and how this may be adopted for environmental applications. General directives (Doxford & Hill 1998; Ferro 2012) and specific applications like vehicle erosion tracking (Gaffer et al. 2008) and general land condition assessment (Mendoza, Anderson & Gertner 2002a; b; Singer et al. 2012) offer useful management advice.

Of necessity a relatively large contingent of sources reported on technical GIS/system requirements and characteristics and analytical techniques – information of note to system operators. Andersen, Thompson & Boykin (2004) and Cameron (2005) on the use of remote sensing, Chen et al. (2011) on visibility analysis, Ding, Wu & Ding (2010), Kettani & Maamar (1997), Liao, Sun & Wang (2003) and Macleod (1998) on system configuration, Kleiner et al. (2007) on mapping language adaptation, Luo et al. (2011) on terrain analysis and Rehak (2010) on mobile geospatial information systems delve deeper into the technologies.

In military environmental management the coverage of military activity impact assessment is important and several related sources were found. These included broad landscape risk (Andersen, Thompson & Boykin 2004) and narrow erosion risk (Gaffer et al. 2008) assessment. Mendoza, Andersen & Gertner (2002a; 2002b) offer insight in approaches towards the evaluation and assessment of military land conditions and the restoration of military-training areas.

Much emphasis in this literature domain deals with terrain/locational analysis in GIS and these are well covered by the source base – as indicated above in various contexts. Andersen, Thompson & Boykin (2004), Ayers, Anderson & Wu (2005), Cameron (2005), Chen et al. (2011), Jha, Karri & Kang (2010), Kang, Jha & Karri (2010), Luo et al. (2011) and Tuvesson (2011) cover from remote sensing application to sophisticated terrain and visibility analysis from digital terrain models (DTMs).

Finally, it is also important to note the suggestions and debates surrounding the need to drive the adoption of military GIS – its military application philosophy and system structure. Pleas for the incorporation of systems in the general operational (Kettani & Maamar 1997; Jun et al. 2011; Joos 2012), urban operational (Cameron 2005), medical situational awareness (DeFraites 2007) and of course military environmental management (Doxford & Hill 1998; Ding, Wu & Ding 2010; Ferro 2012) domains emanate throughout – a call we support from the viewpoint of this research (Van der Merwe et al. 2013).

4.2 MILITARY MANAGEMENT INVOLVEMENT FRAMEWORK

Designing and implementing the geospatial modelling instrument introduced in this chapter requires consideration of the hierarchical command and procedural framework within which environmental and operational plans and actions are derived in the SANDF. This 10-step process is graphically encapsulated in Figure 4.3, which forms the basis of the narrative in this section. This section elaborates on the layers of command responsibility and how these affect the modelling options developed here.

4.2.1 The MIEM command framework

The establishment and maintenance of Military Integrated Environmental Management (MIEM) practices in the SANDF is a legally binding policy commitment that must be complied with. As the logical exponent of ensuring that ‘green soldiering’ (Godschalk 1998) becomes embedded in SANDF business conduct, this study aims to enhance environmental management and operational prerogatives in an integrated framework envisaged as operating in Figure 4.3. The framework sketches the management responsibility structure from national to local base level and indicates the conceptual niche where the GIS-enabled management support system is to be implemented. The framework foresees as the primary (first) driver a commitment embedded at senior military command level, where policy (as in existing official MIEM commitment) is formulated, funding is earmarked and supervision/reporting is enforced. At this level legal/constitutional compliance with national legislation and international commitments are reconciled. Importantly, the uneasy relationship between environmental responsibility and operational efficiency and goal attainment is principally prioritised and cast in command directives. These directives take into consideration the

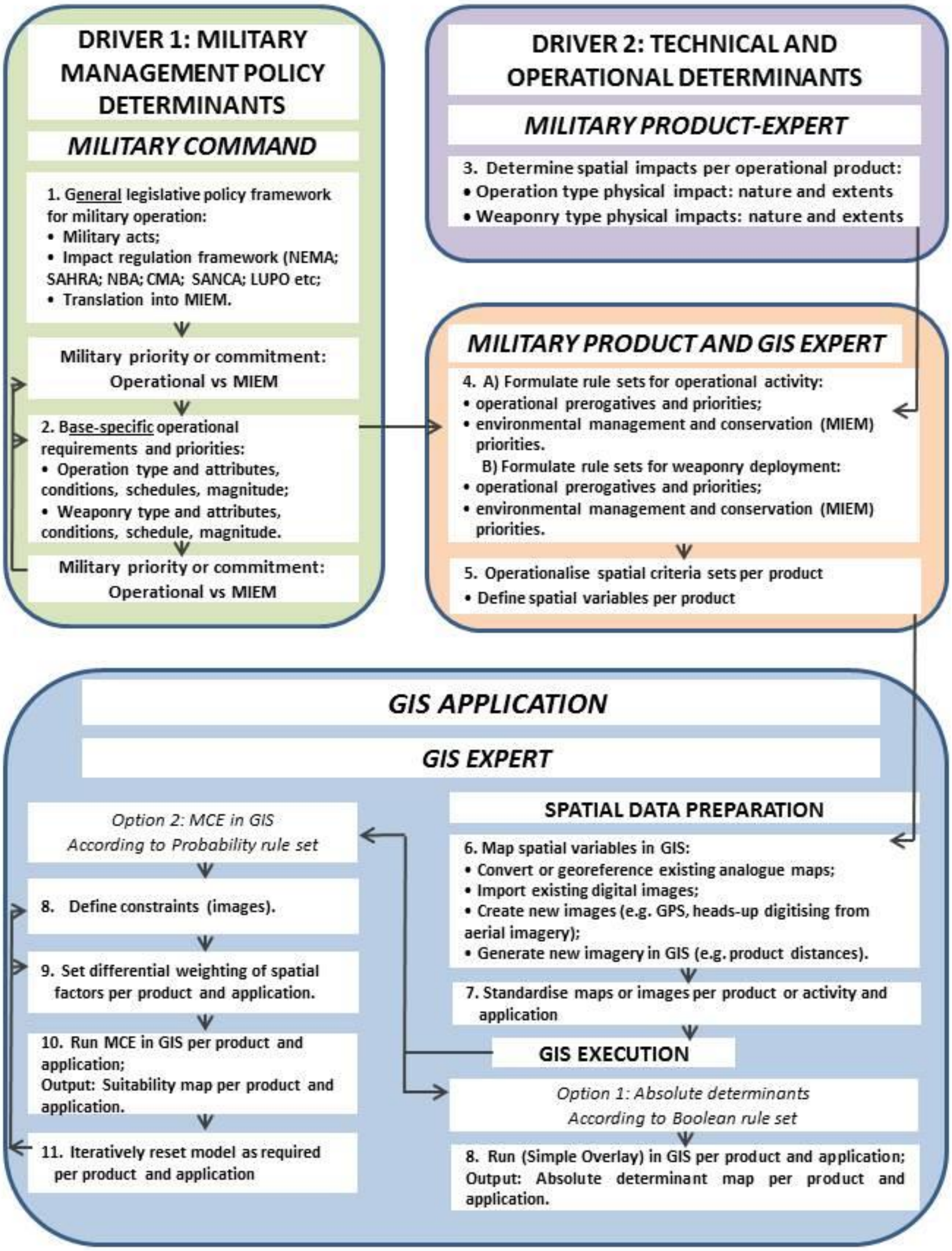


Figure 4.3 Flowchart of decision-making tasks and analytical options for supporting MIEM with GIS

specific imperatives made of particular operational environments and the local bases responsible for them. The end result of this 'driver' is a clear directive to each command post on the alignment between MIEM and operational imperatives to be acted upon by base commands.

As a consequence, at the individual operational level, the geospatial model requirements are driven by the technical military determinants and characteristics of the specific military activity taking place there, i.e., weaponry discharged, vehicular and other movement taking place and creating environmental impacts of a given type and extent. Determining the impact falls within the domain of the military product-expert. This functionary could be locally based, but could also be sourced nationally or even internationally to ensure a proper understanding of impacts is derived for incorporating and translating into the impact rule base of each particular activity type. Up to this point (Steps 1-3) in the modelling framework, the model has national (i.e. all SANDF) relevance and implications. The model construction focus then (Steps 4, 5) moves to the technical level of geographical information system (GIS) construction and tailor-making its operation at the local base level. This requires close co-operation between the military expert and the GIS designer at base level. These functionaries now have to formulate workable rule sets for ensuring that management and operational deployment prerogatives are captured in modelling format. Most importantly, the spatial data sets capturing the essence of the operational space (human, infrastructural, natural and operational) in a GIS database, as prerequisite for designing the geospatial modelling application, must be decided upon.

4.2.2 Military GIS application options

The process executes Steps 6-10 in Figure 4.2 and entails the gathering and construction of the appropriate geospatial data in electronic map format. It includes both the importation of existing electronic data layers, digital conversion of existing maps, and the employment of GIS functions to generate distance and buffering images. Also, some physical features may be manually digitised by heads-up or similar digitising exercises. The final data preparation step typically involves the conversion of the electronic data layers to standardised values reflecting some form of meaningful pronouncement on, for instance, sensitivity to impacts or suitability for various purposes.

Execution of the GIS model can follow one of two options, depending on the decision-making mode envisaged. The option hinges on whether some operational decisions need to be guided or whether best-practice alternatives need to be determined. The former mode is typically applied in operational decision-making and guidance of activity execution and is therefore based on 'hard' determinants. The latter mode allows more subtle decisions to be made based on human judgement and weighted multiple criteria.

In the first decision-making mode the contributing data layers used to generate 'hard' decisions are generated with a Boolean (1=allowed/suitable, 0=not allowed/unsuitable) value scale that therefore allows an activity in a spatial cell or disallows it according to the variable of the layer. Since the 'sifting' of spatial cells occurs through an overlaying procedure, it means that multiple layers can be overlaid to cumulatively generate a Boolean results layer on which of course all cells that have the value 1 allow the activity and all zeroes disallow it. The point is that if one contributing layer has a zero in a particular cell, that cell gets the value zero (disallowed) disregarding the possibility that all other criterion layers may have had 1s in that particular cell – hence the designation as 'hard' decision-making. Some of the applications on offer later in this chapter actually applied this mode – where deemed appropriate for the operational conditions.

The second decision-making mode follows a much different path. The contributing data layers used to generate its more subtle (some might argue more realistic) decisions have ordinal values in their image cells, based on prior classification procedures to produce a suitability or sensitivity rating implied by the original raw values implication for the particular activity being influenced by or impacted on. These contributing criteria are also not simply overlain cumulatively, but the criteria are differentially weighted and then mathematically combined (see Equation 2) to generate a graded value range denoting a cell's suitability or sensitivity for the activity. A final process allows the incorporation of Boolean imagery as 'constraints' disallowing activities in particular areas according to absolute no-go rules. Clearly, human decision-making is better accommodated or even emulated and led by this latter method – one particularly suited to environmental management philosophically residing somewhat uncomfortably beside 'hard' military decision-making? (Van der Merwe et al. 2013).

4.3 OPERATIONALISED MCE IN MILITARY GIS

To operationalise MCE application in GIS and thus to bring the conceptual model from the previous sections to bear in military context on DMTA in this dissertation, a number of operational steps had to be performed. These steps are each deployed in the subsections below and amounted to:

- Develop a set of bounding geographical (impact) rules for each military-training activity expected to take place on DMTA (listed previously in Chapter 1);

- Design, implement and populate a rule base (i.e. database of rules) that captures the geographical manifestation and activity impacts of the conduct rules for each training activity;
- Create an electronic georeferenced geographical database of all relevant spatial features (installations, activity zones), on the DMTA in the relevant GIS format (standardised sensitivity maps);
- Collaboratively design a weighted significance rating hierarchy for all activities and impact vulnerabilities; and
- Develop and implement a protocol (inference engine) to model the potential environmental impacts of individual and combined military activities in DMTA space to demonstrate the capabilities of the system for an example training scenario.

4.3.1 Environmental impact of military operations

The first order of business in MCE application is to determine the range and nature of all possible impacting activities that take place on military terrain and to rate the impacting importance of each activity as shown in Table 4.2. As previously indicated, DMTA offers a uniquely diverse military activity space. Twelve types of weapons or ammunitions discharge, three types of parachuting, three types of diving, three types of surface swimming, three types of boat work, four types of vehicle training, and seven types of miscellaneous training activities (ranging from hiking, climbing, flying to firing of arms) have been distinguished as major activity groups. For each of these 40 types, the affected locational or structural designations, high-impact season or affecting weather conditions and impacts range have been declared. Finally, a Likert-scale rating value between 1 (very low impact severity) and 5 (very high severity) had been awarded. This value was deemed proportional to the extent, magnitude and severity of real or potential damage that have been observed or could reasonably (based on cumulative experience of a team of military officers consulted as part of the exercise) be expected to result from the performance of the particular activity type.

4.3.2 Geographical database development

For this project, a range of spatial data were collected for DMTA. This includes topographical, environmental, cultural, infrastructure and military data. All allocated areas for specific activities executed by operators, support personnel or visiting courses were mapped in accordance with the applicable variables. Activities were categorised in terms of location information, temporal factors, weather conditions and distance threshold as shown in Table 4.2. A viability figure from zero to five was allocated to each activity taking the previous mentioned variables into consideration. In Table 4.2 the weaponry and munitions applied on DMTA are firstly discussed followed by the main activities executed on DMTA. The impact distance threshold can vary during different scenarios for example when house clearing is executed sniper fire will be directed at targets near to advancing offensive troops and indoors stun grenade detonations and small arms fire will be in close proximity of the urban operators. The safety distance for weapons delivering support fire such as the LMG will also lessen considerably from the 3675m mentioned in Table 4.2 when operators are advancing or withdrawing in bounds.

The locational restrictions and environmental impacts of the different operational activities at DMTA were translated to a set of rules that can be used to model and map the potential environmental impact of each activity. The geographical information system (GIS) data that have been collected for DMTA were converted to a rasterised land unit database (LUD) consisting of a square cell (10x10 m) grid. The database stores, for each cell, values or codes for a number of attributes that quantify its distance from relevant geographical features and membership to specific feature classes with activity relevance within the training area (e.g. denoting infrastructure like firing ranges, roads, power lines, and areas considered to be environmentally sensitive). With the land unit database completed, a separate (nonspatial) database was developed and populated with impact rules pertaining to each military activity type. Each rule in this rule base was linked to a specific military activity. For instance, no rock landings are allowed within 10 m of the unique botterboom (*Tylecodon paniculatus*) stands on the northern shore of DMTA. By querying the system, a map can be created of areas where rock landings are permitted or where the environmental impact is minimised. Multi-criteria evaluation (MCE) was used to develop a sensitivity map. The sensitivity map can be used in combination with the activities rule base to consider the environmental impact of individual or multiple activities. A map server (web server capable of creating and serving maps via the internet) was configured at Stellenbosch University's Centre for Geographical Analysis (CGA) to accommodate, develop and demonstrate the system. A graphical user interface was developed to allow users to interact with the system via the internet (Van Der Merwe et al. 2013). The digital elevation model (DEM) used in this study was the 5 m Stellenbosch University Digital Elevation Model (SUDEM), created from a combination of error-free 5-20 m contours, spot heights and the Shuttle Radar Topography Mission (SRTM) DEM

Table 4.2 Military activities, impacts and impact ratings on DMTA

MILITARY ACTIVITY	AFFECTED AND DESIGNATED LOCATIONS OR STRUCTURES	TEMPORAL CONDITIONS	WEATHER CONDITIONS	IMPACT DISTANCE THRESHOLD (m)	SEVERITY RATING
WEAPONS/ AMMUNITION					
Pyrotechnics	All allocated shooting ranges and general training areas	All year	Not to be used during the dry season when the wind is stronger than 30 km/h.	500 m from all infrastructures	5
	Power lines	All year	Ditto	280 m from high voltage power lines; 50 m from low-voltage power lines	1
	Radio antennas and masts	All year	Ditto	280 m radius from center of antennas and masts	1
	Islands	No time during year, especially not Sep to Feb	Ditto	500 m radius around islands	0
	Beaches and Riet Bay	All year but not Dec to Jan	Ditto		3
	Places to avoid with flares: Not in bus, killing house, any building and indoor shooting range or near Hugo's Post.	No time during year		No shooting of flares closer than 1000 m to Hugo's Post perimeter	0
General notes: Port control must be informed 24 hrs. prior to any exercise with illumination devices. Thorough sweeping of the area after exercises is important (see environmentally-harmful impacts). High-voltage power lines stretch from Donkergat to Hugo's Post and Salamander and low-voltage power lines are the 220-volt lines between buildings.					
Grenades (M26 HE)	Field firing and Blouwildebeest Bay (Bwb B) range only	All year	Ditto	100 m	5
Stun and star instant light grenades	Killing house and bus ranges	All year	Ditto	10-20 m	5
	Survival area and on E&E exercises	All year but not Dec to Jan near beaches	Not to be used when the wind is stronger than 30 km/h	10-20 m	3
Demolitions	Demolition range. Field firing range. Charges only up to 3 kg. If in excess of 3 kg it must be approved by the OC 72 hrs. prior to the exercise and warnings must be issued to civilians.	Mar to Aug	No demolitions on land ranges when wind is stronger than 30 km/h	Demolition range may not be used if urban, field firing and pistol ranges are in use	5
		No demolitions Sep to Feb due to birds breeding on islands			0
	Shallow-water dems range charges up to 50 kg (to be changed). Deep-water dems range charges up to 100 kg (to be changed).	No demolitions from May to Dec when whales are in the area	All weather conditions	No underwater demolitions may be initiated if whales/dolphins are within a radius of 6 x SCSD (m). SCSD (Surface Craft Safety Distance) = 15√mass of explosives (kg) = SCSD (m)	3
				Repetitive detonations may only be initiated once birds scavenging on dead fish have left the area.	0
9 mm pistols	All allocated ranges	All year	All weather conditions	50 m. When FX barrels and ammunition are applied all urban and rural training areas may be used.	5
	Demolition and mortar ranges	All year	All year		1
5,56 mm rifles	Classification, field firing and Bwb B ranges	All year	All weather conditions	2 200 m	5
Weapons such as LMG's	Field firing and Bwb B ranges only	All year	All weather conditions	3 675 m	5

Table 4.2 continued

MILITARY ACTIVITY	AFFECTED AND DESIGNATED LOCATIONS OR STRUCTURES	TEMPORAL CONDITIONS	WEATHER CONDITIONS	IMPACT DISTANCE THRESHOLD (m)	SEVERITY RATING
WEAPONS/ AMMUNITION (continued)					
Sniper rifles	Sniper and classification ranges	All year	All weather Conditions	3 675 m.	5
20 mm cannons/40 mm AGL	Bwb B range only	All year	All weather conditions	3 600 m	5
40 mm MGL/ RPG7/ M203	Field firing and Bwb B ranges only	All year	All weather conditions	920 m	5
60 mm mortars	Mortar, field firing and Bwb B ranges only	All year	All weather conditions, except illumination not to be thrown in wind stronger than 30 km/h.	Safety distance 250 m. Smoke and illumination bombs may be fired as long as intended target area is free from buildings, personnel and equipment.	5
	During parades and night exercises	Not on parades near Meeuw Island (on the *Karatara* wreck) from Sep to Feb		500 m radius around islands from Sep to Feb	3
81 mm mortars	Mortar ranges only when firing HE bombs	All year	All weather conditions, except illumination not to be thrown in wind stronger than 30 km/h.	Safety distance 3 000 m. Smoke and illumination bombs may be fired as long as intended target area is free from buildings, personnel and equipment. 500 m radius around islands from Sep to Feb.	2
PARACHUTING					
Land jumps: Static line/ square/free-fall/tandem	Springbok Park and old cultivated lands south of Riet Bay	All year	No jumping if wind stronger than 24 km/h	300 m radius from drop zone (DZ) for any power lines and obstacles (obstacle 1 000 ft above elevation of DZ, 5 km away; 300-1 000 ft above elevation of DZ, 3 km away)	3
Water jumps	Langebaan Lagoon	All year	No jumping if wind stronger than 24 km/h	500 m length for first jumper, plus 60 m for each additional jumper. Width of water DZ according to number of aircraft (500 m for first aircraft plus 100 m for each additional aircraft)	5
Freight and equipment drops	Langebaan Lagoon	All year	Wind restriction 24 km/h	250 m from spectators, DZ length 250 m, width 500 m	5
No activities may take place on Meeuw Island and aircraft may only fly over or touch down for emergencies.					
DIVING					
Attack-diving I	Pre-secured areas, from Salamander Point to Perlemoen Point	All year	Up to sea state 4	Not nearer than 1 000 m to any vessel underway. No diving under vessels	5
	Salamander Point to Jutten Point, except Bwb B and Jutten Bay areas				3
	No diving from Jutten Point to Plankies Bay border				0
Attack-diving II	Pre-secured areas, from Salamander Point to Perlemoen Point	All year	Up to sea state 4	Not nearer than 1 000 m to any vessel underway. No diving under vessels	5
	Salamander Point to Jutten Point, except Bwb B and Jutten Bay areas				3

Table 4.2 continued

MILITARY ACTIVITY	AFFECTED AND DESIGNATED LOCATIONS OR STRUCTURES	TEMPORAL CONDITIONS	WEATHER CONDITIONS	IMPACT DISTANCE THRESHOLD (m)	SEVERITY RATING
DIVING (continued)					
Diving training/ exposure under supervision and testing of new equipment.	Dgt Trg area (dive tank and swimming pool) and closed waters in Stink- and Donkergat Bay).	All year	Up to sea state 4		5
	All other areas not suitable.				1
SURFACE SWIMMING					
Beach landings	Stink-, Bwb-, Jutten- and Plankies Bays Feb to Nov	All year	No training above sea state 3		5
				No landings at Bwb-, Jutten-, Plankies- and Riet Bays during breeding season of oystercatchers (Dec to Jan)	0
Rock landings	Boat Rock, Jutten Point, Bwb B and Elands Point	All year	No training above sea state 1		5
				Not nearer than 10 m from botterboom plants (Salamander Point) and WWII battery structures perimeter	3
General training	All trg area facilities as on map & swimming pool	All year	All weather conditions	Shooting range boundaries when live firing is in process	5
BOAT WORK					
Surf work	Plankies-, Jutten- and Bwb Bays areas	All year	No training above sea state 3		5
				If whales are in the area (May to Dec) not nearer than 300 m from animals	3
Openwater work (hoisting and boat formations)	Lagoon area and pre-approved routes on open waters	All year	No training above sea state 3		5
				If whales are in the area (May to Dec) not nearer than 300 m from animals	3
	Meeuw Island			Not nearer than a radius of 500 m around Meeuw Island	0.
Sailing	All areas in the lagoon. Traveling north from Saldanha area to Lamberts Bay or traveling south from Saldanha area to Simon's Town	All year	Maximum sea state: Winds up to 40 knots can be negotiated with minimum rigging.	If whales are in the area (May to Dec) not nearer than 300 m from animals. Not nearer than one nautical mile (nm) from the coastline except when nearing the operational jetty at Donkergat.	5
VEHICLE TRAINING					
Sedan/trucks	DMTA gravel roads	All year	No vehicles on gravel roads in case of excessive rains (more than 20 mm)	No vehicles on beaches except when recovering capsised boats or during medical emergencies	Sedan 3, trucks 1
	Tar roads				Sedan 5, trucks 2
Cranes	Only at Donkergat and Salamander, for example jetties and slipways	All year	All weather conditions	Not more than 10 m outside developed areas, except for maintenance and emergencies	4

Table 4.2 continued

MILITARY ACTIVITY	AFFECTED AND DESIGNATED LOCATIONS OR STRUCTURES	TEMPORAL CONDITIONS	WEATHER CONDITIONS	IMPACT DISTANCE THRESHOLD (m)	SEVERITY RATING
VEHICLE TRAINING (continued)					
Heavy machinery (forklifts etc.)	Only at Donkergat and Salamander, for example jetties and slipways	All year	All weather conditions	Not more than 10 m outside developed areas, except for maintenance and emergencies	4 max.
Motorcycles/ quad-bikes	Existing routes on DMTA	All year	Not on gravel roads if it rained more than 20 mm	From Nov to Jan not allowed closer than 100 m to any beach areas because of breeding oystercatchers	5
	Dunes, Riet Bay, the sediment track and beaches	Not any time of year			0
MISCELLANEOUS TRAINING					
Helicopter (fast roping/ rapelling)	Springbok Park and killing house range	All year	Wind not more than 30 km/h	Not closer than 50 m from any infrastructure such as power lines, etc.	5
	All other open areas				5
				500 m radius around islands; Meeuw Island out of bounds	0
Firing weapons from sea to land	Bwb B shooting range	All year	During dry season no tracers or any ammunition that can initiate a fire if wind is in excess of 20 km/h.	Not at any other area	3
Mountain-eering (rock climbing)	Operator's Kop area	All year	No climbing if wind is in excess of 20 km/h	Not at any other area	3
	Climbing wall (4.1 Comdo)				5
Urban tactics and techniques	Urban facilities	All year	All weather conditions	Not at any other area	5
Fire and movement techniques	Field firing and Bwb B ranges	All year	No shooting of ammunition that poses a fire hazard if wind is in excess of 20 km/h.	No more than 10 m around perimeters of shooting ranges. All other areas out of bounds	4
Walking/ hiking	Road network on island	All year	All weather conditions	Dec to Jan not nearer than 50 m to oystercatcher breeding areas	5
	Walking on rest of DMTA				3
	Riet Bay and cultural-historic sites				2
	Cliffs and rocky areas along coast				1
	At Bwb B field firing and on land demolition range hikers should keep to existing footpaths.				1
Survival techniques	South Head anticlock-wise to Plankies Bay e.g. rocks at South Head	All year.	All weather conditions	No food collecting nearer than 100 m to oystercatcher breeding areas during breeding season (Nov to Jan)	4
	No survival from South Head clock-wise to Riet Bay				0
	No survival at caves west of Plankies Bay.				0

(Figure 1.2). The SUDEM is currently the highest resolution and most accurate DEM covering the entire extent of South Africa (Van Niekerk 2012). The military activities, impacts and impact ratings on DMTA are shown in Table 4.2. Much of the data in mapped format, already discussed in Chapter 1, were collected using global navigation satellite system (GNSS) (or GPS) technology to ensure accuracy. Some data were also captured from high-resolution (0.75m) aerial imagery or obtained from secondary sources (e.g. vegetation, geology). All of the data were stored in a digital GIS database using a common coordinate system (Lo19) and reference datum (WGS84), allowing exact-fitting superposed overlaying.

The spatial database contained overlays capturing the exact location of the features listed in Table 4.3. Some of these features in map format hence became incorporated in the rules sets as the

Table 4.3 Spatial feature database compiled for DTMA

TERRAIN • Digital Elevation Model • Slope • Aspect • Geology FAUNA • Terrestrial life forms • Marine life forms • Bats	FLORA • Terrestrial natural vegetation • Disused cultivated areas • Marsh communities • Flora on Meeuw Island • Alien plant species • Marine flora HUMAN ENVIRONMENT • Heritage sites • Paleontological resources • Infrastructure • Military facilities and activity areas

receiving phenomena upon which military activity might have some impact or, conversely, that might determine the possibilities and suitability for allowing particular types of military activity. From these base maps, using GIS utilities, further information overlays could be generated.

Salient examples are distance buffering from chosen target and vulnerable features. They were also employed to capture further overlays that were operationally required to bring objectively calculated sensitivity to military activity of features into the modelling domain. This sensitivity mapping endeavour is discussed next.

4.3.3 Environmental sensitivity mapping

An environmental sensitivity map for the DMTA was developed according to the principles of multi-criteria evaluation (MCE) explained in Section 4.1 – to which the discussion reverts regularly. From the military policies studied (Step 1 of the MCE procedures in both Figures 4.1 and 4.2), it was clear that the main factors influencing the environmental sensitivity of DMTA are vegetation, current land use, the coast line and topography (in particular slope gradient and elevation). These factors were consequently selected (Step 2) for inclusion in the MCE. The production of each standardised criterion map is discussed separately in the following subsections (i.e. Steps 3 and 4 of the MCE process). The colour scheme employed in maps was deliberately chosen to denote a range of ecological sensitivity to military and other activities. It ranges from highly sensitive (red) through the spectrum to dark green implying low sensitivity. This is followed by an explanation of how the different criteria were weighted according to their importance (in terms of environmental sensitivity) and how they were combined to produce a composite index of sensitivity.

4.3.3.1 Vegetation sensitivity

As described in Chapter 2, DMTA is home to a range of sensitive terrestrial flora. For the purposes of this study, the vegetation type map that was originally developed by Boucher & Jarman (1977) was spatially refined through accurate field survey and GPS demarcation of discernible stands. The field map was then digitised (as shown in Figure 2.7) and each vegetation type was rated from 1 to 5 (with 1 representing low and 5 high) according to its perceived sensitivity to military-training operations as described under vegetation communities (Section 2.4). Table 4.4 lists the sensitivity ratings for each vegetation type. While the West Coast thicket is generally considered

Table 4.4 Environmental sensitivity ratings for vegetation types

TYPE	**SENSITIVITY RATING**
Coastal shelf	3
Coastal shelf *Atriplex/Zygophyllum*	3
Coastal shelf *Pelargonium/Muraltia*	4
Granite soil communities *Erharta/Maurocenia*	5
Limestone soil communities *Zygophyllum*	4
Dune sand communities	2
Dune sand communities *Didelta*	2
Dune sand communities *Hermannia*	2
Disused cultivated fields	1
Marsh	5
Unsure	1

botanically unique and hence sensitive to all forms of damage to or removal of vegetation, some plant families are more highly rated based on the nature of the plant (size, consistency of stand), the stand size and its known sensitivity to specific types of human or natural interference. The granite and limestone (Operators Kop) soil communities, as well as the Riet Bay marsh area, are small in comparison and the particular species occurring there were rated as having the highest sensitivity.

The coastal shelf and dune sand communities are considered less sensitive, because they cover larger areas, have adapted to animal (and human) movement impacts and can therefore recuperate more readily from incidental damage or challenging climatic events that would normally render them more vulnerable to interference. Likewise it should be noted that the coastline is buffered for 500 m from the shoreline for locational sensitivity, therefore creating an overlap with the vegetation criterion. The least sensitive vegetation type is the disused cultivated fields, which contain no pristine natural vegetation. An 'unsure' category was included for future refinement, but no such category has been mapped at the current resolution. The spatial manifestation of the vegetation sensitivity rating is shown in Figure 4.4. It is clear that most of the DMTA is covered by vegetation with moderate to high sensitivity (as indicated by colours towards the red spectrum) – especially on the peninsula. Only a few areas have relatively low vegetation sensitivity (as indicated by the green shades) and these dominate on the main land area.

4.3.3.2 Land use sensitivity

Current land use types in DMTA were mapped using a combination of field visits and visual interpretation of aerial photographs (as displayed in Figure 1.1). The sensitivity of the land uses were rated (Table 4.5) using the same standardised 1-5 rating scale used for vegetation types (see previous section). The beaches, dunes and the marshland of Riet Bay were deemed highly sensitive,

Table 4.5 Environmental sensitivity ratings for land use types

TYPE	SENSITIVITY RATING
Human settlement/buildings	Constraint/5
Roads	Constraint/5
Cultural artifacts; 200 m perimeter	Constraint/5
Military terrains (ranges), sacrificed	1
Old disused fields	2
Natural vegetation	3
Riet Bay Marsh-Water surfaces	5
Fore dunes and sandy beaches: 200 m perimeter	4

while natural vegetation as a group was considered moderately sensitive to operations. Disturbed areas (i.e. old cultivated fields and shooting ranges) were considered the least sensitive land uses within the DMTA. In addition, structures, roads and cultural artefacts were regarded as no-go areas (no damage allowed) and were consequently also rated as highly sensitive to operations. Due to the extreme sensitivity of DMTA's heritage sites (see Chapter 3), a 200 m buffer area was reserved around all cultural artefacts.

The resulting land use sensitivity map is shown in Figure 4.5. Its spatial patterns highlight the 'islands' of sensitivity around the 'occupied' built-up enclaves in the north and along the beaches to the south. Core land areas on both the peninsula and the main land area are relatively insensitive to military activity on this criterion.

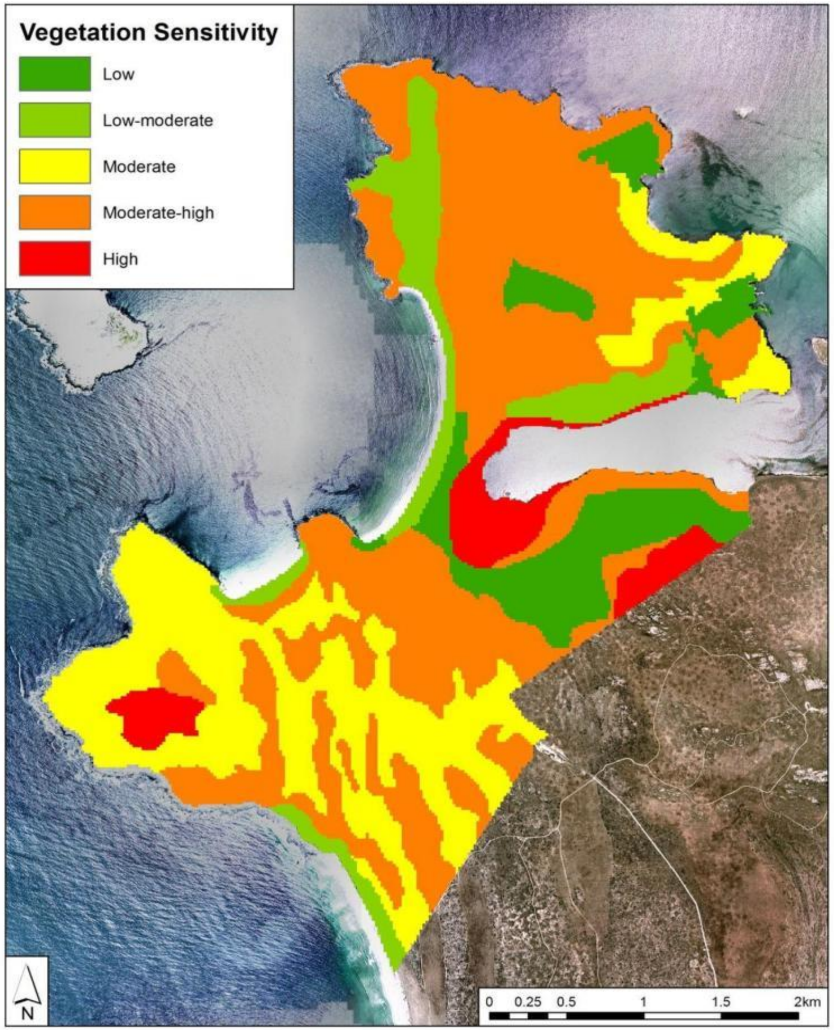


Figure 4.4 Environmental sensitivity of vegetation

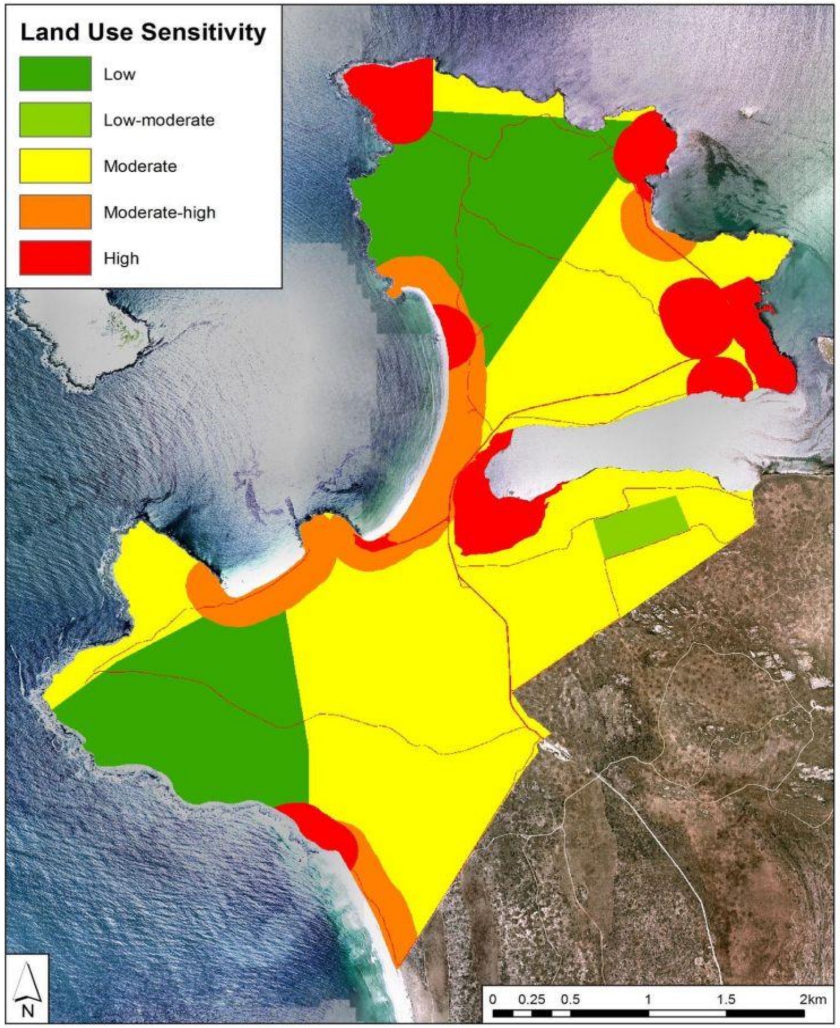


Figure 4.5 Environmental sensitivity of land use types

4.3.3.3 Coastline sensitivity

The relatively long coastline of DMTA is ideal for Special Forces operations training. However, some parts of the coastline are highly sensitive and should be protected from possible damage caused by training activities. A field survey of the coast was conducted with the resulting feature classification map shown in Figure 4.6. DMTA has a fairly long (23.7 km) and decidedly diverse coastline ranging from flat sandy beaches in the centre to vertical cliffs in the north. As Figure 4.6 attests it is possible and imperative to discern nine coastal characteristics that are important from both ecological and concomitant military operational perspectives. The classification scheme is based on a morphologically descriptive point of departure that includes both the coastal surface material (sandy, pebbly, rocky) and the topographical nature (dunes, cliffs).

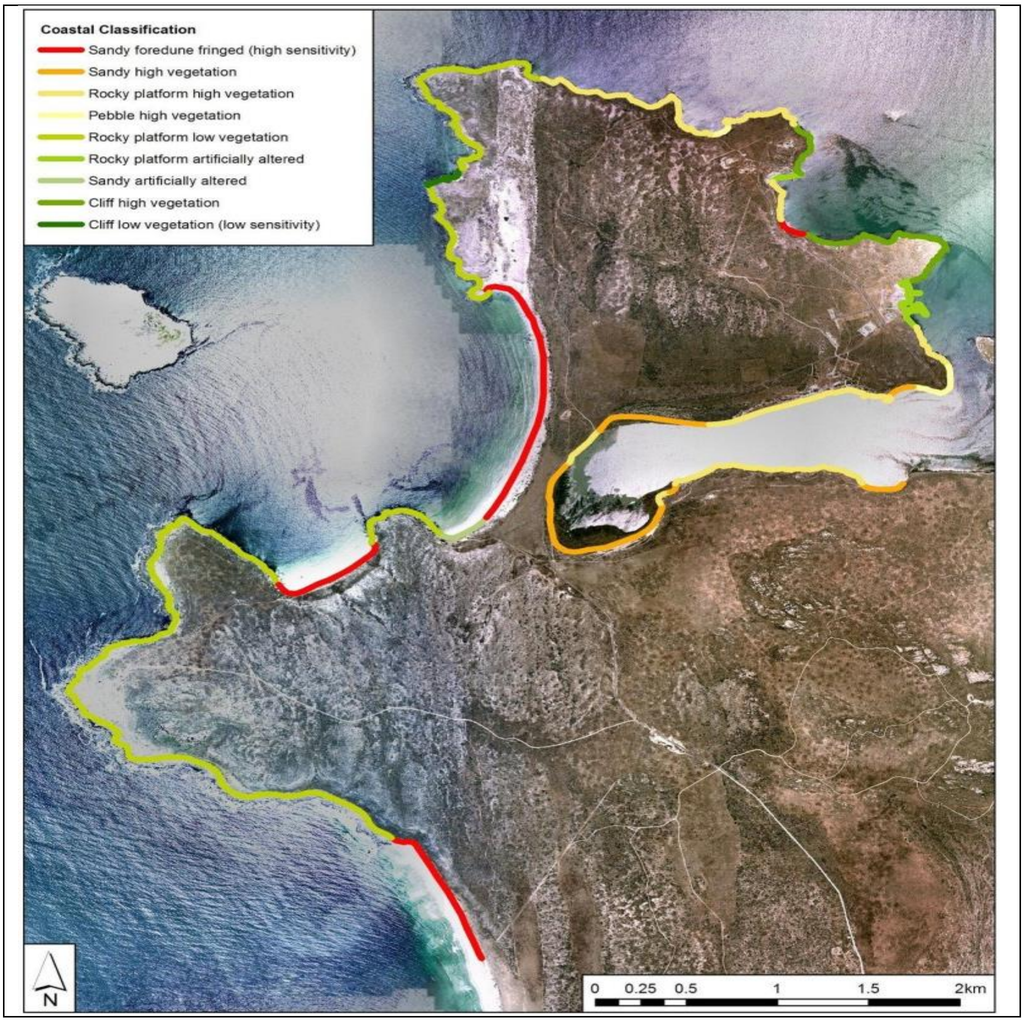


Figure 4.6 Coastline characteristics and sensitivity rating

Table 4.6 shows the sensitivity rating scheme applied to the various coastal features. Clearly, the fringed sandy fore dunes and the sandy high vegetation are the most sensitive parts of the coastline.

The cliffed coast was deemed the least sensitive, due to its difficult and inaccessible terrain and therefore the low likelihood of movement activity there.

Table 4.6 Environmental sensitivity ratings of DMTA coastline

TYPE	SENSITIVITY RATING
Sandy, fore dune fringed	5
Sandy, high vegetation	4
Sandy, artificially altered	2
Pebble, high vegetation	3
Rocky platform, low vegetation	2
Rocky platform, high vegetation	3
Rocky platform, artificially altered	2
Cliffs, low vegetation	1
Cliffs, high vegetation	1

Spatially applied, the coastline map was converted to a sensitivity map in the same way as was done for vegetation and land use, but the sensitivity ratings in Table 4.6 were applied to a 250 m wide buffer strip along the coastline as shown in Figure 4.7 – thereby imposing the coastline influence (actually a zone and not a mere line) more realistically. The sandy beaches (6.5 km) are popular breeding grounds for endangered species of bird such as the black oystercatcher and hence highly sensitive to all military activities. The Riet Bay shore carries an almost similarly high sensitivity rating due to the marine vegetation and fauna found in those shallow waters. From an operational perspective ease of vehicle and personnel movement (e.g. along and onto the 14.7 km platformed coastline) as well as the potentially detrimental impact of exploding munitions on fauna and flora are taken into account when denoting sensitivity.

4.3.3.4 Topographic vulnerability

Two topographical factors, namely slope gradient and elevation, were considered in the MCE. Slope gradient was selected because erosion potential increases as slope gradient increases. Slope gradient was calculated as a percentage using a digital elevation model and reclassified into five significant classes of steepness. Each class was then assigned a sensitivity rating based on the erosivity of slope classes as delimited here and as indicated in Table 4. 7. The sensitivity ratings in the table were applied to the land unit database to produce Figure 4.8, a sensitivity map of slope gradient. Much of DMTA has a relatively low sensitivity in terms of slope gradient, with only a few small coastal fringe areas in the south and north-west having a high sensitivity.

Table 4.7 Environmental sensitivity ratings for slopegradient classes

SLOPE CLASSES (%)	SLOPE DESCRIPTION	SENSITIVITY RATING
21-45	Near vertical slopes	5
11-20	Steep slope	4
5-10	Medium slope	3
1-4	Slight slope	2
≤1	Level	1

Additionally, Table 4.8 shows how the environmental sensitivity ratings for height above sea level (elevation) in the DMTA were calibrated. For simplicity, this criterion was split into high, moderate and low-lying terrain, along 40 m height intervals. Absolute height was deemed important from a sensitivity vantage because the highest ranges in the landscape are visually most exposed, surface features are hard and generate runoff and often richer, more unique and sensitive species (faunal and floral) congregate there. A map of elevation sensitivity is shown in Figure 4.13.

Table 4.8 Environmental sensitivity ratings for height above sealevel

HEIGHT CLASS	CLASS DESCRIPTION	SENSITIVITY RATING
>80 m	Highest landscape regions	5
40-80 m	Medium height	3
<40 m	Low-lying	1

4.3.4 Operational rule set development

Rules regulating the conduct of each activity type to minimise its impact on the operational environment were provided in Table 4.2 in a semi-structured linguistic format, which incorporated several constraint variables for each activity. In addition to described spatial features and distance thresholds from features, constraints were also specified for temporal conditions and weather conditions. To create the required spatial management system, the linguistic rule set was converted into a logical structure incorporating all of the constraint variables. To demonstrate this action, Table 4.2 shows the original semi-structured linguistic set of rules for pyrotechnics and Table 4.9 shows the same rules in a logical structure. To get from the linguistic rule set to the logical set was not a straightforward, logical exercise. Several collaborative work sessions between the author and the technical GIS team were required to create an operational logical rule set. Five activity rule sets were formulated to capture the rules in Table 4.9 for this activity type. Each set specifies whether some areas are excluded or all are included, whether there are temporal constraints allowing (month = 1) or disallowing (month = 0) the activity, and under what wind, rain, sea state or distance at particular locations these would prevail. The spatial outcomes of the rule application are shown in

Figures 4.9 to 4.12 for Rules 1 to 5. This application in fact demonstrates the Option 1 application in Figure 4.2.

Table 4.9 Pyrotechnics rule set in logical structure

Rule	Include/ Exclude	J	F	M	A	M	J	J	A	S	O	N	D	Wind (kph)	Rain (mm)	Sea state	Distance	Location
1	Include	1	1	1	1	1	1	1	1	1	1	1	1	<30	>=0	>=0	<=0	All areas within DMTA boundary
2	Exclude	1	1	1	1	1	1	1	1	1	1	1	1	<30	>=0	>=0	<=500	Islands
3	Exclude	1	0	0	0	0	0	0	0	0	0	0	1	<30	>=0	>=0	<=0	Beaches
4	Exclude	1	0	0	0	0	0	0	0	0	0	0	1	<30	>=0	>=0	<=0	Riet Bay
5	Exclude	1	1	1	1	1	1	1	1	1	1	1	1	<30	>=0	>=0	<=1000	Hugo's Post

Figure 4.9 shows the area available (area in grey) for pyrotechnics exercises after the application of Rule 1 (the entire DMTA, as can be expected from rule calibrations). Rule 2 in Table 4.9 specifies that, at any time of the year and under any wind, rain or sea state, the area within 500m of islands (Meeuw Island on DMTA in particular) is out of bounds and should consequently be removed from the areas available for pyrotechnics exercises. Consequently, Figure 4.10 removes the grey (available) concentric 500 m zone from around that island. Rules 3 and 4 in Table 4.9 stipulate that pyrotechnics activity is not allowed in Riet Bay or on any beaches during December and January as these areas are important breeding areas for local bird species. The geographical manifestation of these rules is shown in Figure 4.11. Finally, Figure 4.12 shows the area available for pyrotechnics exercises after Rule 5 had been applied and the area within 1000 m of Hugo's Post has been removed (pyrotechnics not being allowed in this area with its thatched roofs under any circumstances).

All the rules were implemented in the system. Activity rules can routinely be added, deleted or modified as new environmental or military technology knowledge becomes available, environmental regulation is altered or military operational imperatives are reformulated without affecting the operational integrity or practical implementation of the system.

From the foregoing it should be clear that the rules that are applied on the land unit database depends on the activity, date (month of the year), as well as wind, rain and sea state. These conditions are provided by the operator on the day of action, applied in the system and the result mapped to guide activity. Contingency planning at the time of operational or strategic scheduling of actions allows all rules to be implemented as possible scenarios. The next section explains how the environmental sensitivity of DMTA was incorporated in the system through the use of multi-criteria spatial analysis.

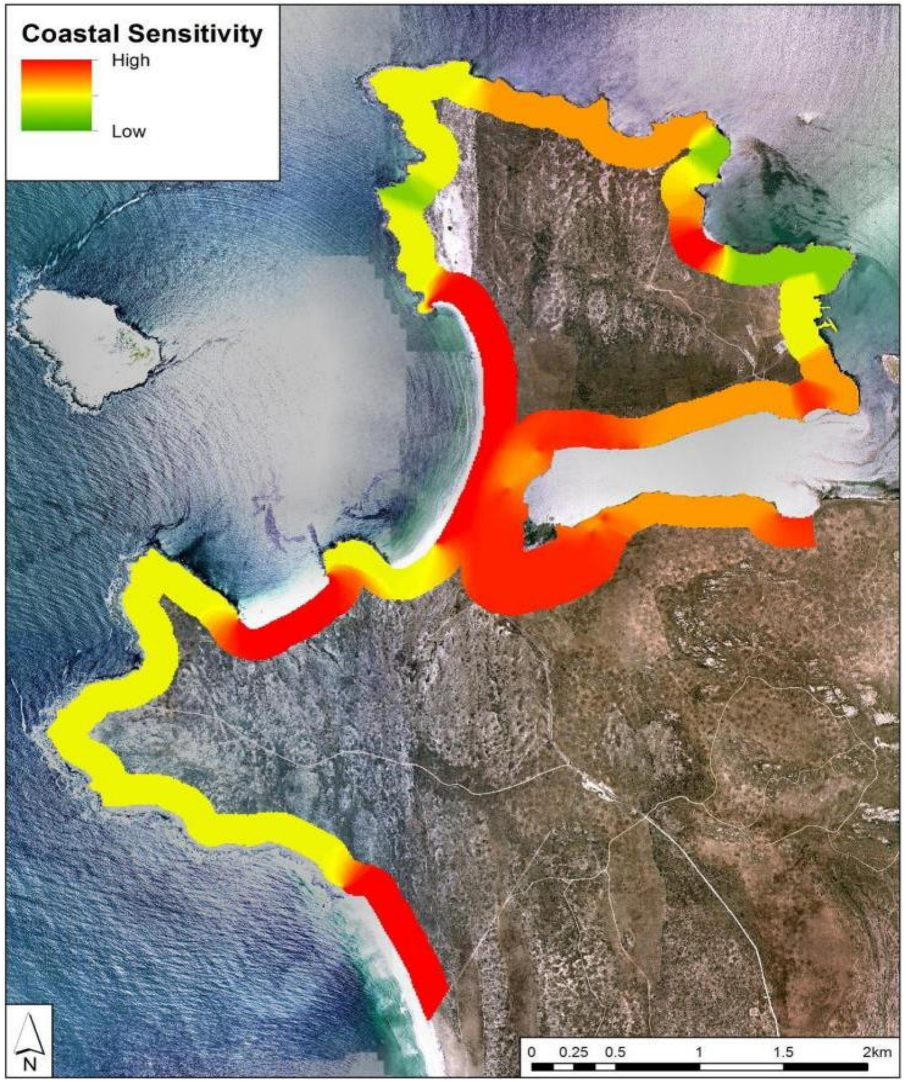


Figure 4.7 Environmental sensitivity of DMTA coastline

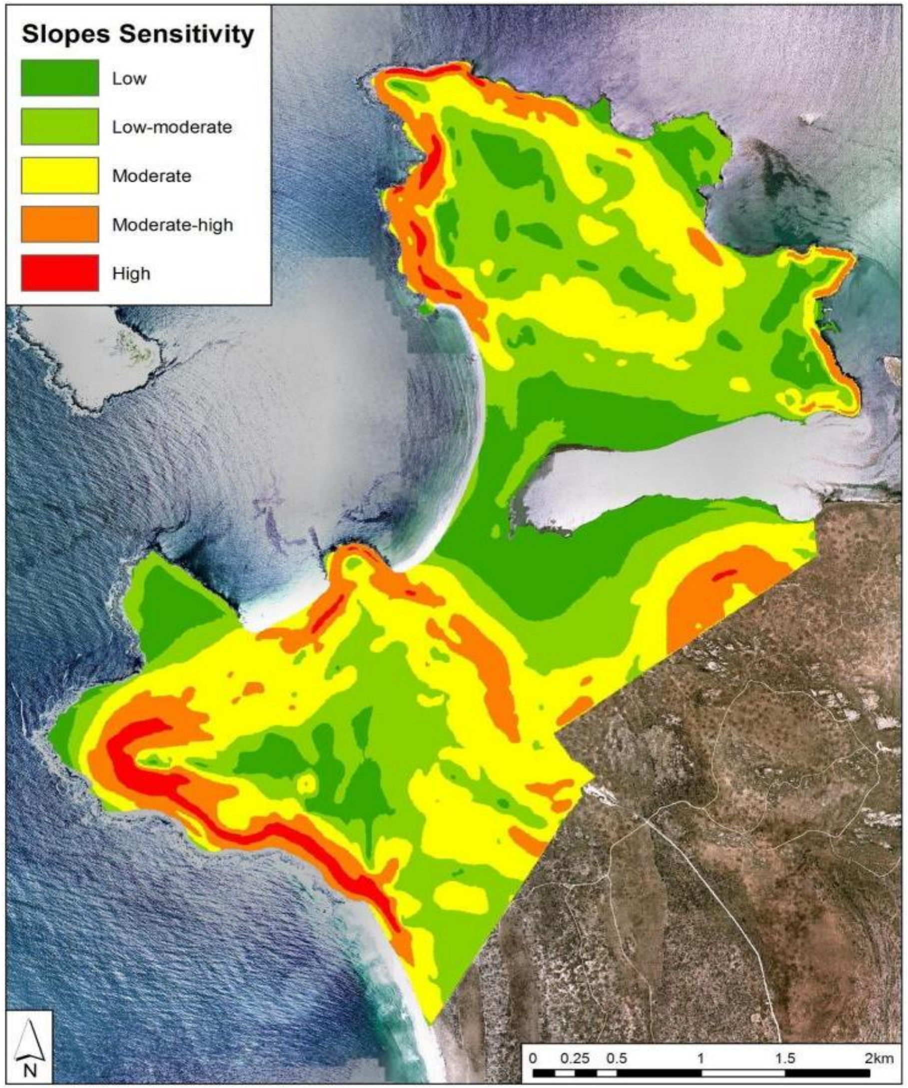


Figure 4.8 Environmental sensitivity of slopes

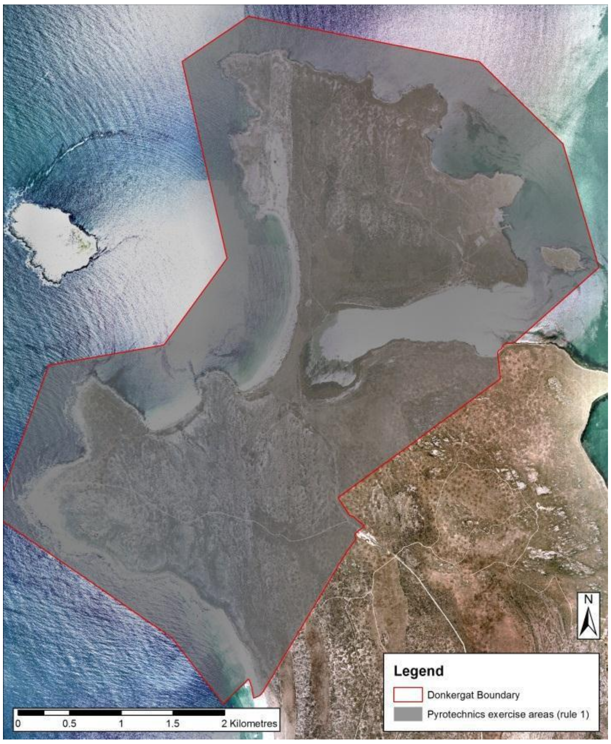


Figure 4.9 Spatial application of pyrotechnics Rule 1

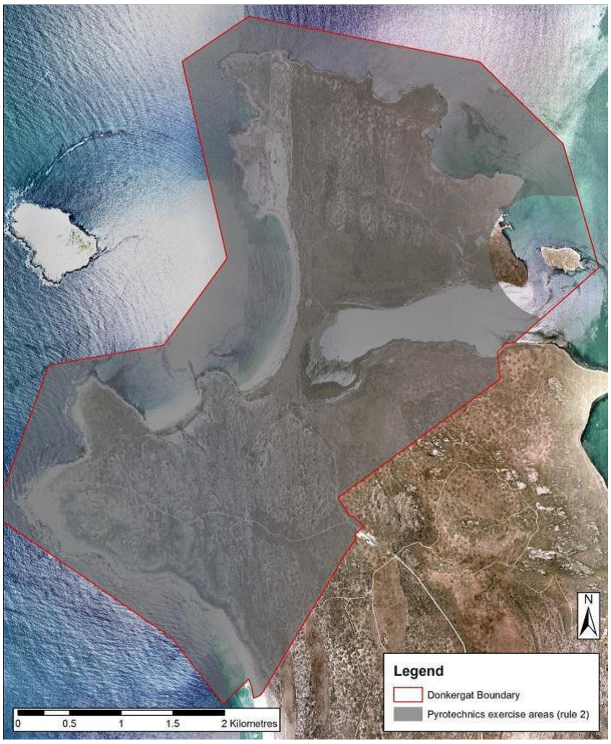


Figure 4.10 Spatial application of pyrotechnics Rule 2

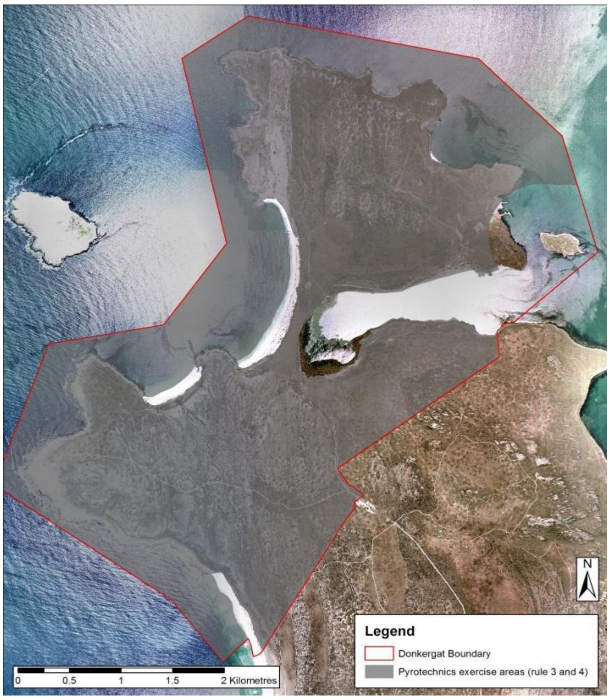


Figure 4.11 Spatial application of pyrotechnics Rules 3 and 4

Figure 4.12 Spatial application of pyrotechnics Rule 5

4.3.5 MCE: Criteria weighting and weighted overlay

The selected criteria were subjected to the AHP (see Section 4.1) to determine their relative importance (contribution) to environmental sensitivity in DMTA. The pair-wise comparison of the criteria resulted in (the weights) Table 4.10 (refer to Table 4.1 for a description of the values), indicating that, according to the researcher, vegetation is deemed the most important determinant of environmental sensitivity in DMTA. Of the five 'natural' factors or criteria, height (elevation) is considered to have the least impact on environmental sensitivity, since military activity is not confined by it in isolation, but actually in combination with the natural features (like vegetation species) located there. Of course, one has to recognise that the objective of the application (whether driven by the operational or by the ecological imperative) determines the weights awarded under the specific circumstance. As Figure 4.2 intimates for this step, this aspect is the one most readily subjected to iterative experimentation to ensure best results of the MCE application (final steps in Figures 4.1 and 4.3).

Table 4.10 Pair-wise comparison matrix

VARIABLE	Vegetation	Land use	Coastal topo	Slope	Height	Weight
Vegetation	1					0.42
Land use	2	1				0.26
Coastal topo	3	2	1			0.16
Slope	4	3	2	1		0.10
Height	5	4	3	2	1	0.06

The AHP Calculation software available at http://www.isc.senshu-u.ac.jp/~thc0456/EAHP/AHPweb.html was used to calculate the consistency index (0.02) of the matrix and to determine the relative weight (importance) of each variable. As seen in Table 4.10, vegetation contributes 42% of the 'influence', i.e. plays the strongest role in determining environmental sensitivity. This is followed by land use (26%), coastal features (16%), slope gradient (10%) and height (6%).

The individual criterion maps were functioned according to Equation 2 using the weights calculated in Table 4.10. ArcMap's Raster Calculator was henceforth used to create an overall environmental sensitivity map as depicted in Figure 4.14. This map demonstrates the outcome of the cumulative decision-making described in the preceding sections. Areas of specific sensitivity designation can be clearly relayed to the ratings of particular constituent factors or criteria portrayed earlier. Considering the cumulative influence of the constituent layers and – most importantly – their

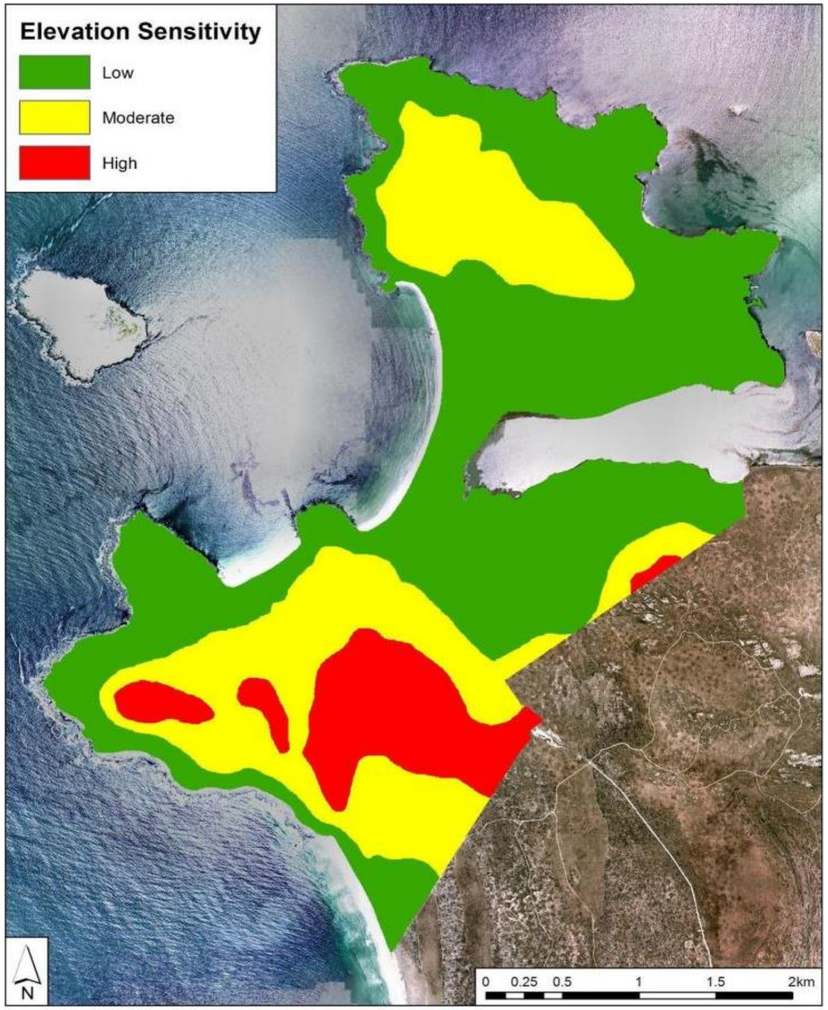


Figure 4.13 Elevation environmental sensitivity

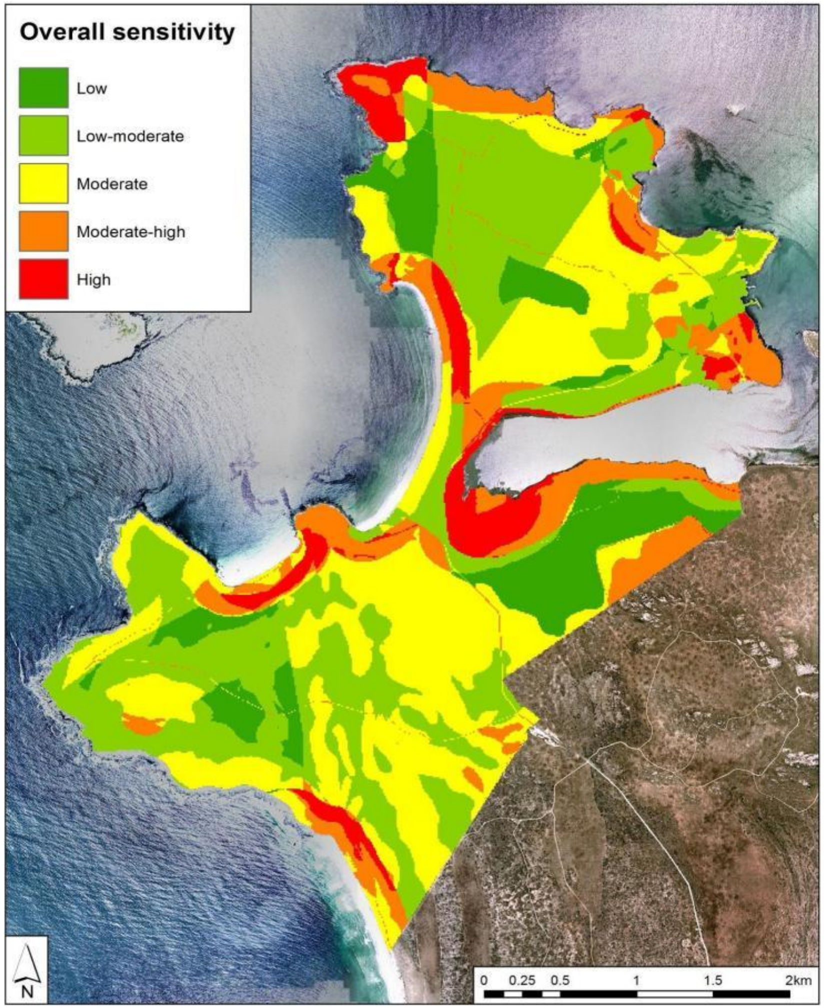


Figure 4.14 Overall environmental sensitivity

relative weighting. It is clear that the areas bordering much of the sandy coastline, particularly in the Riet Bay area, as well as along the north coast (WWII batteries, pelargonium vegetation zones, built-up areas) and where coastal dunes occur are highly sensitive. The old fields and adjoining natural areas are generally fit to be considered as 'sacrificed' areas for operational purposes. Note that this product (Figure 4.14) represents the outcome of the final Step 6 in the MCE process of Figure 4.1 and in fact demonstrates the Option 2 application in Figure 4.3. A reminder: decision makers (military officers and planners in this case) are now empowered to reconsider and revisit various earlier steps as required until an acceptable, functional operational plan – still in compliance with MIEM principles – is finalised.

The next section explains how the environmental sensitivity map can be incorporated into the SDSS to minimise the environmental impact of training activities.

4.4 SDSS: APPLICATION EXAMPLE

Following the capture of all spatial data, and having completed the MCE analysis, the development of the operational web-based system could commence and some real-world examples developed to demonstrate its utility. The web-based system consists of three main components: The first is the web application, developed in Adobe Flex, which provides the interface for the user to view and manage the data; The second is the ArcGIS Server Map Service, which serves the spatial layers to the web application, along with their pre-configured symbology; The third is the ArcSDE Geodatabase, which stores the spatial layers accessed by the map service. These systems are not fully explored here, because the technical service was rendered by a GIS team at CGA and as such does not form part of the dissertation reporting.

In this section a limited selection of military activities that take place on the area is presented to demonstrate an application of the proposed operational model. Figure 4.15 shows the allocated shooting ranges of DMTA of which the utilisation is elucidated, taking into account the localities where other overlapping training activities may be executed simultaneously. This consideration is important where shooting ranges fully encircle some of the training areas such as the one at Jutten Bay (Figure 4.15) where other training activities such as beach landings are performed. Training exercises in the bay cannot be conducted simultaneously with shooting exercises on, for example, the field firing range (compare spatial overlap on Figures 4.15 and 4.16).

The web application includes activation of several information layers. A topographical base map layer (Figure 4.17) from ArcGIS Online provides context and orientates the user. The extent of this

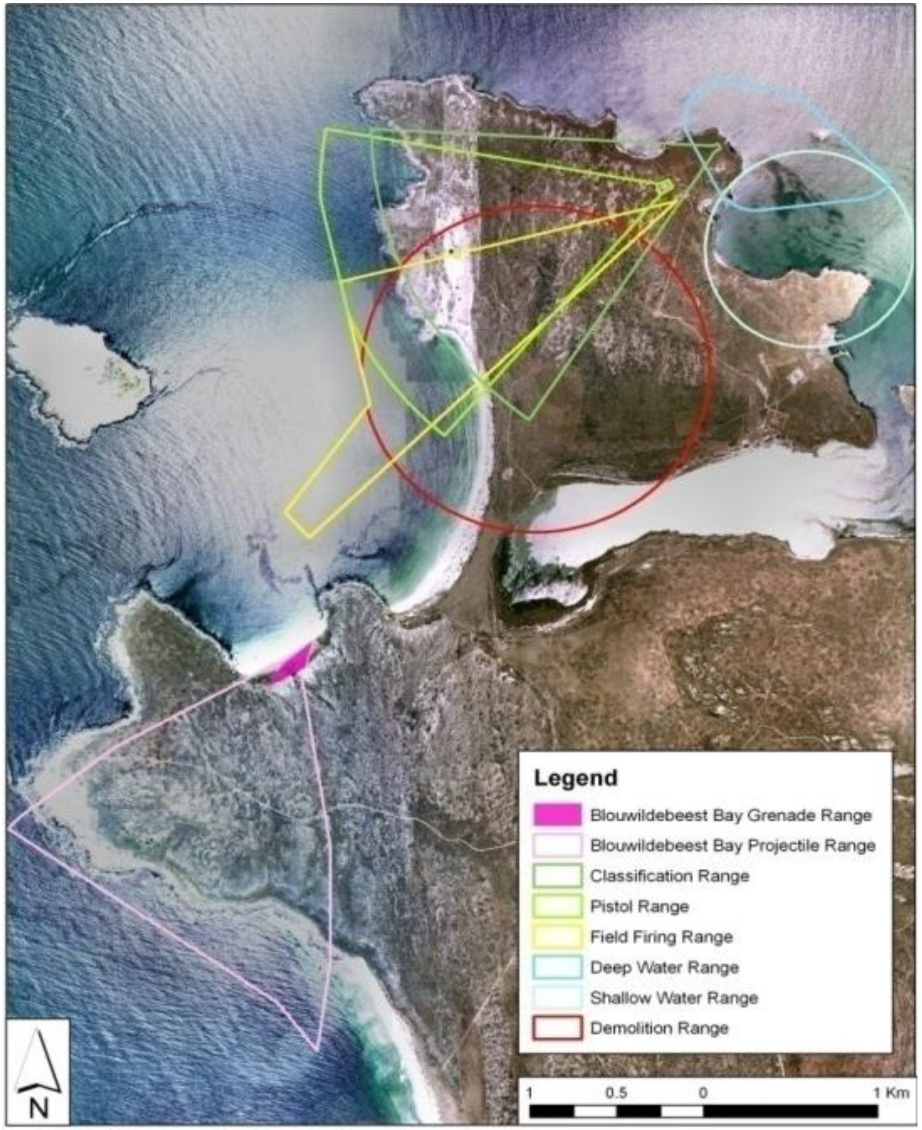


Figure 4.15 Shooting ranges on DMTA

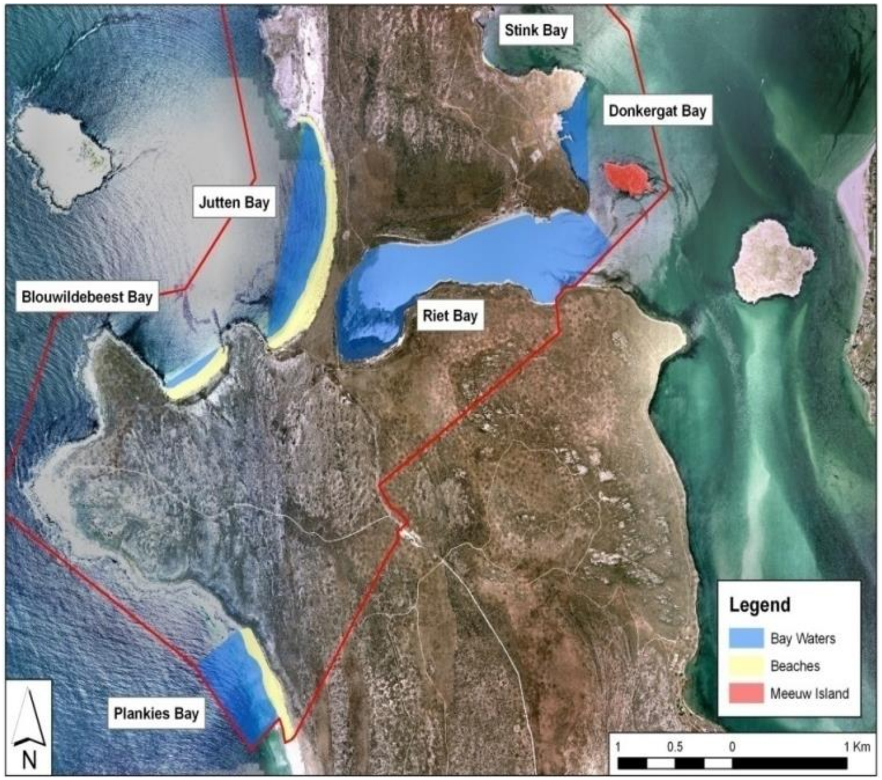


Figure 4.16 The bays where training activities take place in DMTA

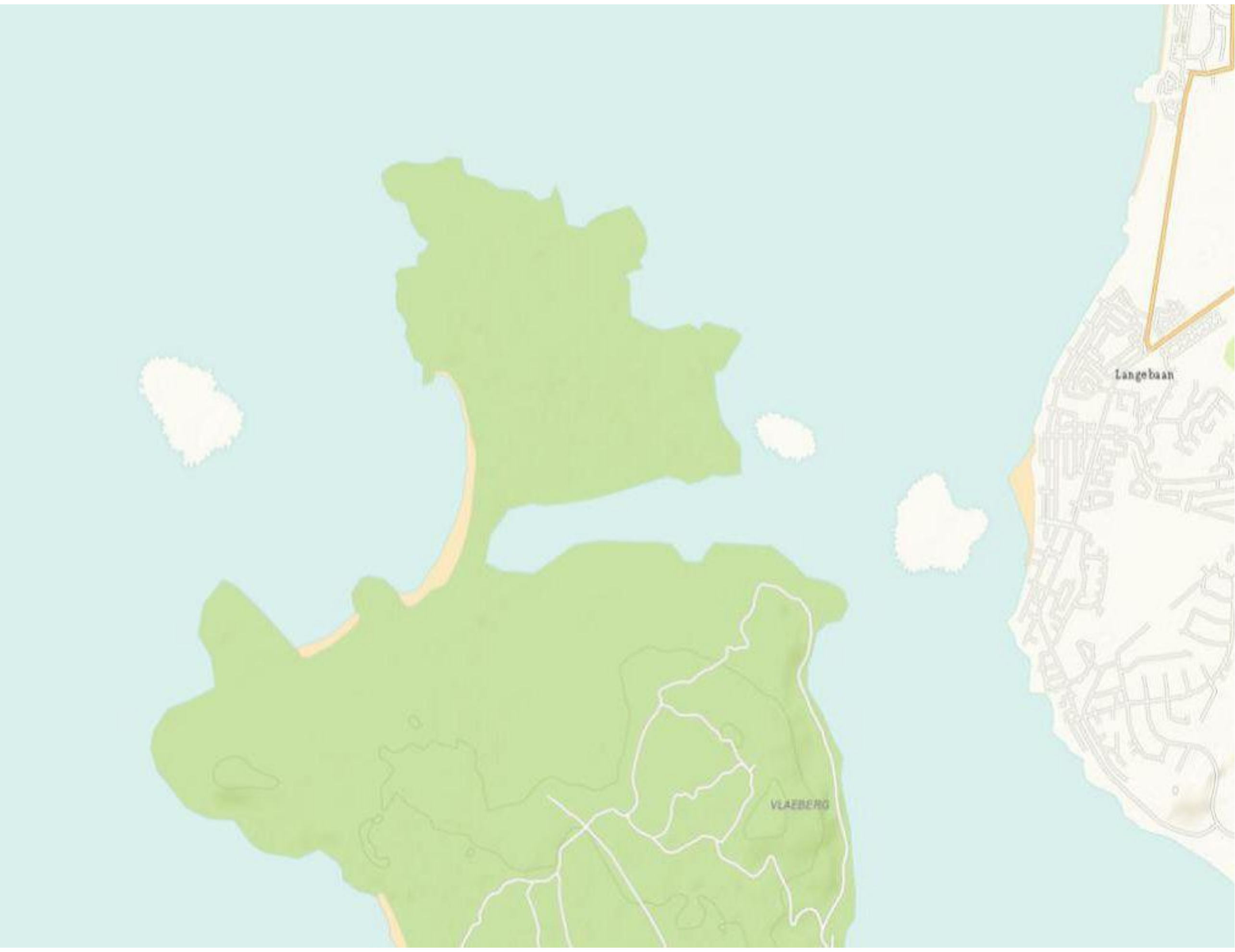


Figure 4.17 ESRI topographical base map as orientation

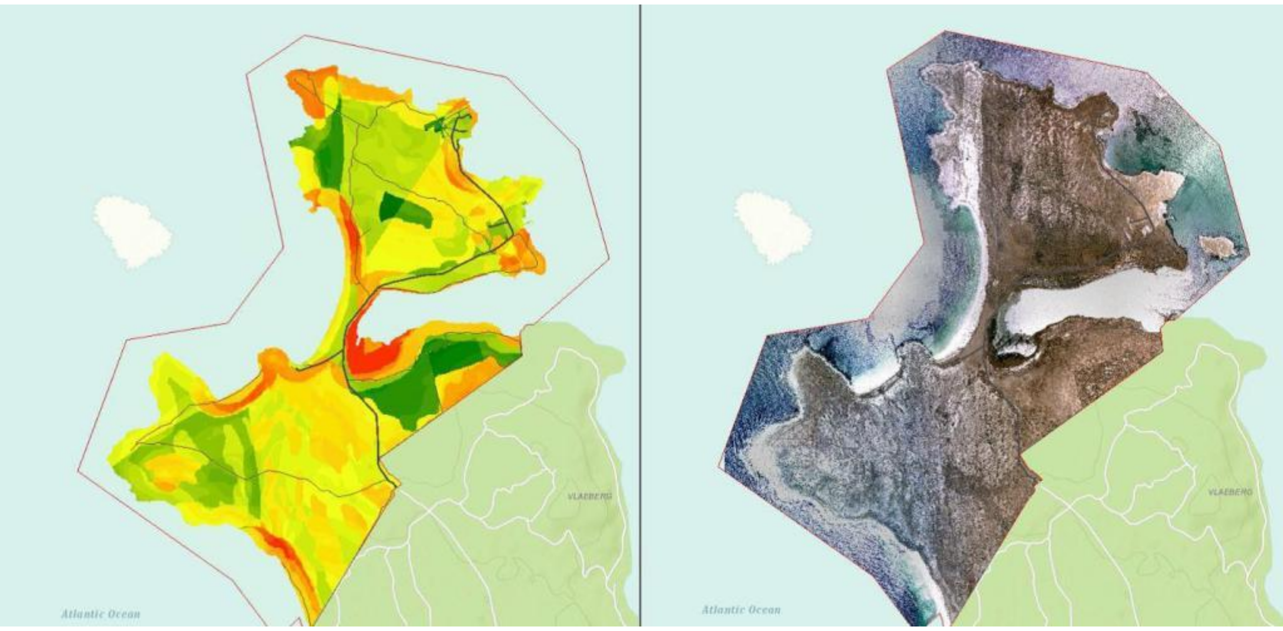


Figure 4.18 Environmental sensitivity and aerial photograph as backdrops

layer is much wider than DMTA. As described in the previous section, the user can also choose to display a sensitivity raster or a high-resolution aerial photograph as backdrop for DMTA (such as those in Figure 4.18). In both cases, layers detailing the boundary of DMTA (including sea area) and roads are also provided. Depending on the operation selected by the user and the conditions specified, the web application loads a semi-transparent layer that greys out the areas where a particular training activity is not allowed. Some examples of such activities and the areas where they are allowed are shown in Figure 4.19.

If some of the activities shown, such as shooting, urban training, diving, survival, mountaineering and rock landings, affected areas are plotted together with the other SDSS criteria. The outcome displayed in Figure 4.20 shows that only a very small portion of the peninsula is available for all training simultaneously.

By combining different layers representing activities, and by incorporating the environmental sensitivity within the areas where the activities are allowed, the user can geographically plan operations that limit environmental damage. Of course, the model can be adapted and developed further by expanding on these examples to enable its application to other activities in different military areas. The next section provides an exercised example of how the system can be used for operational planning.

4.5 SDSS: APPLICATION EXERCISE

A hypothetical training exercise is used in this section as an example of how the system can be employed for operations planning. The hypothetical exercise entails a series of consecutive actions: It commences with a beach landing, followed by a cross-country hike to perform a pyrotechnics exercise, after which another cross-country hike leads to a concluding helicopter-borne fast-roping exercise. Figures 4.21 and 4.22 show how the locations for the most suitable sites for the different activities could be selected and the least destructive connecting routes determined.

A more extensive demonstration of the employment of the system for operational planning is given in Van Der Merwe et al. (2013). It is clear from this demonstration that the system is quite user-friendly and intuitive. For demonstration purposes, a simple hypothetical operation was used, but much more complex scenarios with various combinations of exercises can be produced using the available tools. The incorporation of the environmental sensitivity layer as background allows the user to select sites and routes that will limit environmental impact. The GUI also allows various options for producing high-quality maps, which can be used during planning, as guidance in the field or in post-operational reports. The system usage can also be extended to include alternative activity scenarios, employ different GIS functions and database layers (including ones experimenting with differential environmental sensitivity).

The operational application of the SDSS has potential for exploitation further afield in the military. The system can be adapted for more universal application (i.e. for other areas as well as for other activities). An interface for hand-held devices (e.g. GPS, smartphones etc.) can for instance be developed to provide geographical information from the field in an augmented reality format. The system's functionality can be extended from a planning tool to a planning and operational tool by improving it to the level where it can accept data from PDAs of operators in the field and update the central database in real-time.

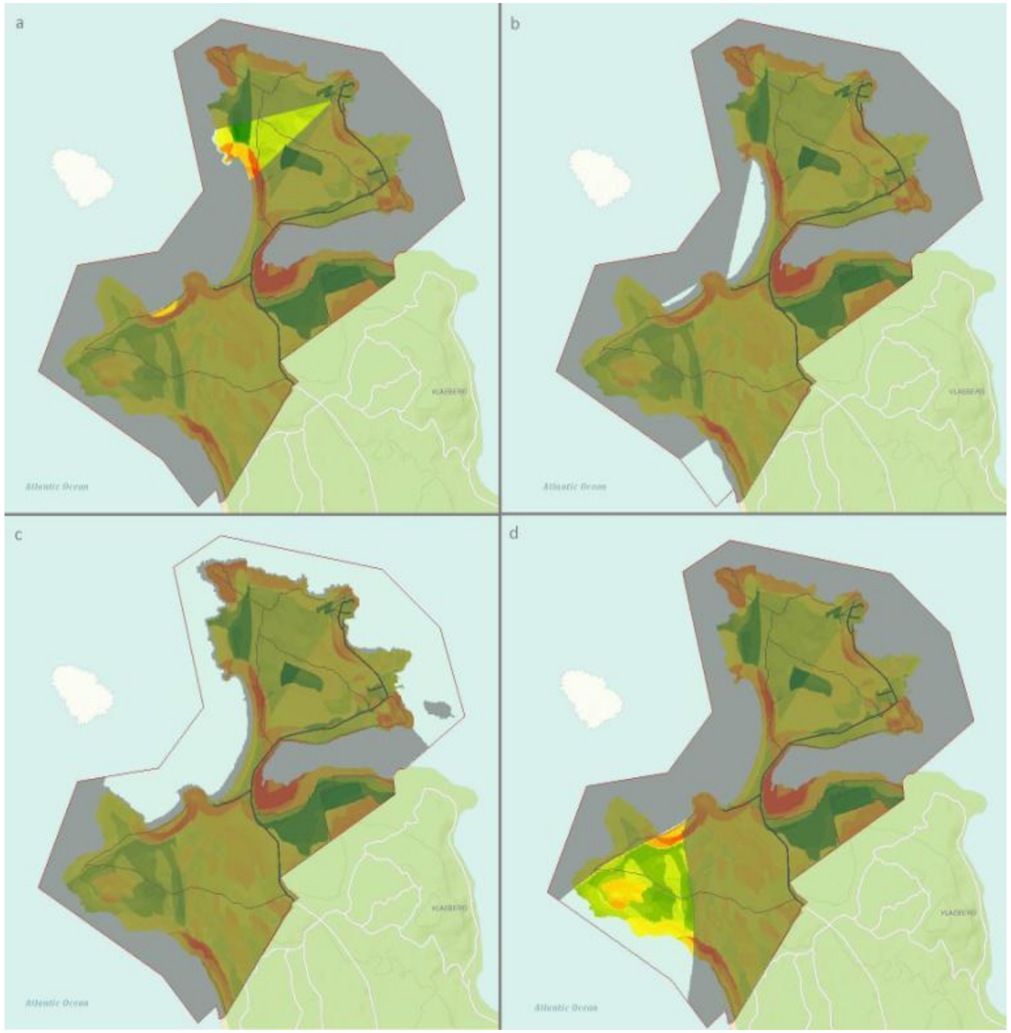
4.6 SDSS: FURTHER DEVELOPMENT AND TESTING

Further development to realise the full potential of the system is essential. Four aspects of reality that have to be factored into system development and application are highlighted here. They include catering for the eccentricities of nature, regular and extreme realities of military conduct and the possibilities inherent to ever refined technological gadgetry.

4.6.1 Accommodating vagaries of nature

Long term and short term changes in natural conditions are unpredictable which might necessitate continuous or episodic updating of the SDSS model. For example, survival courses were presented at the caves west of Plankies Bay until 2007 (see Figure 4.16) but the survival course venue was subsequently relocated to safeguard stalactites and stalagmites that had started forming there. The growth of the stalactites and stalagmites would potentially have been adversely affected by firemaking activities of the learners as the heat dried out the interior of the caves. Furthermore, Cape horseshoe bats suddenly occupied one cave during March 2012 and resided there until winter, supporting the cave prohibition decision. The bats subsequently vacated the cave during the cold months and did not migrate back again, but a possible revisit is monitored monthly since then. According to Monadjem et al. (2010), the Cape horseshoe bat is endemic to South Africa, occurring in the extreme southwest only and is closely associated with the fynbos and succulent Karoo biomes where they fulfil niche ecological functions.

The bats have South African as well as global red data status of near-threatened and roost in caves and mine adits where they sometimes form colonies of thousands. A large colony of Cape



(a) landing areas/60 mm explosive mortars, (b) boating exercises/surf work, (c) attack-diving I, (d) 20 mm guns/40 mm AGL

Figure 4.19 Areas prohibited or allowed for specific operations

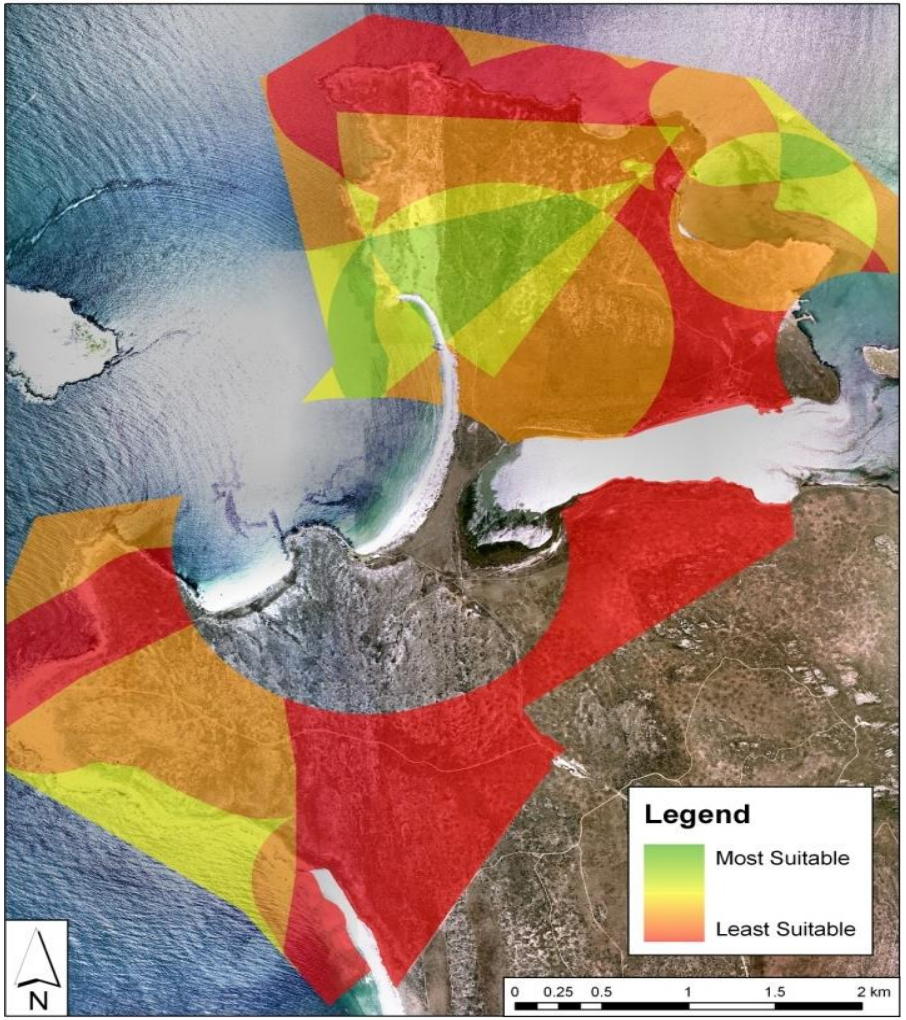


Figure 4.20 Overall suitability for training

horseshoe bats resides at the De Hoop Guano Cave and there is an influx of bats to these caves during winter time. No migration data exists for this species, but the possibility of migration between the West Coast and the De Hoop caves cannot be ruled out. The Cape horseshoe bat is potentially threatened by habitat loss and disturbance (Wikipedia 2012).

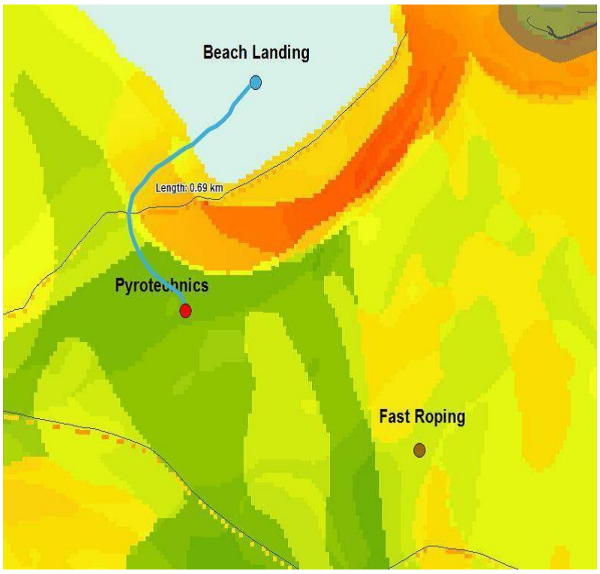


Figure 4.21 Site selection for fast-roping

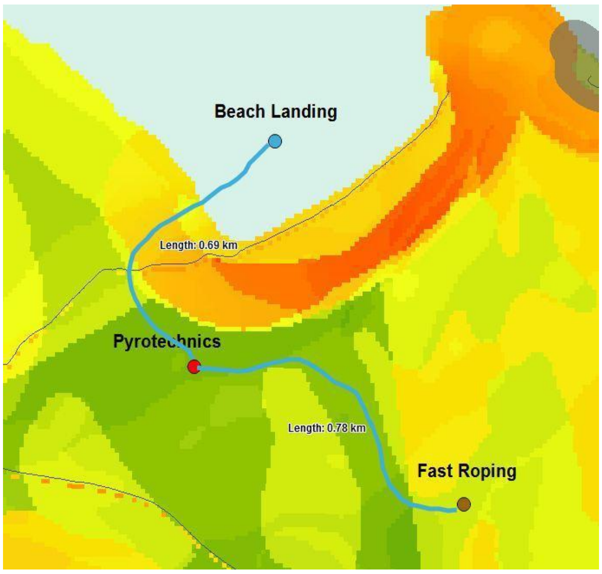


Figure 4.22 Determining the hiking route between the pyrotechnics and fast-roping sites

As a result of the stalactites and stalagmites and the bats in the caves an alternative venue for survival training had to be identified, so the base camp is now set up at South Head. From there the learners can do survival in an area that stretches clockwise to the end of Wildebeest Bay and anticlockwise to Plankies Bay with access being denied to the caves (Figure 1.4).

4.6.2 Accommodating operational realities

During October and November 2012 the possibility for the practical application of the SDSS programme was field-tested by operators during both day-time and night-time activities on DMTA. This was done in conjunction with staff from the Technology for Special Operations (TSO) branch of the Council for Scientific and Industrial Research (CSIR) as follow-on to the initial system development. The tests that were executed proved that the programme can, with ease, be practically implemented and is sufficiently user friendly for team leaders to employ during the planning phase of exercises.

For scenario development, previously formulated SDSS guidelines can be altered to deliver different exercise outcomes while still maintaining the role to make planners cognisant of environmental sensitivities and concerns. Swimming activities, for example, have no influence on the environment but certain areas such as the WWII battery and the gravesites at Salamander and Riet Bay are, according to the SDSS criteria, out of bounds for beach/rock landings and approaches. If approach routes have to traverse these sensitive areas, the rule can be ignored, but the briefing to the operators will, for example, stipulate that operators must keep to the existing footpaths.

Not all SDSS rules can be adapted to accommodate specific outcomes. The criteria for activities like airborne exercises on DMTA that have to avoid heritage sites such as graveyards at all costs is an example. In the case of jumping activities standard work procedure (SWP) rules are also applicable and DZs should be planned and laid out according to the SWP: Parachuting in 4 Special Forces Regiment, Appendix E to Part One Order, SWP Parachuting dd December 2011 (Part One Order 2011). Weekly, daily, diurnal or conditional variation, for example typical to the movement of game, cannot be predicted by the SDSS model and team leaders should execute pre-exercise reconnaissance and take precautionary measures based on the specific guidelines provided in Chapter 3 of this dissertation. For instance, game frequent the Wildebeest Bay shooting range area during the dry season, raising the spectre of game getting hit during night exercises. Before last light, the area should therefore be patrolled and the game chased from the area.

4.6.3 Accommodating extreme military activities

The SDSS model must also not be seen as absolute since it should develop in response to new challenges. One example is the research on demolitions at DMTA that commenced in September 2013 as mentioned earlier. Once the experiments with different kinds of explosives and changes in the size of charges at different locations under a variety of temporal conditions have been completed, predicted impacts gleaned from test results should also be included in the SDSS model. The model can stipulate, for example, what charge size to be used at a given temperature or atmospheric regime or which shooting range to employ depending on other variables such as wind direction and bird breeding seasons.

The examples mentioned above clearly prove that the SDSS model cannot be rigid and should be altered as needs arise to accommodate desired training outcomes or to cater for changes that can occur in nature. The flexibility of the programme will in future be tested as considerable development, that poses a threat to the health and biodiversity of the bay (Saldanha Bay, Langebaan

Lagoon and the islands), is planned (Clark et al. 2012). Scrutiny of the military by developers and the public will escalate in future and the SDSS model must be improved and used consistently as a proactive tool to contest unsound allegations regarding environmental misuse of DMTA. To make this practically applicable and user-friendly, DMTA must be seen as a multiple-use conservation area. For the SDSS to succeed as management plan, biodiversity of the area, management projects, reserve objectives and detail of military activities should be included. The relevance to other SASF training areas can then in future be investigated and appropriate models for them be developed.

4.6.4 Technical SDSS development

The Internet is a publicly accessible worldwide system of interconnected computer networks. It is based on the packet-switching Advanced Research Projects Agency Network (ARPANET) created by the US Department of Defence in the early 1970s (Longley et al. 2002; Wikipedia 2005). Since the development of the World Wide Web (WWW) by Berners-Lee (1989), the uptake of WWW (or Web) technology has been remarkably quick. This hypertext-based service has brought the Internet into the realm of everyday use. In 2002 it was estimated that the Web consisted of two billion publicly-indexed web pages (netz-tipp.de 2002), while in a more recent study this figure was estimated to be 11.5 billion (Antonio & Signorini 2005) – providing some indication of the staggering numbers that could be expected now, 10 year later.

The Internet is fast becoming a primary source of information and web users increasingly resort to it to support their decision making (Jarupathirun & Zahedi 2007). DSS are being web-enabled owing to the increased accessibility and familiar interfaces of websites (Salewicza & Nakayama 2004; Thysen & Detlefsen 2006; Wang 2005; Wang & Chein 2003) and because Internet technologies offer tighter integration with existing information systems (Vahidov & Kersten 2004).

Concerning spatial technologies, the Internet has been the greatest external stimulus for GIS since the late 1990s. It has shifted the vision and basic role of GIS, i.e. to perform spatial tasks more efficiently, to communicating geographical information between users. The Internet provides an easy, cost-effective way to access spatial databases distributed worldwide. Greatly stimulated by market demand for geographical information, web applications that serve spatial data have grown rapidly since the first Internet mapping site was introduced by Xerox PARC in 1993. In 2002, more users made use of GIS functionality through the Internet than through all the other types of GIS software combined (Longley et al. 2002).

Since its introduction in the middle to late 1990s, web mapping has been increasingly used to distribute geographical data over the Internet. Web mapping software such as Google Maps (Google 2005), Map Machine (National Geographic Society 2005), AlertNet (Reuters Foundation 2005), MapQuest (MapQuest 2008) and StreetMap (MWEB 2005), enables anyone with access to a computer and the Internet to explore geographical data online and produce maps on demand. With these tools, users can access geographical information without the need for expensive GIS software (Van Wyngaarden & Waters 2007).

The introduction of products such as Google Earth has highlighted the value of web mapping for spatial decision support. Many organizations have recognized the potential of such systems for the cost-effective distribution of maps and other spatial information within organisational structures to improve productivity and to make better decisions. The functionality of most web mapping applications is however limited to data display and does not support GIS functionality such as editing, spatial analysis and modelling (Pummakarnchana, Tripathi & Dutta 2005).

Web mapping solutions that offer more advanced functionality often require supplementary software to be installed on the user's computer. The installation of these so-called plug-ins and interpreters (Jiang 2003) is a deterrent to many web users who are not familiar with downloading and installing software. In addition, many users regard software downloads as a security risk – a very real concern to possible military adoption. Consequently, for optimal accessibility, web-based SDSS should preferably be compatible with existing web browser software. In the military context it would be possible to protect the integrity of databases and information flows through advanced encrypting technology and related security protocols among users.

GIS functionality is difficult to implement using web technology due to the complexity of managing the data used, created and updated during these operations (Green & Bossomaier 2001). However, the gap between GIS and web mapping applications is expected to close as the demand for more functionality increases. The addition of spatial analysis and modelling capabilities to web mapping applications holds much potential (Jiang 2003), especially for the cost-effective development of web-based spatial decision support systems. Such systems are of particular interest to the military as much of the spatial information that is needed is dynamic (e.g. movement of units, events, contingency plans) and need to be constantly updated and distributed to multiple users, either at the base or in the field (i.e. remotely).

CHAPTER 5 SPECIAL FORCES INTEGRATED ENVIRONMENTAL MANAGEMENT

This final chapter aims to perform the generic functions of a concluding dissertation chapter: summarise the results of the research by revisiting each of the original guiding research objectives to ascertain the extent to which they have been achieved, encapsulate the salient conclusions that the research generated and to make recommendations – both of a practical nature in terms of management guidelines, but also looking to the future in suggesting the way forward to a younger generation of scientific researchers.

5.1 SUMMARY OF RESULTS

As stated in Section 1.3, the research aimed to build an inventory of all discernible environmental impacts resulting from the interaction between military activity in a highly sensitive natural setting the Donkergat Military-training Area (DMTA) on the South African West Coast. The research successfully built this inventory to reflect a comprehensive record of developments over time, and analysed and determined the efficacy of ongoing management procedures enacted to alleviate these problems in a recommended military integrated environmental management (MIEM) framework. In the final instance it described in detail the design of and demonstrated and tested an electronic spatial decision support system (SDSS) to enable these measures in a format that can be replicated elsewhere. This research aim was met by achieving each of the five research objectives, covered in the various chapters and sections as indicated. To achieve the objectives the research adhered to a mixed methodological approach (Van der Merwe and De Necker 2013), where some parts employed a descriptive mode (mainly in Chapter 2) where site observations and experiences over an extended period were compiled, a descriptive-managerialist approach where military impact inventories and management experiments were inventoried (Chapter 3), and finally a quantitative-technological application in Chapter 4 where an advanced geographical information technology (GIT) tool for practical environmental management was designed and tested. The five objectives are revisited in the following subsections.

5.1.1 A resource inventory for DMTA

Objective 1 had the establishment of a resource inventory for DMTA as its goal and all of Chapter 2 was devoted to achieving it. This task is fundamental to any management system where a large and complex spatial environment is the affected entity. Since the integrated management of the total DMTA environment consisting of its natural attributes in their variety and complexity, together with the human activities impacting on it is aimed for, as comprehensive a grip on the resource base as possible is necessary. The intent was also to build a reference database to serve as benchmark and reference source to all future managers as and when they are appointed.

This goal was achieved by recording detail on the generic environmental factors of average climate and weather to inform on conditions that are likely to prevail during military operations and that can lead to or mitigate particular impacts. The Langebaan area was shown to be exposed to fairly moderate *climatic conditions*, low incidence of extreme conditions, however, high fog incidence pose a threat to military activities and long dry summer periods posing a challenge to game on the range. *Marine-water attributes* recorded are essential to comprehend, because of the unique setting of DMTA on the Atlantic seaboard and the Langebaan Lagoon – a highly-sensitive and officially-denoted Ramsar site with its salt marshes and tidal currents. These aspects are especially important considering the demands of beach-based exercises and have been subjected to severe changes due to the harbour developments out in the Bay. Water temperatures and current speeds are moderate, but wave action can be severe to contend with during exercises under winter-storm conditions.

Section 2.3 was devoted to an overview of the *geology and geomorphology* of the site, since it explains much about the topography upon which all military activity take place and the natural land cover unfolds. The area is dominated by granite outcrops higher up in the landscape, providing the silicon-rich sands that cover the lower-lying areas. No surface water is evident or run off the landscape and is therefore not a management factor – except where erosion occurs along gravel roadways. Fairly unique features could be highlighted in the shallow Riet Bay inlet and the sinkhole appearing recently in the calcareous substrata. The importance lessons that evidence of historical sea-level change hold for climate change scenarios on the DMTA were mentioned.

Because of it ready exposure to all military activity, the occurrence of and nature of six *natural terrestrial and marsh as well as various marine vegetation* communities and its sensitivities were covered in some detail in Sections 2.4 and 2.5. Using the SANBI vegetation index system the Langebaan Dune Strandveld (FS5) vegetation is generally vulnerable, highly transformed elsewhere in the region and conserved in the West Coast National Park of which DMTA is a virtual part. More than 120 plant species occur onsite and are claimed to have outstanding medicinal, cultural and botanical value. Six subcommunities are discussed in terms of their occurrence, dominant soil type, defining genera, average height and especially the sensitivity towards human disturbance. Full species lists with vernacular and scientific naming appear in the appendix, but identification and recording remain an ongoing management task on DMTA. Natural vegetation poses a need for enhanced management strictures on landscape use and thus a serious challenge to the integrated management of military activity and nature.

The *faunal record* of DMTA offers a serious challenge, due its high public profile and the exceptional species richness on the verge of the Atlantic Ocean and on the Langebaan Ramsar site. Consequently, Section 2.7 offers a record ranging from the rich fossil finds in the region relating to millions of years ago to the multitude of exceptionally rich birdlife species. Human settlement has left the region bereft of significant mammal life, but a number of vertebrate species were re-introduced by conservation actions since 1964, including blue wildebeest, bontebok, eland, gemsbok, kudu, red hartebeest, springbok and zebra – game species requiring close monitoring and management in this severe environment. The dangers inherent to several terrestrial and marine invasive species are noted. Birdlife and its preservation among military activities require close scrutiny – and this is offered by fairly minute attention to a range of distinctive marine species. Appendix C is a full list of mammal and bird species (111 recognised types on DTMA) list for reference purposes. Much detail on a multitude of species, their distinctive appearance, habits and preferences are noted. Detailed information is given about certain oystercatchers, penguins, cormorants, gannets, gulls and terns that are under threat. The section concludes with salient pointers from a management perspective on what has been achieved in the past, what current initiatives are underway and what key management concerns should be.

Of course, the exceptionally rich birdlife depends on *marine life forms* to sustain their large population numbers, placing an additional burden on environmental management. In this lagoon environment more than 500 different species of invertebrates occur and Saldanha Bay is a major centre of the West Coast fishing industry. The military shares responsibility for the protection of a number of threatened and protected marine food species like rock lobster and various important angling fish species listed here. The threat of invasive species like the Mediterranean mussel is noted, similarly the need to maintain conservation measures in keeping with those implemented at marine systems surrounding the military area in what constitutes an open biological system.

The chapter concludes in Section 2.8 with a description and record of the several significant *cultural-historical artefacts* on the terrain. These include war-related structures – WWII gun batteries and installations and buildings serving the whaling and seal hunting industries, graves, wrecks, fortifications or ruins. These structures are by definition subject to national conservation legislation and the military are its custodians.

The documenting of foundational knowledge to support the compilation of a MIEM plan for DMTA was accomplished in this manner and can in future serve as prototype for formulating management principles and guidelines applicable to other Special Forces (SF) areas such as Madimbo, Savong, Skiettog, SF School, Swartkop Park and 5SFR. Preliminary to MIEM initiation at these institutions research on applicable military orders and procedures, relevant scientific literature, interviews with neighbouring stakeholders, establishing the status of the study area broadly, its history, orientation, administrative attributes and ecological phenomena in conjunction with the variety of military actions being executed, must be prioritised.

5.1.2 Assessment of military impacts on DMTA

Objective 2 endeavoured to measure and record instances of how military activity had harmful impacts on the DMTA environment and half of Chapter 3 was devoted to doing so. Scrutiny will show that the chapter commences in Section 3.1 with an inventory of all the military activities taking place on DMTA, followed in Section 3.3-3.6 by recording of instances where four types of impacts were noticeable. Note that in each of the four types the nature of each type of impact is recorded photographically where possible, followed by suggested management solutions – the latter aspect revisited under Objective 3 in the next subsection.

Military activities and the utilities to accommodate them were divided in three groups: waterborne, airborne and general. Table 3.1 lists 21 seaborne activity types of urban, indoor and outdoor training nature – so demonstrating the versatility and value of DMTA as training facility. *Waterborne training actions* are described in some detail and the collateral nature of damage caused by accompanying vehicles on beaches and in other pristine locations is emphasised. Negative impact on the environment of activities with air support or live firing onto land is disturbance of birds by low flying helicopters, game sustaining injuries and getting entangled in devices and blinds being left unattended on the shooting ranges. Attack-diving activities are problematic because of the detrimental effect of underwater detonations on birds in the adjoining Ramsar park.

Airborne training activities include parachuting and freight drops from three conveniently close airfields, helicopter jumping into the water, fast roping, rappelling, hoisting and emergency (hot) extractions from land and moving vessels. The waters around DMTA are ideal for combined air and water work and consequently the noted negative disturbance impact on birdlife a constant concern.

General training includes land demolitions, sea survival and mountaineering, as well as a range of survival training exercises by non-military institutions (including the South African Police and various civil organisations). Generally such activity is strictly controlled and hence the impact on the fauna and flora is minimal – with the exception of demolitions, but then the amount of explosives can be strictly controlled.

Identifying environmentally harmful impacts on DMTA was achieved through critical, thorough investigation over a long period of time by a variety of military managers and severe challenges were identified. As a result a range of mitigating or preventative management measures had been instituted or were experimented with as discussed in the next section.

5.1.3 Military management on DMTA

Objective 3 set the establishment of a proper environmental framework on a routine basis as part of integrated military management on DMTA as goal. This objective was largely achieved in Chapter 3 in a range of non-contiguous subsections. It commenced with a background probe of the legal framework imposed on environmental management in South Africa and to which the military are automatically subservient. The theme was elaborated on and impacts by particular military activities were dealt with. The attention then shifted to nature conservation measures per se, and the chapter concludes with an integrating vision for MIEM frameworking on DMTA.

Environmental management on DMTA is regulated by a range of national legislation which was noted to be subject to periodic revision – the National Environmental Management Act (107 of 1998) is at the apex of the range. Since military terrains are located in various provinces and municipalities, the relevant regulations of these levels of government must also be adhered to. Department of Defence (DOD) environmental policies and procedures require application. These formal measures need to be integrated in the MIEM framework guiding military management in a sensitive natural and human settlement environment.

Activity management on DMTA takes many forms and solutions mainly concern *infrastructure*: extraction excavations, roads, disused cultivated areas, fencing, water-dispensing points, electricity transmission lines. Existing and poorly located sites should be avoided or rehabilitated, and a new sites should be proactively located, planned, designed and encamped. All waste material should routinely be transported to licensed and well-managed (municipal) landfill sites. Road maintenance methods employed by applying construction waste and refuse coal from whaling-era deposits are used as demonstration of good practice – countered by some examples of failed rehabilitation efforts. Rehabilitation of previously-cultivated areas proves difficult and demonstrates the longevity of natural interference. Being a restricted military terrain, fence maintenance is a priority, but in this case the process is complicated by the need to allow free game movement to the neighbouring park – especially during the dry summer when grazing is at a premium. Experimentation with and research on types of game fencing is recommended. Electricity transmission lines offer a major challenge to safeguard birdlife in this highly sensitive location. Many instances of bird fatalities have been recorded and in response a number of bird-flight diverter types were experimentally fitted until a drop of 50% in fatalities had been achieved.

Damage to *cultural-historical heritage* has been addressed in various ways. Firstly, a recording effort in building a spatially intelligent database, containing photographic recording of artefacts like graves and installations had been launched to act as benchmark against which to monitor conditions in future. Protective measures include prohibiting training on and around these sites and minimising and controlling the number of visiting groups. While the Heritage Act prohibits structural repairs to heritage artefacts, certain routine maintenance activities to graveyards and gun batteries have been carried out. However, the absence of a comprehensive and professionally-informed heritage rehabilitation plan is bemoaned.

Achievement of Objective 3 also involved implementing *ecological management measures* consistent with normal practice for large land areas. These refer to encouragement of even game distribution to restrict hoof erosion and vegetation trampling through a water-trough rotation plan, fencing that allows migration gaps, culling to maintain scientifically determined carrying capacity, bird nest removal as delicing measure on fixed structures, and policing of covert sewage disposal by private contractors.

Countering *military residue* nuisance entails the proper maintenance of facilities and equipment and the routine clean-up of spent materials. Long-term stability is ensured through dedicated staff designation and a formal terrain management plan. Off-road vehicle driving training is recommended to take off-site to private specialist facilities. On bases where mechanised exercises are common practice, military off-road traffic disturbs ground and vegetation cover of landscapes, increases potential rainfall-related runoff and soil erosion (Wang et al. 2007). The land condition maps these authors developed are useful tools that can be implemented for land managers and decision-makers at RSA training areas such as the Combat Training Centre (CTC) at Lohatlha in the Northern Cape Province and De Brug in the Free State to guide military training programmes and formulate management plans.

Managing demolition activities on DMTA poses a special challenge, as noted before. Experimentation has, as systematically reported in Table 3.2, established a 'timetable' of bird sensitivity to explosives. Nevertheless, a threshold explosives mass of 3 kg has been set in the unit standing orders. Underwater detonations are now restricted to the summer months from January to April and the need to determine more accurately the effect of detonations on whale communications is articulated – the latter a public concern. Further generic management measures concerning game animals, exotic and problem plant and animal species as well as water quality issues are provided in conclusion.

All management directives come to a head in the *MIEM plan* suggested for implementation on DMTA. The management procedures implemented to reduce further unrestrained progress of environmentally harmful impacts must be addressed by formulating pro- and re-active solutions in a comprehensive MIEM plan. International prediction methods are available. Howard et al. (2013) quantified land condition measurement through gauging soil erosion severity from ground and vegetation cover as a surrogate measure. The impact of mechanised action on vegetation can be further developed by using the evaluation tool designed by Althoff et al. (2009) at the Fort Riley military installation. Their results showed that one of the primary impacts of tracked vehicle manoeuvres is the destruction of vegetation. This results in significant secondary effects such as soil loss through erosion (Grantham et al. 2001). From the perspective of erosion, ground cover is a key indicator of ecosystem health. While at DMTA deterioration of vegetation cover is mainly the result of hoof erosion, at training areas where mechanised exercises take place (such as the CTC and De Brug), this model can be implemented. On a much smaller scale, the influence on some sensitive areas on DMTA, such as the sediment track shown in Figure 3.59, negotiated by quadbikes used by SF, should remain under close surveillance.

The three environmental concern themes shown in Table 3.3 and the examples given in Appendix D must be developed and implemented on DMTA and other SF training facilities and it must become the responsibility of every planner to incorporate MIEM into the prescribed unit order format for everyday activities as suggested under Subsection 3.8.3. By implementing this procedure the MIEM plan will stipulate the most suitable locality for the exercise, areas to avoid, access routes to be taken, the responsible person for the MIEM, the authorities to contact if flares or explosives are to be used, parking area for vehicles, the maximum amount of explosives that can be detonated, the collection sites for spent cartridges, the area that must be swept for mortar parachutes, the procedure for disposing of waste, the fire-fighting plan and the indication method for blinds. Similar applicable variables can be listed for all the different training or rehearsal activities and made available as a practical template the operator can implement.

5.1.4 A military spatial decision support system

Objective 4 had the design and testing of a spatial decision support system (SDSS) that can be used to manage the sensitive environmental resources for DMTA as part of an integrated MIEM as its goal and Chapter 4 was exclusively devoted to achieving it. It provided an overview of geospatial technology applications in the military and drafted a suggested framework for such an application within the military command hierarchy. A stepwise exposition was then given of the implementation principles for such a system, followed by the actual construction and design of a comprehensive spatial decision support system (SDSS) on DMTA as the core of the chapter's material. The concept of an SDSS running off a geographical information system was finally demonstrated for DMTA and the chapter concluded with application test results and some suggestions for future refinement. These issues are revisited in summary fashion here.

Since by nature military activity plays out in locations and deploys over spaces, geographical information technology (GIT) finds application in military SDSS. The opening sections of Chapter 4 provided an overview of the concepts relevant to understanding SDSS application in the military. Firstly, the nature and functionality of decision support systems, and their dedicated application in a spatial format were explained through recent literature survey. Mainly the approach to developing SDSS is to modify and customise GIS to incorporate the functionality of DSS and in military context to perform typical or routine screening or modelling tasks. Geographical Information Systems, again in concept, were overviewed next, with special attention devoted to development trends in its technology and, lately, ever more sophisticated modelling applications. Multi-criteria spatial analysis is such an application and since it was earmarked for application here, its basic concepts required detailed explication. Figure 4.1 served to systematise the process application in six data gathering, decision-making and technical application steps to be carried out later. Since the multi-criteria model entails the weighted summation of factors, the weighting principle, the calculations mechanism and the equations operationalised in it were explained thoroughly to augment comprehension. Before applying the model, an overview derived from a thorough literature review, was provided. It showed that military application was novel as yet and largely confined to operational military management tasks. Only very recently had the encouraging trend towards integrated operational/environmental military management become a focus in a very few studies. Fortunately it was noted that suggestions and debates surrounding the need to drive the adoption of military GIS, its military application philosophy and system structure, has begun to be advocated.

Visualising the implementation of the SDSS in a military setting required a vision on how such a system would fit into existing decision-making hierarchy in the SA military. Figure 4.3 makes clear how the twin driver roles of decision-makers (military command and top and local levels, and the product expert) could be captured in an integrating mode through GIS application to merge environmental and operational decision-making and management in the MIEM framework. These dichotomous application modes and their merger in the MIEM GIS were developed to create a two-pronged approach to the model's application – each utilising different GIS overlaying functionality. Operationalised MCE in military GIS, specifically in terms of an application to DMTA, then became the prime focus. This entailed the operationalization of five distinctive steps or tasks, namely to set bounding geographical (impact) rules for each military-training activity, populate a rule base, create an electronic georeferenced geographical database, design a weighted significance rating hierarchy, and implement a protocol. Much of the essence of these steps is captured in Table 4.2 in which the severity impact of various military activities was estimated along a Likert scale, and according to which the spatial features were captured in a GIS database. Several spatial variables (notably vegetation, land use, coastal morphology, slope and landscape elevation) had their values rated on the same scale for impact sensitivity to complete the operational database. The semi-structured linguistic format rule base was now converted into a logical structure incorporating all relevant variables (see Table 4.9) incorporating optional temporal and conditional variance that might apply under particular operational conditions. These rules were implemented in trial runs of the system, and can be varied according to the activity, date (month of the year), as well as wind, rain and sea state. After applying the pair-wise comparison matrix of factor weighting in Table 4.10, an overall sensitivity rating image for all military activities (Figure 4.14) was produced to guide decisions on the most suitable terrains for various training activities. Subsequent model runs produced output showing best practice solutions for the performance of various types of military operations – thus completing the promised two-option application of the system.

Having demonstrated the functional operation of the system, the chapter concluded with a reflection on aspects of reality that have to be factored into future system development and application, namely catering for the eccentricities of nature, regular and extreme realities of military conduct and the possibilities inherent to ever refined electronic spatial technology. Instances where operational decisions and the system use for it would have to be under operator (i.e. not automatised) control were argued, as were unpredictable weekly, daily, diurnal or conditional variations that would require operator cognisance. It was shown that rules for deploying severe military activities could be accommodated through rule alteration and the chapter concluded by pointing out how technological development of internet connectivity, communications gadgetry, web mapping and GIS refinement and improved functionality would enhance the application of GIS in SDSS as part of efficient MIEM. Hypothetically, MIEM, supported by this SDSSS, becomes an asset to be used in a cradle-to-grave environmental management approach for rehabilitation of existing negative impacts and of all new developments and operations.

5.1.5 Military base management in regional environmental management context

The final research objective is reached in this section by summarily projecting the foregoing essentially practical management solutions and measures pertaining to a specific military case study (DMTA) against a theoretical backdrop. The backdrop is provided by the conceptual frameworks of integrated military and spatial marine environmental management (MIEM and MSP) planning – currently in the process of being adopted internationally and nationally. The research results reflect on implications for military bases elsewhere in South Africa and internationally of adopting the proposed planning frameworks and meeting the management framework demands only now becoming evident in international practice and developments. The latter demands are exploited in this section.

Essentially, a generic environmental management and conservation role for the military is envisaged. Military training activities by its very nature degrade land, but military land occupation could conversely also contribute to increased biodiversity and aid in stabilising ecosystems (Wang et al. 2014). The application of a MIEM framework at DMTA already resulted in ecological restoration and enhanced biodiversity – examples are elevated oystercatcher numbers and distribution, the occupation of survival caves by horseshoe bats and vegetation re-established on previously disturbed areas. The approach of the proposed MIEM programme for DMTA provides essential information frameworks and sound recommendations to range managers that may be projected to other SANDF and indeed international facilities, enabling more effective military management training and biodiversity conservation. Although ecosystems and military activities differ among locations, the MIEM and SDSS systems developed for DMTA are adaptive and transplantable. As such they can assist in scheduling training activities in ways that mitigate negative military influence and to initiate rehabilitation projects qualifying training areas to contribute to enhanced global conservation status and protected area networks. Zentelis & Lindemayer (2014) point out that, globally, military conserved areas and training facilities cover 5-6% of the earth’s surface. Poor data on MTA areas in Africa, South America and Asia obscure the extent, but MTAs occur in all major global ecosystems and therefore have the potential to increase global protected area networks by some 25% – a major complementary role in global conservation and allowing the minimum 10% ecological conservation target to be met. Similar to Brazil in South America, with its global EMS approach adopted from American, Canadian and NATO practice (Ferro & Santos 2012), South Africa should set an example for the rest of Africa.

The MIEM and accompanying SDSS proposed for DMTA is a comprehensive environmental management system (EMS) developed to accommodate environmental considerations amidst military activities. In this system, the complexity of environmental data and variety of military actions and applicable variables such as meteorological conditions or wildlife breeding seasons are pooled in a central framework, enabling prediction of locality-specific environmental impacts by military activities. In the exceptional case of DMTA, given its sensitive and strategic marine location, this model must be cognizant of the encompassing national maritime spatial planning (MSP) framework (Douvere & Ehler 2011) in which it is nested. It has to abide by the same reasoning to improve risk management methods and to continually develop its spatial and temporal environmental monitoring of training areas. Koponen (2013) advocates this approach through the development of a GPS-based environmental assessment system (particularly for the Finnish Defence Forces). Similar to DMTA, Finnish training areas are partly restricted and usually harbour important environmental assets. Similarly located close to inhabited areas, measurement of noise caused by military activities form part of their investigations into site-specific risk management measures. DMTA has likewise now begun investigation into disturbances it might cause in the Greater Langebaan-Saldanha region.

Concerning the DMTA niche in the overarching framework for maritime spatial planning (MSP), international benchmarks exist. An MSP model for Canada's Pacific coast (Ban et al. 2013) identified as critical components to ensure effectiveness, thorough coverage of ecological and social data – the latter useful for identifying areas of significance to marine industries, while the combination of ecological and human-use data allows identification of interrelating interest to multiple users as well as biodiversity conservation opportunities. These requirements are fairly met by the MIEM and SDSS developed for DMTA, while their proposed multi-criteria decision support tool (called Marxan) (Ban et al. 2013) employs spatial data similar to the GIS application and its SDSS functions for DMTA. A review of 16 international MSP models, spatial plans and frameworks, allowed Collie et al. (2013:10) to distil five key characteristics for an idealised marine spatial plan: a legal mandate with political capabilities to implement; a concerted move from conceptual objectives to specific, operational objectives early in the planning process; meaningfully inclusive plan leadership; standards and expectations commensurate with financial and human resources; plans designed for feedback, adaptive learning and future revisions linked with monitoring. Even though DMTA is a military area with limited social involvements, the concept of the proposed MIEM plan meets these characteristics. Improved societal interaction, collaboration and mutual accommodation is aimed for in the currently planned demolition experiments to be conducted, as part of general environmental research by the Saldanha Bay Water Management Initiative, the incorporation of DMTA land assets into the delineated Ramsar wetland of international importance, and the expansion of the salmon farming industry in the vicinity of DMTA.

South African marine spatial planning has been formalised through CSIR modelling over the past five years, as evidenced by a cohesive set of recent publications (Taljaard, Slinger & Van Der Merwe 2011; Taljaard et al. 2012; Taljaard & Van Niekerk 2013; Taljaard, Slinger & Van Der Merwe 2013). The MSP model developed by Taljaard et al. (2012) contains the necessary maritime attributes to allow accommodation of war fighting actions in the waters surrounding DMTA. The model operates in a sector-based governance system and can be tested against military orientated as well as theoretically derived criteria sets to verify model suitability, application range, scientific credibility and tolerance for the wide variety of disciplines that Taljaard et al (2012) suggest. The fourteen operational criteria to measure the scientific credibility of contextual, integrated coastal management (ICM) implementation models can be tested using DMTA as case study. The follow-up research (Taljaard, Slinger & Van Der Merwe 2013) found a prototype design for ICM implementation that complies with twelve of the fourteen evaluation criteria – scientific and financial support being the two unmet criteria. Evaluating the MIEM plan design for DMTA against the 14 criteria in terms of their practicality, accessibility of information and applicability to other MIEM plans that include coastal areas, emphasises the necessity to have such plans incorporated in comprehensive MSP initiatives and frameworks.

In the final analysis, when compiling a management plan, it is imperative that nature conservation priorities should be categorised and real-world problems should be identified – as was the case for the DMTA MIEM plan. Zacharoula et al. (2013) accentuates the importance of prioritising nature conservation during marine spatial plan construction. Various international initiatives are shown to fail to incorporate an applicable framework to reach this objective. Nature conservation should remain the central means to achieve an elevated environmental and ecosystem status. The DMTA MIEM plan preserves conservation as the main planned priority and possible solutions are advanced and aimed at execution at all levels of management responsibility. The consideration of environmental factors while compiling exercise orders and the mitigation measures applied to detonation exercises to conserve resident island bird populations afford examples. This sound nature conservation foundation in the DMTA MIEM plan provides an applicable framework as guideline and reference for future military actions and developments – an approach recommended for both MIEM and MSP in South Africa and beyond.

5.2 CONCLUSIONS

Conclusions, though potentially multifarious and wide-reaching after completing a broad system investigation and completing an innovative technical management system, can be similarly wide-reaching. However, in line with normal dissertation practice, the more speculative and philosophical conclusions are avoided and reflection is limited to balancing the value attributable to the research, by the limitations of the research as encountered and noted.

5.2.1 Strategic value and contribution of the research

DMTA is unique regarding its flora and fauna and occupies an exceptionally important position in the structure of protected areas in South Africa primarily as it is located adjacent to a water system of international conservation importance. According to the 2006 SANBI classification the inland area accommodates Langebaan dune strandveld (FS5), generally regarded as of high conservation importance. The fauna that DMTA houses are diverse and range from genetically pure bontebok to the protected Cape horseshoe bat. It also serves as breeding area for scarce marine animals, like abalone and accommodates vast numbers of scarce birds such as the African black oystercatcher on the peninsula and the Bank cormorant at Meeuw Island, one of the importand island eco-systems of South Africa. The value of this study is that the long term conservation of the unique biodiversity of DMTA can be optimised through the implementation of the proposed MIEM model.

The value of the proposed MIEM model and complementary SDSS tool is that it will contribute to sustainable environmental management of military areas to ensure that the quality of land resources is maintained for realistic training in future. Secondarily, by incorporating environmental practices into military procedures and operations it will have financial benefits such as reducing energy and clean-up costs, disposal or litigation expenses. An imperative contribution of the implementation of a scientifically-sound MIEM plan is that it lays the foundation to enhance public relations that are of utmost importance at training areas such as Madimbo bordering the Kruger National Park and DMTA adjacent to Postberg Nature Reserve. During the study a number of limiting factors influenced some projects but these are identified to be attended to during future research as discussed later.

5.2.2 Reflection on management and research limitations

The limitation on public accessibility to DMTA resulted in the ongoing environmentally harmful impacts going largely unnoticed since 1978 and not being addressed by professional conservationists. Implementation of formal conservation measures commenced only following appointment of the author in 1997, but it was only in 2013 that a base environmental manager, reporting on and attending to these matters on a permanent basis, was assigned. This limited the number of mitigation projects that could be initiated and the timeline for these ventures. On a higher level the DOD Environmental Services that must ensure commanding officers adhere to the guidelines for correct environmental management, were never really involved at base level and only gave attention to serious DMTA issues on request.

Some research projects are still in process due to limitations on available personnel and allocation of funds. One example is the demolition predicament and suggested solutions discussed in Chapter 3. As the detail investigation in this regard must still be done, demolitions exercises are not presently being executed, resulting in reduced combat readiness of the operators. Another limitation is that the EIA process is not yet entirely accepted by all the role players during new developments.

EIA is still experienced as a burden and not as a tool that, with the related information required, must support informed decision-making.

Throughout the dissertation applicable detail recommendations for the alleviation of problems were proposed where they were uncovered, but salient suggestions are encapsulated below.

5.3 RECOMMENDATIONS

Salient recommendations address insights regarding the continued occupation of DMTA as a Special Forces base, the conduct of military operations on the base and some long term futuristic conservation management measures – all geared towards application within a proper MIEM framework.

5.3.1 Maintaining DMTA as specialised military-training facility

The question is recurrently posed why 4SFR should not be relocated to an existing naval service such as Naval Base Simon's Town and still satisfy the potential as 'point of the spear' for the SANDF. The fourfold answer is that the unit fulfils a vital role regarding national security, it renders specialised capabilities to the SANDF in facilities and operators, DMTA is exclusive as operational base and furthermore the uniqueness of its location provides the required ideal milieu for specialised seaborne training and operational preparation. In addition, the locational security of the area is a major contributing factor as it allows for secret activities such as AD2 and a variety of experiments, for example testing of specialised explosive devices developed by TSO. Preparations for sensitive internal or cross-border operations can be performed in seclusion and this elite force can be deployed undetected by naval or air assets. The logistical independence of DMTA and its potential to be 'locked down' ensures that activities can be carried out without outside assistance or interference. Without sacrificing the war fighting capability of the unit, the execution of these military activities on DMTA must nevertheless occur in harmony with the environment, taking into consideration that the military inherited some environmentally harmful impacts from previous occupants of the base area.

Worldwide, Special Forces (SF) are force multipliers of military powers compelling governments to allocate natural areas for training and operational preparation to enable these services to deliver on their required service potential. In South Africa the SANDF controls one of the largest state land portfolios in excess of 400 000 hectares (DOD Instruction 2000). The areas under South African Special Forces (SASF) control are primarily ordinary state land, but defence-endowment properties, nature reserves and privately owned land are also used for specific rehearsals and exercises. DMTA is one of the permanent SF bases of the SANDF of which the operational component is a 1 384 ha area of pristine land adjacent to the Langebaan Lagoon Ramsar site. SF is exceptionally fortunate to occupy DMTA, but is increasingly bound by international and national legislation to protect its land as a natural resource.

In addition, justification for 4SFR being situated in this specific location has been debated heatedly by the non-military public with its increasingly critical approach towards the SANDF, especially following conclusion of the South West Africa/Angolan conflict. The general public is unaware that, despite the end of these former formal hostilities, authentic seaborne operations continued to be conducted from this base. This dilemma raises questions concerning the legitimacy of 4SFR to continue claiming the Peninsula area as sole owner. It must also be stated that the general public querying SF presence is largely oblivious of the ongoing secret nature of projects and highly classified operations planned and rehearsed at DMTA. General public opinion is often prejudiced, but some complaints – notably those levelled at the continuing demolition exercises and new developments taking place without proper EIAs – do have merit. This reproach by the public must be seen against the urban transformation of Langebaan since the early 2000s as the town and surrounding area developed into a water- and wind- sports tourism mecca with tourists flocking in from all parts of the world. Consequently, sound environmental management and the implementation of a MIEM plan for DMTA are of the essence to guarantee the continuation of this exclusive SF operational base.

The research approach aimed to provide a comprehensive review of the status of the study area, its history, orientation, administrative attributes and ecological phenomena in conjunction with the variety of military activities executed at DMTA. In developing DMTA as an environmentally-sustainable military facility that can serve as example of a delicate ecosystem co-existing in harmony with human activity, a critical approach is required that might lead to the continual identification of environmentally harmful impacts and high cognisance of the relevant legislation the military should adhere to. Using the environmentally harmful impacts as examples, possible solutions that can be practically implemented were identified to proactively guard against public criticism and laying the foundation for an applicable MIEM plan for DMTA that address the general concerns raised publicly. To harmonise military activities with environmental sensitivity in lieu of improved public relations, the SDSS was developed as a tool for exercise commanders to minimise negative impacts.

5.3.2 Recommendations concerning military operational measures

The DOD Environmental Services must primarily be concerned with managing the impacts of military activities on the environment, whether directed to natural or urban settlement settings. Furthermore, it must aim to ensure the environmentally-sustainable management of military activities and facilities by following an advanced and comprehensive approach of MIEM encapsulated by the phrase ‘green soldiering’ – an evocative phrase capturing an environmentally-conscious mode of war conduct first advocated by the USA military forces. Under this banner, MIEM becomes integrated into all military activities dovetailing with the following collateral elements:

- environmental research and planning on and around the base;
- ecological management;
- soil and erosion management;
- integrated waste management;
- pollution control;
- environmental education and training; and
- cultural resource management.

Through MIEM the effective integration of military utilisation with environmental considerations can be achieved and biotic diversity can be maintained and even enhanced. To ensure that the proposed MIEM adheres to these elements to ensure biotic diversity, the systems developed for a MIEM should employ proven assessment tools.

A number of international assessment tools on offer to local military institutions, including DMTA, have been developed and tested during the last decade**.** Wang et al. (2007) introduced land condition maps based on soil erosion status as a useful assessment method for planning training activities and land management. Althoff et al. (2009) experimentally determined the impact of mechanised transport on tall grass prairie ecosystem ground cover by M1A1 Abrams tanks, concluding that vegetation resilience depends on soil type and training conditions and that recovery period must be adapted accordingly. Douvere & Ehler (2011) proposed the adaptive maritime spatial planning (MSP) system in which monitoring and evaluation of the effectiveness of spatial and temporal management measures are implicit. Howard et al. (2013) determined that to sustain the military training land carrying capacity at Fort Riley in the US state of Kansas, land managers must monitor and predict changes to the land condition under various military training activities. He proposed that land condition be quantified using soil erosion as criterion and ground and vegetation cover the surrogate measures. An innovative development in assessment is derived from measuring spatial distributions and patterns of military training-induced disturbance frequency from plot and point observation-based methods (Wang et al. 2014). This research conducted over a three-year period indicated that spatial and temporal assessment of the impacts of military training and other management practises and their interactions is critical to the management of military areas. This point observation-based method could be usefully employed on DMTA and other bases to determine the effect of on-land and submerged detonations. Current development of alternative underwater demolition ranges and the application for new off shore floating net cages in Jutten Bay by Southern Cross Salmon Farming (Pty) Ltd (DEA 2014) could be assessed through the adaptive maritime spatial planning (MSP) proposed by Douvere & Ehler (2011). It uses a range of relevant monitoring and evaluation measures to determine the effectiveness of spatial and temporal management proposals. To counter the lack of adequate knowledge, data and information at the start of MSP processes, advanced tools and techniques, such as remote sensing, GIS, GPS, and underwater autonomous systems are employed to deliver spatial and temporal data more readily and could improve maritime spatial plans considerably. For DMTA, a diversity of maritime data such as those collected by Clark et al. (2012) is available and can be incorporated into the development of a separate MSP encapsulated in the existing MIEM plan as required. To evaluate the effectiveness of such an MSP plan, a variety of ecological, socio-economic and institutional indicators needs to be developed (Douvere & Ehler 2011).

As DMTA is the SF base area in South Africa allowing and accommodating the most diverse activities, the SDSS model developed in this research can be further refined, exported and adapted for application at other Special Forces and SANDF military-training bases. To successfully manage DMTA as a multiple-use conservation area the DOD Environmental Services should become involved with the updating of the ecological management plan that outlines the strategic and tactical military importance of DMTA, management projects and reserve objectives highlighting their relevance, especially on national level. In doing so, the encompassing environmental policy of the SANDF can be adhered to and more transparency regarding DMTA status and activities can be achieved.

5.3.3 Recommendations concerning conservation management measures

Since the first occupation of the area by the whaling industry, the DMTA environment has been subject to detrimental and damaging activities that continually inflated and diversified with the establishment of the military base. These environmental challenges, some inherited, are however not unsolvable and the solutions proposed can effectively be implemented. Re-active rehabilitation of for instance roads, fences and dumping sites were practically experimented with, with slight effort and the results are already visible as discussed in Subsection 3.3. For new developments, regular full EIAs must be executed in formal compliance with national legislation before commencement of the projects. Realistic and effective mitigation measures must be implemented to prevent escalating negative conditions from developing – as occurred with the Salamander boat park construction mentioned before (Yeld 2010a; 2010b).

Environmentally-sustainable management can be ensured if MIEM is incorporated in daily activity orders and the SDSS tool applied when exercises or rehearsals are planned – as demonstrated in the application example in Chapter 4. By implementing this system as part of the legally prescribed MIEM in the SANDF and incorporating EIA principles and procedures, the impact of military activities on the environment can be minimised and ‘sacred’ or ‘sacrificed’ areas can be effectively identified and delimited. This measure will ensure that military areas are utilised in an environmentally-responsible manner in line with MIEM prescriptions and commitments to comply with environmentally-responsible conduct.

A more visionary recommendation reaching beyond the military confines entails a motivation for the inclusion of a number of DMTA land assets to be incorporated into the delineated Ramsar wetland of international importance at Langebaan. Specifically Meeuw Island and Donkergat Bay, Riet Bay and Salamander Bay should be so denoted. The voluntary inclusion of these military areas into the formally recognised Ramsar site is possible, as was evidenced by the precedent-setting expansion of the De Hoop Nature Reserve and its accommodation of the weapons test range at the De Hoop rocket-testing facility in the Cape Overberg region (Cowan 1995). It is proposed that the present demarcation of Langebaan as a Wetland of International Importance should be revised and the stipulation for the inclusion of the abovementioned areas should be considered and so appended. Presently, the Langebaan wetland is formulated as: “The designated site is composed of the islands Malgas, Jutten, Marcus and Schaapen; Langebaan Lagoon (15 km long, 12.5 km wide) up to the high-water mark, including marshlands and precincts of the lagoon, and a section of Sixteen-mile beach" (Cowan 1995:16). The suggested inclusions will amplify the environmental responsibility of the military, but on the other hand give part of DMTA international conservation status and add to the value of Meeuw Island and Riet Bay as 'sacred' areas. Since the entire DMTA coastline from Salamander Bay in the north to Perlemoen Point in the south borders on the designated Langebaan wetland, the suggested functional inclusion of Meeuw Island (7 ha), Donkergat Bay (39 ha), Riet Bay (186 ha) and Salamander Bay (46 ha) will expand the existing Ramsar area definition by a significant 278 ha. According to the signatory criteria adopted at the Conference of Contracting Parties held in Montreux in 1990 (Cowan 1995) no major objections can be raised to the proposed DMTA area inclusion into the current Ramsar site. Such inclusion would compel the DOD to shoulder an increasingly significant responsibility in the conservation of the natural environment entrusted to its care – essential to counter increasing pressure being placed on all natural domains on training areas of the DOD.

5.3.4 Recommended future research

Six research domains have been isolated for future researchers. These include finalisation of floral and faunal checklists, determining the effect of temporal conditions on shock-wave intensity during demolition exercises, proper EIAs for new developments, early-warning systems to counter illegal abalone poaching in DMTA waters, further refinement and promotion of the SDSS tool and enhanced involvement in general environmental studies as part of the Saldanha Bay water management initiative (Clark et al 2012).

The *checklists of plants and animals* that were compiled for DMTA remain incomplete at best, especially when compared to the bird, mammal and reptile lists provided in Schaefer (1993) for the neighbouring WCNP. Additional systematic identification by specialists, especially regarding plants, reptiles and insects must still be completed for the DMTA lists. The zoning and detailed mapping of natural plant communities and exceptional species occurrence can be upgraded with assistance from professional botanists to narrow down specific border specificities. Aid from geologists on the fine-scale geological composition of DMTA would be conducive to understanding this diversity. The identification of the spectrum of plants and detail composition of the communities should remain an continuing management task on DMTA. Furthermore, limited existing knowledge concerning the outstanding medicinal and cultural value of vegetation species occurring on DMTA land provides challenging research opportunities.

Research to determine the effect of temporal conditions on the *shock-wave intensity* of demolitions and establish limits to maximum amounts of explosives of different compositions that can be deployed under varying climatic conditions without disturbing breeding birds on the various islands or the residents of the surrounding urban areas is a prominent priority. In Finland Koponen (2013) found that the irritating effects of noise can be decreased by re-scheduling shooting events, an active information policy and co-operation with residents. A request for this investigation to be initiated was submitted to the responsible authority (Logistic Support Formation of the SANDF) during July 2013. As this research is subcontracted to institutions such as the CSIR, it is expensive at approximately R2.5 million. Funds for this venture must still be obtained, but approval is in process. Once this research effort is launched, a two-pronged survey methodology could be followed: One a natural sciences instrument-based measurement of physical shock-wave intensity received at various locations, and the second a social science-based questionnaire distributed to residents in the neighbouring areas to gauge human sensitivity and tolerance. Research staff at Stellenbosch University's Department of Geography and Environmental Studies have expressed keen interest in this research once explosives testing gets under way – provided that synchronisation of schedules can be achieved.

The boat park and breakwater *EIA* debacles alluded to (without divulging details) remain ongoing and must be addressed, where applicable, with public participation. The new boat park was completed under challenging conditions, but the public raised serious complaints about the military's non-adherence to set standards and the facility's visual pollution of the Bay's pristine appearance. Although currently merely in the planning phase, the construction of a 50 m breakwater has already proved controversial to members of the public (Richards 2013, Pers com). Scientific evidence for the need of this structure and the absence of significant possible influence on water circulation patterns in the Bay is demanded. With this new development the Langebaan Residents' and Ratepayers Association (LRRA) has declared opposition to the dogleg-formatted breakwater until proper detailed hydrographic studies had been completed and the results made public. The LRRA claims: "it was to prevent scouring or any further damage to the lagoon, such as had resulted from past constructions where only the immediate area had been looked at in advance" (Richards 2013, Pers com). In conjunction, the survey of submerged wrecks and the recovery of artefacts must be conducted by SAHRA or their authorised archaeological specialists. Due to the demands from pressure groups and institutions striving to obtain dominion over DMTA, it is mandatory that military impact on the environment be diminished and annoying activities be limited to the absolute minimum.

Because of its status as a strictly-prohibited military terrain that is actively enforced under armed surveillance, DMTA serves as a safe haven for threatened marine species harvested commercially elsewhere. *Abalone* and *West Coast crayfish* present as priority species. Along the coastline of the Langebaan Peninsula large numbers of these crustaceans occur and because of prevalent military activities poachers are relatively cautious to venture into the area. In the past poaching attempts have been met with aggressive responses, arrests and convictions, resulting in largely non-disturbance of the animals. However, improved evasion technology became available to the poaching community, resulting in increased pressure on this resource over the last five years. Research into early-warning systems to detect vessels trespassing into the military area and underwater trip wires for scuba divers was initiated and must now be further developed as a priority.

Current *environmental research* indicates trends of erratic or declining numbers of specific bird species that frequent the region and high concentrations of toxic trace metals in Donkergat Bay and Salamander Bay (Clark et al. 2012) have been reported. Monitoring of ecosystem indicators through regular survey and measurement of phenomena such as bird numbers, water quality, sediment quality, benthic macro-faunal composition, surf-zone fish numbers and rocky intertidal macro-fauna presence at DMTA must be diversified and intensified. DOD personnel should assist in influencing research and monitoring decision makers in the Saldanha Bay area. By being pivotally involved in such research, the DMTA can play an increasingly important role as a baseline ecosystem to benchmark and detect development impacts. The presence of unconditionally-sacred areas confined in the military area, such as Meeuw Island and Riet Bay, yet with potential for international conservation status, will add to the value of DMTA as ecological touchstone.

To succeed in assuring the survival of DMTA, this military area must be managed and developed as a reference model for the larger Saldanha Bay region and other DOD assets in South Africa. The *SDSS tool* can be implemented to ensure that DMTA, as a national asset, retains its long-term sustainable potential and, as DMTA is the SF area in South Africa where the most diverse activities take place, the SDSS concept can be developed to serve as model for other SF and SANDF military-training areas. This uniqueness status, linked to demonstrable competence and excellence in integrated impact management and meeting the demands of military conduct in a pristine natural environment, must be projected at all levels of society. Even the boot print of the Special Forces operator must guarantee that future elite candidates ‘tired of the rest and wanting to join the best’, will find a useful societal niche and haven at Donkergat.

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APPENDICES

APPENDIX A CO-ORDINATES OF DMTA BOUNDARY SHOWN IN FIGURE 1.4

The first bearing namely 33°05’10”S 18°00’45”E, is east of Meeuw Island and from this point the following bearings run anticlockwise with DMTA bounded by a line joining the points:

- 33°05’10”S 18°00’45”E
- 33°04’55”S 18°00’42”E
- 33°04’43”S 18°00’38”E
- 33°04’31”S 18°00’29”E
- 33°04’05”S 17°59’54”E
- 33°03’50”S 17°58’36”E
- 33°04’04”S 17°58’09”E
- 33°05’06”S 17°58’27”E
- 33°05’33”S 17°58’04”E
- 33°05’39”S 17°57’22”E
- 33°06’27”S 17°57’02”E
- 33°07’07”S 17°58’04”E
- 33°07’27”S 17°58’23”E
- 33°07’22”S 17°58’39”E
- 33°06’40”S 17°59’09”E
- 33°06’33”S 17°59’16”E
- 33°06’21”S 17°59’08”E
- 33°05’43”S 18°00’08”E
- 33°05’38”S 18°00’07”E

APPENDIX B LIST OF TERRESTRIAL PLANT SPECIES IDENTIFIED IN DMTA FROM 1988 TO 2010

Afrikaans common names used and if known English is mentioned (list being continuously developed and updated).

Agathosma sp.	Boegoe
Albuca flaccida	Slang-tamarak
A. maxima	Wittamarak
Amellus tenuifolius	Grysastertjie
Apiaceae sp.	
Arctopus echinatus	Platdoring/ Platanna doring
Arctotis breviscapa	Sandveldgousblom
A. hirsuta	Gousblom
A. revoluta	Krulblaargousblom
Aspalathus sp.	Ertjiebos
Asparagus capensis	Katdoring
Atriplex semibaccata	Rankbrakbossie
Babiana ambigua	Bobbejaantjie
B. ringens	Rotstert
Ballota africana	Kattekruie
Berkheya rigida	Disseldoring/ Krammedik
Boophane haemanthoides	Kwaslelie
Brunsvigia orientalis	Kandelaar
Carpobrotus acinaciformis	Elandsvy
C. edulis	Hotnotsvy
Chasmanthe floribunda	Piempiempie
Chlorophytum triflorum	Gifkool
Chrysanthemoides incana	Grysbietou
C. monilifera	Bietou
Clutia daphnoides	Vaalblaar
Crotalaria excise	Wildeklawer
Cybistetes longifolia	Malgaslelie
Cyanella hyacinthoides	Blouraaptol
Cynanchum africanum	Bobbejaantou
Cyphia crenata	Kleinbokkies
Diascia longicornis	Bokhorinkie
Dimorphotheca pluvialis	Reënblommetjie
Diosma hirsuta	Rooiboegoe
Didelta carnosa	Seegousblom
Dipogon lignosus	Bosklimop
Dorotheanthus bellidiformes	Bokbaaivygie
Drimia capensis	Maerman
Drosanthemum floribundum	Persdouvygie
Ehrharta calycina	Polgras/ Doppiesgras (Common or Dune Ehrharta)
E. erecta	Shade Ehrharta
E. villosa	Muggiesgras/ Pypgras
Empodium veratrifolium	Breëblaar-sterretjie
Eragrostis sp.	
Euclea racemosa	Kersbos
Euphorbia burmannii	Steenbokbos
E. mauritanica	Geelmelkbos
E. tuberosa	Melkbol
Euryops multifidus	Hanepootharpuisbos
Exomis microphylla	Brakbossie
Feliscia elongate	Astertjie
Ferraria divaricata	Geel-spinnekopblom
Festuca scabra	Munniksgras/Munnik Fescue
Ficinia nigrescens	Grasbiesie
Gethyllis afra	Koekemakranka
Gladiolus gracilis	Bloupypie
G. caeruleus	Saldanha-pypie
Grielum humifusum	Pietsnot
Haemanthus pubescens	Poeierkwas

H. coccineus Rooikwas (April fool)
Heliophilia digitata Kleinblomflaks
Hermannia scabra Gewone poproos
H. pinnata Kwasblaar-kruippoproos
Jordaaniella dubia Helderkruipvygie
Lasiochloa longifolia Haasgras
Lachenalia mutabilis Bontviooltjie
L. rubida Sandviooltjie
Lampranthus aureus Gouevygie
L. multiradiatus Helder-sandvygie
Lampranthus vredenburgensis Vredenburgse kruipvygie
Lebeckia spinecsens Sandganna
Limonium equisetinum Saldanha seelaventel
L. peregrinum Strandroos
Lotononis prostrata Kruip-wildeklawer
Lycium afrum Bokdoring
L. ferocissimum Slangbessie
L. tetrandrum Kraaldoring (Honey thorn)
Massonia angustifolia Bobbejaanboek (Orange buttonhole flower)
Maurocenia frangularia Hotnotskersie
Melasphaerula ramosa Feëklokkie
Mesembryanthemum alatum Akkedisplant (Lizard plant)
M crystallinum Ice plant
Microloma sigittatum Bokmaellie
Muraltia harveyana Saldanha-skilpadbos
Nemesia versicolor Bontleeubekkie/ Weeskindertjies
Nylandtia spinosa Skilpadbessie
Oncosiphon suffruticosum Stinkkruid/ Wurmbossie
Ornithogalum thyrsoides Tjienkerintjee
Orphium frutescens Teeringbos
Othonna filicaulis Bobbejaankoolklimop
Oxalis obtusa Geeloogsuring
O. pes-caprae Suring (Sorrel)
O. tomentosa Wolhaarsuring
Oxalis versicolor Candystick
Pelargonium fulgidum Rooimalva
P. hirtum Wortelblaarmalva
Pharnacceum incanum Regop-sneeuvygie
Protea sp.
Pteronia uncinata Strandgombos
P. divaricata Geelgombos
P. ovalifolia Grysgombos
Pterygodium sp.
Rhus clauca Taaiblaar
R.. laevigata var *laevigata* Taaibos
R.. laeviagata var *villosa* Koerentebos
Ruschia tecta Regopvygie
Sarcocornia perennis Seekoraal
Salsola kali Rolbossie (Russian thistle)
Salvia africana-lutea Strandsalie
Satyrium odorum Soettrewwa
Senecio elegans Veldcineraria
S. sarcoides Soetkopdikblaar
S. burchelli Gifbossie
Septulina glauca Kersies (Candles)
Silene undulata Wildetabak
Solanum quineense Melklelie
S. linnaeanum Gifappel
Spartina capensis Strandkweek
Sutherlandia frutescens Kankerbos
Tetragonia fruticosa Kinkelbossie
Thamnochortus spicigerus Duineriet
Trachyandra ciliata Hotnotskool
T. falcata Namakwakool
Zygophyllum flexuosum Spekbos
Z. morgsana Slaaibos

Sources: (Goldblast & Manning (2000), Manning & Goldblast (1996) and Smith (1966)

APPENDIX C LIST OF ANIMAL SPECIES IDENTIFIED IN DMTA FROM 1988 TO 2010

A comprehensive list for the West Coast National Park is available in Schaefer (1993)

MAMMALS

Alcelaphus buselaphus caama	Red hartebeest
Antidorcas marsupialis	Springbok
Atilax paludinosus	Water mongoose
Bathyergus suillus	Cape dune molerat
Connochaetes taurinus	Blue wildebeest
Cryptomys hottentotus	Common molerat
Cynictis penicillata	Yellow mongoose
Damaliscus dorcas dorcas	Bontebok
Felis caracal	Caracal
Equus zebra zebra	Cape mountain zebra
Felis lybica	African wild cat
Galerella pulverulenta	Small grey mongoose
Genetta genetta	Small spotted genet
Georychus capensis	Cape molerat
Hystrix africaeaustralis	Porcupine
Ictonyx striatus	Striped polecat
Lepus capensis	Cape hare
Lepus saxatilis	Scrub hare
Mus minutoides	Pigmy mouse
Mus musculus	House mouse
Otocyon megalotis	Bat-eared fox
Vulpes chama	Cape fox
Otomys irroratus	Vlei rat
Oryx gazella	Gemsbok
Pelea capreolus	Grey rhebok
Procavia capensis	Dassie
Raphicerus campestris	Steenbok
Rattus rattus	House rat
Rhabdomys pumilio	Striped mouse
Rhinolophus capensis	Cape horseshoe bat
Sylvicapra grimmia	Common duiker
Tragelaphus strepsiceros	Kudu
Taurotragus oryx	Eland

(Source: Skinner & Smithers 1990)

WHALES, SEALS AND DOLPHINS

Actocephalus pusillus pusillus	Cape fur seal
Balaena glacialis australis	Southern right whale
Cephalorhynchus heavisidii	Heuviside's dolphin
Balaenoptera edeni	Bryde's whale
Lagenorhynchus obscurus	Dusky dolphin
Megaptera novaeangliae	Humpback whale
Orcinus orca	Killer whale

(Source: Skinner & Smithers 1990)

TURTLES AND TORTOISES

Caretta caretta	Loggerhead turtle (shell found)
Chersina angulata	Angulate tortoise

LIZARDS

Agama atra.atra	Southern rock agama
Bradypodion pumilum	Cape dwarf chameleon
Mabuya capensis	Cape skink

SNAKES

Aspidelaps lubricus	Coral snake
Bitis arietans	Puff adder
Dispholidus typus typus	Boomslang
Lamprophis fuliginosus	Brown house snake
Naja nivea	Cape cobra

Pseudaspis cana	Mole snake

Source: Branch (1992)

BIRDS

Acrocephalus gracilirostris	Cape Reed Warbler
Alopochen aegyptiacus	Egyptian Goose
Anhinga melanogaster	Darter
Apalis thoracica	Barthroated Apalis
Ardea cinerea	Grey Heron
A. melanocephala	Blackheaded Heron
Arenaria interpres	Turnstone
Bostrychia hagedash	Hadeda Ibis
Bubo africanus	Spotted Eagled Owl
B. capensis	Cape Eagle Owl
Bubulcus ibis	Cattle Egret
Burhinus capensis	Spotted Dikkop
Buteo buteo	Steppe Buzzard
B. rufofuscus	Jackal Buzzard
Calidris alba	Sanderling
C. canutus	Knot
C. ferruginea	Curlew Sandpiper
C. minuta	Little Stint
Charadrius hiaticula	Ringed Plover
C.leschenaultii	Sand Plover
C. marginatus	Whitefronted Plover
C. pecuarius	Kittlitz's Plover
C.tricollaris	Threebanded Plover
Circus maurus	Black Harrier
C. ranivorus	African Marsh Harrier
Cisticola subruficapilla	Greybacked Cisticola
C. textrix	Cloud Cisticola
C. tinniens	Levaillant's Cisticola
Columba guinea	Rock Pigeon
Colius striatus	Speckled Mousebird
Corvus albicollis	Whitenecked Raven
C. albus	Pied Crow
Cossypha caffra	Cape Robin
Delichon urbica	House Martin
Egretta garzetta	Little Egret
Elanus caeruleus	Blackshouldered Kite
Emberiza capensis	Cape Bunting
E. impetuani	Larklike Bunting
Erythropygia coryphaeus	Karoo Robin
Euplectes orix	Red Bishop
Eupodotis afra	Black Korhaan
Falco rupicoloides	Greater Kestrel
F.tinnunculus	Rock Kestrel
Francolinus capensis	Cape Francolin
Fulica cristata	Redknobbled Coot
Gallinago nigripennis	Ethiopian Snipe
Haematopus moquini	African Black Oystercatcher
Himantopus himantopus	Blackwinged Stilt
Hirundo albigularis	Whitethroated Swallow
H. cucullata	Greater Striped Swallow
H. rustica	European Swallow
Hydroprogne caspia	Caspian Tern
Lanius collaris	Fiscal Shrike
Larus dominicanus	Kelp Gull
L. hartlaubi	Hartlaub's Gull
Lybius leucomelas	Pied Barbet
Merops apiaster	European Bee-eater
Morus capensis	Cape Gannet
Motacilla capensis	Cape Wagtail
Nectarinia famosa	Malachite Sunbird
Numenius arquata	Curlew
Numida meleagris	Helmeted Guineafowl
Oena capensis	Namaqua Dove
Oenanthe monticola	Mountain Chat
O. pileata	Capped Wheatear
Onychognathus morio	Redwinged Starling

Passer domesticus	House Sparrow
P. melanurus	Cape Sparrow
Pelecanus onocrotalus	White Pelican
Phalacrocorax africanus	Reed Cormorant
P. capensis	Cape Cormorant
P. carbo	Whitebreasted Cormorant
P. coronatus	Crowned Cormorant
P. neglectus	Bank Cormorant
Philomachus pugnax	Ruff
Phoenicopterus minor	Lesser Flamingo
P. ruber	Greater Flamingo
Platalea alba	African Spoonbill
Ploceus capensis	Cape Weaver
P. velatus	Masked Weaver
Pluvialis squatarola	Grey Plover
Pycnonotus capensis	Cape Bulbul
Recurvirostra avosetta	Avocet
Saxicola torquata	Stone Chat
Scopus umbretta	Hamerkop
Serinus sulphuratus	Bully Canary
Sigelus silens	Fiscal Flycather
Spheniscus demersus	Jackass Penguin
Spreo bicolor	Pied Starling
Stercorarius parasiticus	Arctic Skua
S. pomarinus	Pomarine Skua
Sterna bergii	Swift Tern
S. hirundo	Common Tern
S. sandvicensis	Sandwich Tern
Streptopelia capicola	Cape Turtle Dove
S. senegalensis	Laughing Dove
Struthio camelus	Ostrich
Sturnus vulgaris	European Starling
Tadorna cana	South African Shelduck
Telophorus zeylonus	Bokmakierie
Threskiornis aethiopicus	Sacred Ibis
Tringa glareola	Wood Sandpiper
T. nebularia	Greenshank
T. hypoleucos	Common Sandpiper
T. stagnatilis	Marsh Sandpiper
Turdus olivaceus	Olive Thrush
Tyto alba	Barn Owl
Upupa epops	Hoopoe
Vanellus armatus	Blacksmith Plover
V. coronatus	Crowned Plover
Zosterops pallidus	Cape White-eye

The bird Species listed were identified between 1997 and 2010 (111 species) on DMTA. Not all the birds in the checklist compiled by the Perzy Fitzpatrick Institute of African Ornithology for the West Coast National Park, (see Schaefer 1993) have yet been confirmed on DMTA.

APPENDIX D ANNUAL PLAN OF MANAGEMENT OBJECTIVES (2011 AS EXAMPLE)

These management objective guidelines are only those implemented at DMTA but can be used at other SF areas and be expanded to include the management of all the lifecycle elements (acquisition, utilisation, planning, maintenance, disposal and conversion) of infrastructure, training areas and the natural environment.

BASE ENVIRONMENTAL MANAGEMENT

No	Objective	Tasks	Status			Target date
			New	Existing	Achieved	
1	Water run-offs	Construct run-offs where needed and maintain existing ones on the roads to South Head, the water reservoir and from the main gate to Plankies Bay.	To be identified by environmen-talist.	*[1]	*	Continuous. Maintenance before rainy season
2	Fence mainte-nance	Repair and maintain the fences around DMTA and the three exclusion plots. Military area notice boards must at all times be maintained and displayed at all the road entrances and game-migration gaps in the fences.	Attention must be given to fences around Port Control installations such as at Elands Point.	*	Border fence upgraded in 2010.	Continuous
3	Terrain rehabilita tion	Investigate the possibility of rehabilitation of the quarries at the DMTA gate and the whaling excavation. Remove the periodically-deposited rubbish at the old dumping site north of Riet Bay.	*	*	Dumping site north of Riet Bay rehabilita ted.	July 2011 and continuous
4	Eradica tion of invasive plants such as Bros	Uproot all invasive plants outside the HQ perimeter and dispose at the Langebaan rubbish dump. Bros/dissel doring to		*		Continuous, to be monitored once every month.

[1] Asterisk indicate continuing or completed activities in the three status categories

No	Objective	Tasks	Status			Target date
			New	Existing	Achieved	
	doring, Gifappel, Manatoka, Rooikrans and Port Jackson	be eradicated inside the HQ perimeter as well				
5	Water provision for game	Clean all troughs every second week and fill those at South Head and below the magazine every Friday during the dry season.		*		Continuous
6	Road mainte-nance	Spray vegetation next to tar road with herbicide or remove physically. Sweep road if pebbles are present and fill existing holes with tar.		*		Continuous, quarterly
7	Mainte-nance of cultural-historical heritage sites	Maintain the gravesites and the WW II battery structures by regularly removing rubbish and eradication of weeds. Cover the areas between the graves with shell grit.	The 16-inch barrels obtained from Fort Wynyard must be transported to Hugo's Post and an information plaque displayed.	*	The hole in the WWII structure was repaired. Plaque with history of guns in process	Continuous, quarterly
8	Bird-flight diverters	Monitor the Hugo's Post power line north of Riet Bay for bird mortalities on a weekly basis. Fit more of the new, reflector diverters next to the existing pigtails. Space the pigtails already fitted and secure with tie-downs. A longer stretch of line must be safeguarded.	Experiment with the different reflector designs.	*		Continuous
9	Game manage-ment	Execute quarterly game counts on DMTA and Postberg in conjunction with SANParks and monthly on DMTA. Condition, age, young individuals and distribution must be documented.	More game must be removed and animals released in the park must be tagged or marked to make them easy to	*	Some animals were removed to Mooimaak and Robben Island.	Continuous, quarterly and monthly

No	Objective	Tasks	Status			Target date
			New	Existing	Achieved	
		Assistance with culling must be given to SANParks if requested.	identify and to determine if they move back to the place of capture.			

ECOLOGICAL MANAGEMENT

No	Objective	Tasks	Status			Target date	Executed by
			New	Existing	Achieved		
1	Data processing: Game counts, marine life surveys, natalities, mortalities, plant identification and weather parameters	Keep data updated, plot, process and file. Consolidate all relevant data on GIS.		*		Contin-uous	Lt Col JT Marx WO1 R Guthrie
2	Presentations	Update the oil pollution contingency plan and the DMTA environmental awareness presentations.		*		Dec 2011	Lt Col JT Marx
3	Game dispersion	Rotation between water -supply points		*		Season-ally	Lt Col JT Marx Environ-manager
4	Plant identification	Identify and list the vegetation and uniqueness of DMTA. Allocate species to the different communities, e.g. the Meeuw Island and the marsh community around Riet Bay to obtain data for motivation for the inclusion of these areas into the Langebaan Ramsar site.		*		Continu ous	Lt Col JT Marx
5	Impact of game on the vegetation	Taking of fixed-point photos at the three exclusion plots		*		Quarter -ly	Lt Col JT Marx
6	Water-savings plan	Identify the localities of all water points. Compile a water-savings plan and implement.	*			Decem ber 2011	Lt Col JT Marx Environ-manager
7	Bird surveys	Document numbers of black oystercatchers once yearly as part of the Percy Fitzpatrick venture. Quarterly survey of birds on Meeuw Island in conjunction with DEAT. Identify and mark oystercatcher nests.		*		Contin-uous	DEAT Lt Col JT Marx Environ-manager
8	Research	Liaise with personnel from research institutions, e.g. the		*		Contin-uous	Lt Col JT Marx

No	Objective	Tasks	Status			Target date	Executed by
			New	Existing	Achieved		
		IZIKO Museum and Stellenbosch University interested to conduct research on or near DMTA.					
9	Game management	Co-ordinate game reduction and relocation programme with SANParks.		*		January 2011	Lt Col JT Marx RSM
10	West Coast National Park management committee	Attend quarterly meetings if requested.		*		Quarter ly	Lt Col JT Marx
11	Environmental committees	Attend the Spespark, oil pollution contingency plan, Western Cape Environmental Forum and meetings with the Langebaan community.		*		Contin-uous	Lt Col JT Marx RSM Environ-manager
12	Law enforcement	Execute law-enforcement actions in conjunction with DEAT and allocated SAPS units.		*		Contin-uous	Lt Col JT Marx Environ-manager RSM Unit members
13	Cultural-historic heritage sites	Maintain gravesites and the WW II Battery structures. Include the history and maintenance proposals received from Logistics Support Formation in the DMTA Management Plan.		*		Contin-uous	Lt Col JT Marx Environ-manager

ENVIRONMENTAL EDUCATION AND TRAINING

No	Objective	Tasks	Status			Target date	Executed by
			New	Existing	Achie-ved		
1	Survival centre	Maintain the survival centre and expand the edible and medicinal value plants at the outdoor exhibition. Develop information boards for the different divisions enabling the centre to be self-explanatory. Continue with new exhibitions such as the escape, evasion and detention section.		*		Dec 2011	Lt Col JT Marx
2	Marine aquarium	Obtain a sponsor for a marine aquarium. Test the system at the survival centre with a few algae, anemones, limpets, molluscs, and starfish. If the system is functional inhabitants such as members of the Arthropods, and other marine plants and animals can be added.		*		Dec 2011	Lt Col JT Marx
3	Education	Present lectures and talks to unit members, school groups, survival-course learners and other visitors.		*		Contin uous	Lt Col JT Marx Environ-manager

APPENDIX E PARTICIPANTS IN SPATIAL DECISION SUPPORT SYSTEM MODELLING

NAME	INSTITUTION	ACTIVITY
Mrs A Aggenbach	Assistant Director, Logistic Support Formation	Cultural-historical heritage sites and MIEM
Prof PB Best	Mammal Research Institute, IZIKO Museum	Cultural-historical heritage sites and the influence of demolitions on sea mammals
Lt Cmdr M Bisset	Ex-curator SA Naval Museum	Cultural-historical heritage sites and DMTA WWII history
Mr C de Villiers	Retired Union Whaling employee	Identification and naming of whaling-era infrastructure. Member supplied photographic material of high value that is presently being transformed into digital format.
WO2 WC Dettmer	4SFR Fire Services	Pyrotechnics, fire hazards and survival
Mr D Heart	City of Cape Town Senior Heritage Manager	Cultural-historic heritage sites
Sgt B Meyer	4SFR Training Commando, General Training	Shooting ranges and infantry associated activities
WO1 RH Snyman	4SFR Training Commando, Commando WO	Swimming, boat work and sailing
Maj FH Sundermann	4SFR Training Commando, Air Wing	Parachuting and infantry associated activities
Prof JH van der Merwe	Chairman, Department of Geography and Environmental Studies, Stellenbosch University	Detail on shoreline geomorphology and vegetation community boundaries.
Capt J van Niekerk	4SFR 4.1 Commando, Dive Team	Diving
SSgt PL van Niekerk	4SFR Operations, Senior Operations Clerk	Infantry weapons, pyrotechnics and weather influence on weaponry