APPENDIX E

Infrastructure Condition and Capacity Assessment

These guidelines are designed to assist the Government of Nauru infrastructure asset managers to:

a. undertake condition assessments of infrastructure assets
b. undertake capacity assessments of infrastructure assets under their control.

Undertaking these assessments will help to prioritize investments into asset repairs, renewal, replacement and capacity augmentation and to ensure the investments in infrastructure are economically efficient. These guidelines also provide information on the design and construction details of existing infrastructure assets and describe their degradation, which impact on the assets' operating performance.

These guidelines cover the following infrastructure asset types:

- buildings
- roads
- airport runway
- wharves, jetties and channels
- electricity generating and distribution plant
- telecommunication plant
- water supply infrastructure
- waste water treatment plant
- solid waste management
- coast protection assets
- motor vehicles
- motor boats and ferries.

1. Infrastructure condition assessment methodology

Infrastructure assets degrade in their operating environment over time. Degradation of assets' operating condition gradually retards their functional performance and when the functional performance drops below a pre-determined acceptable level, the asset is deemed to have reached the end of its useful service life and must be retired from service and replaced. The typical useful life of an asset is the time period in years the asset is expected to perform at acceptable levels before reaching the end of its useful service life.

The typical useful life for a class of asset is based on the historic average service life of an asset under typical normal operating conditions. But the actual useful service life of an asset can deviate significantly from the typical useful life, depending on asset's operating environment, conditions of service, exposure to climatic events or major storms, and the level of preventative maintenance an asset receives. Some assets fail prematurely, long before they reach their typical useful life, while others continue to provide reliable service for many years beyond their typical useful life.

Therefore, rather than planning the replacement of an asset when it reaches its typical useful life, it is be prudent to periodically assess the condition of assets, to determine their remaining service potential, so assets found in “poor operating condition” can be targeted for retirement and replaced at the appropriate time.

These guidelines describe a methodology to objectively assess the condition of infrastructure assets. In case of simple assets, assets’ operating condition can be assessed through evaluating an asset’s overall performance in meeting its intended functions, but in case of complex assets, operating performance of assets’ major components should be assessed first and the results of individual component’s performance are summed through use of an appropriate algorithm. After the operating condition of a batch of assets in a class is assessed, the assets in similar conditions can be grouped together. Table E-1 provides objective and rationale criteria for expressing and ranking the operating condition of infrastructure assets or their components.

Table E-1: Condition assessment criteria for infrastructure assets and their components

Asset or Asset Component's Operating Condition	Condition Rating
Asset or asset component is in “brand new” condition, with no defects and no impairment; excellent operating condition, meeting or exceeding the service level requirements - Only routine maintenance is needed	5
Asset in “Like-new” condition, with no defects and no impairment; good operating condition, meeting the service level requirements - Only routine maintenance is needed	4
Asset or asset component shows minor age-related wear, with minor defects and/or minor degradation in operating performance; the lower threshold of required service level is still being met	3
Asset or asset component has worn out to a stage, where its performance no longer meets acceptable performance level . However through refurbishment/renewal it is possible to improve asset's performance to acceptable levels	2
Asset or asset component has degraded to a stage that its performance cannot be restored to acceptable levels through renewal and asset must be replaced.	1
Asset or asset component has failed in service or it poses the risk of catastrophic failure in service posing serious public safety risk and must be retired immediately and replaced.	0

While Table E-1 provides useful and objective criteria for expressing assets’ operating condition, in some cases it may be difficult to accurately measure asset’s operating performance in field. There are limits to the in-situ tests and field inspections can be economically performed to detect and identify all defects in assets. Because the scope and frequency of preventative maintenance play a major role in sustaining an asset’s operating performance in the long run, the accuracy of assets’ remaining useful life estimates provided through a physical condition assessment can be improved by including an asset’s maintenance history among the assessment criteria. Table E-2 indicates how an asset’s maintenance history can be used to rank and express an asset’s readiness to provide its intended functions.

Table E-2: Use of assets' maintenance history for condition assessment

Asset's Maintenance History	Condition Rating
Asset maintained in accordance with the maintenance strategy throughout its service life, with adequate funding available for maintenance	5
Asset maintained in accordance with the maintenance strategy during most of its service life, with adequate funding available for maintenance	4
Asset maintained in accordance with the maintenance strategy since last renewal, with adequate funding available for maintenance	3
Asset has not been maintained in accordance with the maintenance strategy during most of its service life, which has resulted in significant impairment of asset condition	2
Asset has not been maintained in accordance with the maintenance strategy during most of its service life, which has resulted in major impairment of asset condition	1
Asset was not maintained in accordance with the maintenance strategy during most of its service life, which has resulted in total impairment of asset condition and asset is at end of its service life	0

And finally, an asset may be in perfect operating condition, but may not be able to meet the public need for services because the user needs have evolved or the regulations have changed and the new needs cannot be met with an asset's obsolete design. Therefore, it is important to assess assets' functional obsolescence and include it among the criteria to assess assets' conditions, as summarized in Table E-3.

Table E-3: Use of assets' functional obsolescence for benchmarking performance

Degree of Functional Obsolescence	Condition Rating
Asset design and construction fully meet the functional requirements, conform to the applicable standards and regulations and are the most economically efficient alternative available	5
Asset design and construction fully meet the functional requirements, conform to the applicable standards and regulations and represent one of the economically efficient alternative	4
Asset design and construction fully meet the functional requirements, conform to the applicable standards and regulations, but other alternatives offering greater economic efficiency are available	3
Asset design or construction do not meet the full functional requirements and are not economically efficient, original suppliers no longer manufacture the product	2
Asset design or construction do not meet the full functional and regulatory requirements and are not economically efficient, original suppliers no longer manufacture spare parts	1
Asset or asset component has failed in service or it poses the risk of catastrophic failure in service posing serious public safety risk and must be retired immediately and replaced.	0

After a condition assessment, obsolescence assessment, and maintenance history assessment for an asset have been completed using the criteria provided in Tables E1–E3, the results of these assessments can be combined to determine the remaining service potential (RSP) of assets on a normalized scale. The algorithms for calculating the RSP for each class of asset are described in the following sections.

2. Buildings

The government-owned buildings in Nauru primarily consist of administrative office buildings, warehouses, and institutional buildings, i.e. hospital and health care buildings, school buildings and airport buildings and do not include any residential dwellings. The building assets are managed by a number of ministries including Health, Education, Transport, Fisheries, Administration, and public-sector enterprises such as electricity and water utilities.

2.1 Building components and their functions

Most of the government buildings in Nauru are one or two storey buildings. The buildings commonly consist of some or all of the following components:

- foundation
- building structure, including load bearing walls, floor joists (if any) and roof trusses
- floor finishes
- roof (exterior only, not including roof trusses)
- exterior wall cladding
- interior finishes for walls and ceilings
- building services, i.e. ventilating and air conditioning, plumbing and electrical wiring
- sewer and sanitation service.

Building foundations provide a stable base for bearing structural members. A building's structure supports the weight of the floors and roof to create a space that consists of self-supporting walls, posts and beams, floor joists, and roof trusses. The floor finishes provide visually appealing floor surfaces, capable of being easily swept and kept clean. Building roofs play two distinct roles: they provide a water-tight envelope on top of the building to protect the interior space from rain and sun and they are also used to harvest rain water for water supply. Partition walls separate the space into different rooms, and interior finishes provide visually appealing paintable surfaces. Windows allow entry of natural light and openable windows also permit ventilation. Ventilating fans and air conditioning are used to control interior building temperature to improve comfort. Plumbing provides pressurized water supply into buildings and drains to remove residue from sinks, bathtubs, and toilets into the sewer or septic holding tanks. Electrical wiring facilitates lighting and power plugs throughout the building. Air conditioning and ceiling fans help maintain interior temperature and air quality at comfortable levels.

2.2 Building construction details

Government buildings in Nauru typically use concrete slabs supported on footings or pillars as the building's foundation. For a small number of portable buildings used in schools, the buildings' foundations consist of concrete posts.

The commonly used building structures in Nauru consists of:

- reinforced concrete walls
- masonry walls
- steel posts
- timber framing structures.

When a concrete slab is used as a foundation, it also serves as the subfloor to support floor loads. However, some portable buildings used in schools use plywood for the subfloor. Ceramic or linoleum tiles are commonly used for floor finishes, although some buildings with a concrete slab as the subfloor do not use any floor finishes.

For building roofs, two types of building materials are commonly used—hot-dip galvanised corrugated steel sheeting, which is less expensive and more commonly used for building construction and paint-finished galvanized steel sheeting.

No exterior wall cladding is required when the exterior walls are made of reinforced concrete or masonry. But in case of wood or steel framing structures, external wall cladding in form of aluminum, galvanised iron, engineered wood or fiber-reinforced cement siding is commonly used for government buildings in Nauru.

Interior finishes for partition walls and ceilings generally consist of paintable grade drywall panels (gypsum/gyprock). Windows and exterior doors generally use painted steel frames or painted aluminum frames and glass louvers. Interior doors are commonly made of wood panels. Central air conditioning systems are only used for large buildings. For plumbing, PVC pipes are used for both high-pressure water pipe and drains. Electrical circuits use PVC or XLPE insulated copper wires. Building with critical power needs are equipped with stand-by generation, in addition to the grid power supply. Some of the school buildings are equipped with solar panels.

Virtually all buildings have a separate section for toilets, which are connected to a septic tank. All buildings are equipped with above-grade water storage tanks.

2.3 Common degradation modes for buildings

Strength of most construction materials and adhesives decreases with age mainly due to oxidation. Typical degradation for concrete building structures involves concrete spalling and corrosion of steel rebars, both of which result in reduced structural strength. Buildings located in close vicinity to the coast line experience accelerated degradation due to salt spray from ocean carried by wind. Similarly, if sand from the ocean or ocean water is used to mix sand during construction, sea salt in sand significantly reduces the useful life of structures. The structure is considered to have reached the end of its service life when the reduced strength lowers the safety factor for the structure to less than acceptable level.

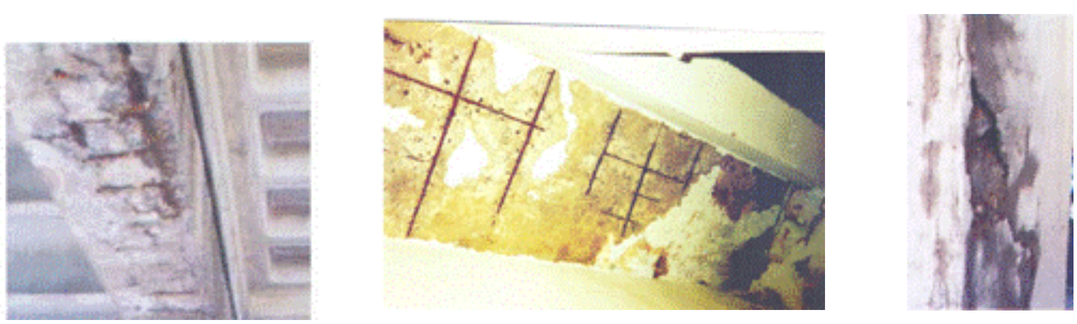


Figure E-1: Degradation of building concrete structures

In some cases, a building's structure can develop serious deficiencies, such as cracks in concrete beams, columns, walls and slabs, and deformation of vertical structural members (getting out of plumb), due to poor design, poor detailing of steel reinforcement in structural members, poor quality of construction and settlement of soil under concrete foundations.

Masonry walls can develop cracks due to uneven settling of the soil below foundation walls, as shown in Figure E-2.

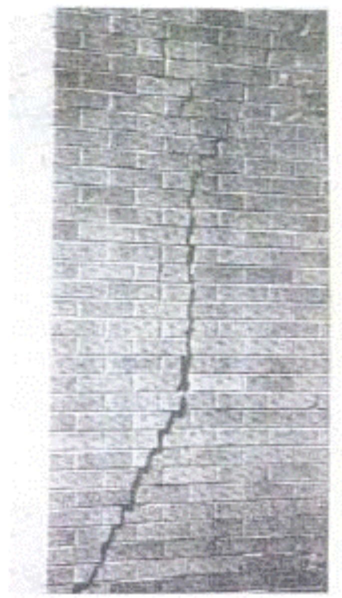


Figure E-2: Structural cracks in masonry

Wood framing walls get weakened in structural strength due to wood rot, in particular, if wood is repeatedly exposed to moisture. Any cracks in wall cladding or roof leaks can expose structural timber to moisture, causing asset impairment. Wood framing can also be weakened by insects that can bore through wood, i.e. termites.

Ceramic tile floors can experience premature degradation when installed incorrectly using inappropriate cement for grout. Similarly, linoleum floors experience accelerated aging when exposed to moisture.

Corrugated iron roofs are particularly subject to corrosion, which can severely reduce their service life when the building is in close proximity to the ocean. If a roof develops a leak, all other components including the structure, walls, flooring and electrical wiring can experience impairment.

All components with steel members, such as door and window hinges and louver hardware, air conditioner frames experience corrosion under ocean spray. PVC water pipes may develop leaks due to incorrect use of pumping motors with excessive pressure.

Service life of electrical wiring, when properly designed and protected against overcurrent and over-voltage, should over last the building structure; however, if the overcurrent protection becomes dis-functional, electrical wiring can fail prematurely. Joins in plumbing pipes may fail if they are accidentally subjected to excessive pressure due to fault pumps.

All building components, including structures, may fail or experience impairment, resulting in loss of service life during a cyclonic storm or storm surge. Building roofs, structural walls, or columns may fail from excessive force exerted by cyclonic wind or water surge and building foundations can be structurally damaged if the soil below the foundations shifts.

2.4 Typical useful life of building components

The useful life of various building components can vary significantly, based on the type of construction, quality of materials, and workmanship. The useful life of building components is also impacted by environmental and operating conditions and the scope and quality of preventative maintenance. Based on typical building design and construction, as well as the prevailing environmental conditions and preventative maintenance practices, assumptions used in this report for typical useful life of building components are indicated in Table E-4.

Building foundations and structures have the longest service life of the various building components. Many building components reach the end of their useful service life well before the building structure, but these can be replaced independently when they reach the end of their service life. Most building components are replaced or renewed entirely when they reach the end of their service life and, therefore, the cost of these building components is not further broken into long-term and short-term components. For some building components, such as electrical and plumbing services, renewal can take place at subcomponent level and, as shown in Table E-1, these components are further split into short life and long life subcomponents.

Table E-1: Typical useful life of building components

	Typical Useful Life (TUL) in years		
Building Components	**Basic Design**	**Standard Design**	**Superior Design**
Substructure	40	60	60
Structure	40	60	60
Roofing	10	20	30
Exterior Wall Cladding	20	30	40
Fitouts	40	60	60
Floor Covering	20	30	40
Service Mechanical	10	20	30
Services Electrical	20	30	40
Services Sanitation	20	30	40
Services Water	20	30	40

2.5 Building condition assessment techniques

a. Condition assessment of building components other than the building structure

Condition assessments of all building components other than the structure can be performed by a competent building inspector through visual inspections and by carefully looking at the symptoms and identifying root causes of degradation. For example, damaged ceilings, walls, and floors can be identified through visual inspections, but the root cause of such damage may be exposure to water from condensation, plumbing pipe leaks, or leaks in roof or exterior walls. Degradation of windows and doors may be indicated by deformation of the frame and sashes, rusty frames and hardware, or broken or cracked glass. Faulty plumbing may have leaky joints in pressurized water pipes or drains. Compressors in air conditioning systems may fail due to excessive corrosion of the moving parts. Electrical systems may display arcing due to loose connection.

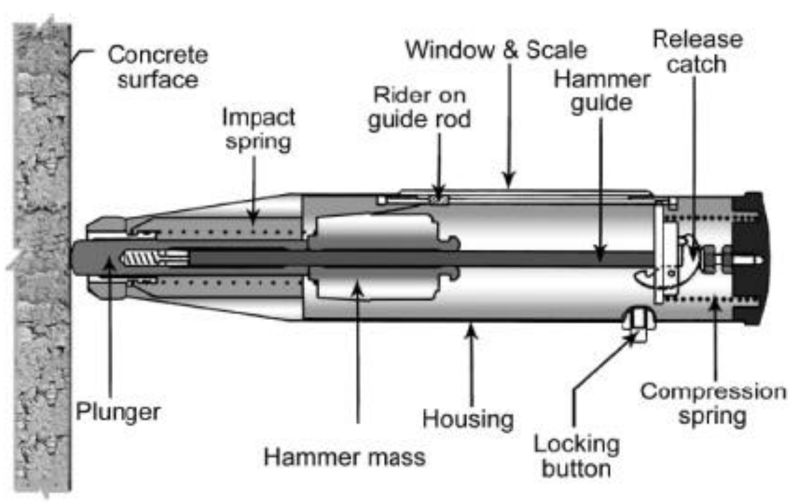
b. Condition assessment of building structure and foundations

After inspection of the structural components during warranty period, structural inspections are not required until after the building structure has passed half of its normal economic life. After this, structural assessments should be performed once every 10 years. Condition assessments of structures are also necessary immediately after a major natural disaster that may have affected the building structure.

Condition assessments of structures should be performed by a structural engineer to determine the probable remaining useful life of the building's structure and recommend mitigation when structural integrity is compromised.

Common condition assessment techniques for concrete and masonry building structures include visual inspections to identify cracks in structural members, concrete spalling, and corrosion of rebar. For a structural engineer to perform a complete condition assessment of a building through visual inspections, it is extremely important to maintain complete records of a building's design details and drawings, architectural details, construction details and drawings including the specifications of materials used, geotechnical details of the area and foundation details, and details of any previous repairs or retrofitting.

When visual inspections reveal serious defects, a number of non-destructive tests are available to determine the extent of degradation: (a) measurement of concrete surface hardness through a rebound hammer test, and (b) performing compressive and tensile strength testing on core samples.[1]



Rebound hammer test

Figure E-3: Condition assessment of concrete structures

[1] Civil Engineering, The constructor, http://theconstructor.org.

2.6 Buildings’ remaining service potential

To determine a building’s RSP, the physical condition of all building components, as well as the maintenance history and degree of functional obsolescence for the building, should be assessed using criteria provided in Tables E-1, E-2 and E-3. The results of the assessment should be combined through the algorithm shown in Table E-6, to determine the RSP of each building. In Table E-5, the weights assigned to various condition parameters are based on their criticality to the asset’s ability to perform its intended functions, as well as the economic viability of renewable asset components.

2.7 Building capacity adequacy index

Building capacity adequacy Index for a class of buildings is expressed on a scale of 1 to 5 and it indicates if the existing capacity of buildings is sufficient to meet the current and immediate future needs or if an increase in building capacity is required through construction of new buildings. Table E-5 lists the criteria for building capacity adequacy index.

Table E-5: Buildings—Capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
There is more than 5% spare capacity in existing buildings to fully meet the users’ current and future needs for next five years and beyond	5	Very good
There is less than 5% spare capacity in existing buildings to fully the meet the users’ current and future needs for up to next five years	4	Good
There is just adequate capacity to meet the current needs, but no spare space to meet growth in office staff in coming years	3	Fair
There is significant shortage of space—supply is exceeded by demand less than 10%	2	Poor
There is severe shortage of space—supply is exceeded by demand by more than 10%	1	Very poor

Table E-6: Buildings—RSP calculation algorithm

Component	Substructure Condition	Structure Condition	Roofing Condition	Exterior Wall Cladding Conditon	Fitouts Condition	Floor Covering	Mechanical Services	Electrical Services	Sanitation Service	Water Supply	Obsolescence Rating	Maintenance History	Total	RSP
Max Rating	5	5	5	5	5	5	5	5	5	5	5	5		
Actual Rating	?	?	?	?	?	?	?	?	?	?	?	?		
Weight	2	4	1	2	3	1	1	1	1	1	2	1		
Actual Score	?	?	?	?	?	?	?	?	?	?	?	?	?	
Max Score	10	20	5	10	15	5	5	5	5	5	10	5	100	Actual Score/Maximu Score

3 Roads

Roads in Nauru can be classified into two main categories:

- paved sealed roads
- unsealed gravel roads.

The Ring Road is the major sealed road in Nauru, serving all the 13 districts along the coast. Additional sealed roads connect land parcels on the hill to Ring Road. The unsealed gravel roads serve the mining areas and solid waste landfill site in the hills.

3.1 Road components and their functions

Sealed roads consist of the following essential components:

a. seal—surface layer
b. pavement base course
c. formation—earthwork grading.

The following additional assets associated with sealed roads, can be treated as additional components of sealed roads or treated as independent assets, but they impact the overall effectiveness and functionality of road system:

a. concrete curbs
b. concrete foot paths
c. road drainage.

The road network in Nauru does not have any bridges and at the time of writing this report and there are no traffic control signals.

The unsealed roads have only two main components:

a. pavement—graded aggregate surface
b. formation—earthwork under the pavement.

Sealed road surface, in the form of asphalt or chip seal, provides a smooth sealed surface for traffic flow at required speed in a safe manner. The paved road surface also prevents ponding of road surfaces by draining water into gutters along the curbside and prevents degradation of the base. Unsealed roads are also intended to provide a pathway for traffic, but due to unsmooth pavement, both the ride comfort and speed are compromised. Concrete curbs provide structural support to asphalt paving and help extend its service life. In the absence of concrete curbs, the pavement will experience erosion at the edges and will degrade quickly, compromising the width of travel lanes. Road surface layer also has the road markings, the purpose of which is to help drivers to stay within their lanes, thus avoiding the risk of collisions. For safe driving conditions, the lane markings should be visible. Maximum road speed in Nauru is 50km/hour, which is reduced to lower posted speeds in some sections.

3.2 Road construction details

Most sections of the sealed roads in Nauru, including the Ring Road and the Buada Hill Road were constructed by the Japanese Government in the 1970s. The Ring Road circles the perimeter of the island in a flat formation and is approximately 17.8 km. Most of the sealed roads are 7.2 m wide around most of the island, except for the town centres where it is wider to cater for on-street parking and right-turning lanes. Different sections of the Embassy Roads vary in width from 6.3 m to 9.1 m.

The Ring Road has a thin asphalt concrete (AC) surfacing layer. In most locations, both sides of the carriageway are contained by a cast in-situ concrete dish channel and curb and a channel for carrying surface water to the nearest sump. Most of the Ring Road has a concrete footpath of approximately 1.2 m width, on one side of the road, but some sections have the footpath on both sides of the road and there are some sections of the road without footpath on either side.

The Ring Road and the Buada Hill Road network are equipped with a drainage system, which was installed when the roads were first constructed. The drainage system consists of gravity sumps, installed on the side of the roads behind the channel, which drain into soak holes, on the side of the road constructed, close to the sumps.

The Hospital Hill and Embassy Roads are mainly residential roads, with about 100 vehicle movements per day. These roads have a low stone walls constructed as borders to prevent surfacewater runoff to the sides to safeguard against soil erosion on the hill. The roads have high shoulders along the stone walls and the middle of the roads is the lowest point. This causes the water to pond on the roads. The poor drainage on these roads results in accelerated degrading of the surface layer and in the absence of maintenance, most of the surface layer has eroded.

3.3 Common degradation modes for roads

Typical degradations for asphalt pavement are the oxidation of binding material, which gradually decreases the pavement strength. With age, the pavement begins to become brittle and starts to develop surface cracks, as shown in Figure C-4.

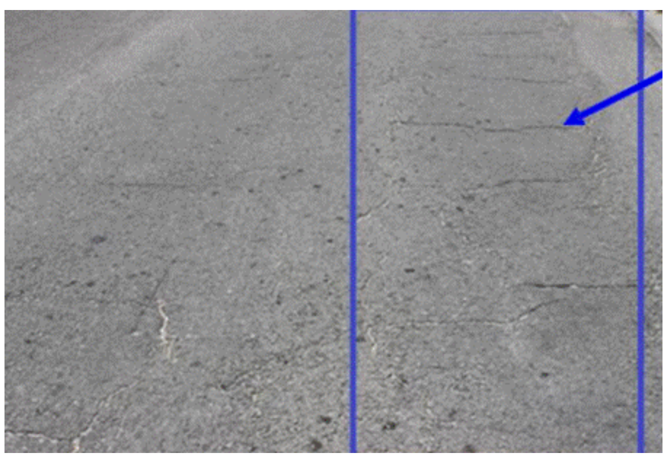


Figure E-4: Road degradation modes—surface cracks

Water seeps underneath the surface pavement through these cracks, further accelerating the AC aging process. The AC surface eventually starts crumbling and breaking up, resulting in formation of potholes in road, as shown in Figure E-5. Hot climates increase the oxidation rate in asphalt and over time, the pavement becomes brittle more swiftly than it would if the asphalt was located in a temperate climate. Traffic volume and weight of motor vehicles also play a role in degradation of road surfaces. High traffic volume with heavier trucks degrades the road surfaces faster. Ocean spray and frequent flooding of road surfaces with saltwater accelerate degradation of the paved surfaces.

Figure E-5: Degradation modes of roads—surface degradation due to ponding

Timely resealing of asphalt pavement prevents moisture from penetrating its surface and slows down the rate of oxidation of the underlying pavement, substantially. If cracks in the road surface are resealed in a timely manner, it helps extend the service life of paving, but when the cracks are not resealed, the paved surfaces degrade more quickly.

Road markings made with paint begin to wear and fade over time.

Concrete curbs also degrade in strength over time, but concrete degrades more slowly in relation to asphalt. However, if the soil below the concrete curb washes away, in the absence of any steel reinforcing, concrete curb would break up. Once the curb has been damaged, it exposes the asphalt surface to seepage of water from the edges and road edges begin to crumble and break up. Therefore, to protect road pavement, it is important to repair the concrete curbs promptly.

Concrete footpaths experience degradation due to soil erosion if the soil below the footpath is washed away during a rainstorm. Grass and weed roots can start growing through the footpath, causing cracking of the concrete footpath, as shown in Figure E-6.

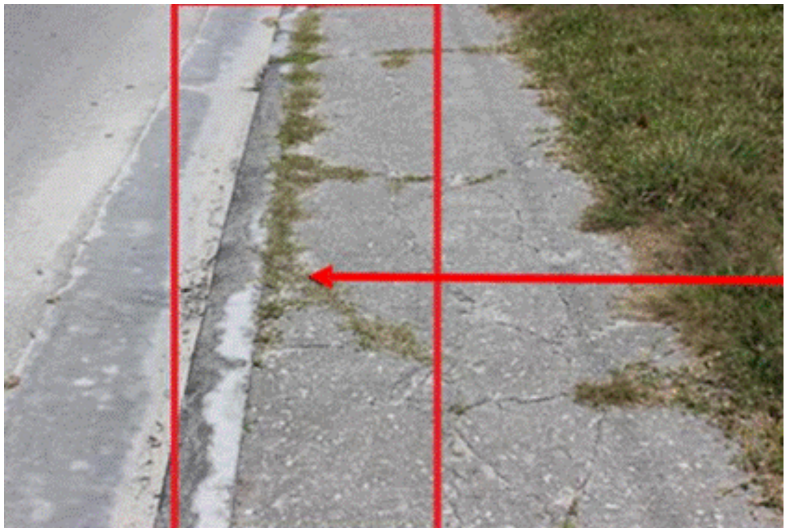


Figure E-6: Degradation modes of concrete footpath

Roads experience accelerated degradation when the drainage system fails to function, resulting in ponding of the road surfaces over extended durations. Lids of the sumps can get damaged under heavy vehicle loading, allowing debris to get into these sumps and cause blockages. When the pipes connecting the sumps to soak pits are clogged, or the soak pits are saturated, they result in failure of the road drainage system.

Figure E-7: Degradation modes—clogged drainage sump

3.4 Typical useful life of roads

The typical useful life of road components can vary over a broad range, based on the quality of surface and pavement, traffic volume, effectiveness of drainage, and the quality and scope of preventative maintenance. For example, if clogged drains are not promptly repaired and water is allowed to stand on the road, it would result in accelerated degradation of the surface. Similarly, if the defects in road surface are not promptly repaired, it would lead to formation of larger potholes, causing degradation of the base pavement. And if the pavement is not promptly repaired, it may lead to soil erosion under heavy rain, resulting in impairment of the formation.

The road surface renewal typically involves milling of the overlay AC to remove corrugations (“shimmies”), with a fine-profile milling machine and resurfacing of the top layer. Because only the top part of the surface layer is milled and resurfaced, the lower level of AC (layer beneath the milled depth) is considered the long life component and the milled depth is considered the short life component. The short useful life of the surface is the average time between the surface renewal treatments e.g. mill and replace for AC or reseal with chip. The long useful life for the surface is the time between complete road reconstruction and it is estimated to be about five times the renewal cycle.

If the road seal is not renewed on time and the pavement base below the surface is damaged, typical base renewal process is to rip and remake the top 150–200 mm depth of the base pavement. During re-pavement of the base, the sub-base (layer beneath the ripped depth) is considered the long life component, as this layer of the base is not replaced, during renewal of the pavement base and the upper layer (which is ripped and removed) is considered the short life component. The short useful life for the base is the average time between renewal treatments e.g. a rip and remake or granular overlay and the long useful life is the time between complete road reconstruction and it is estimated to be twice the base renewal cycle.
For unsealed roads, the short life is based on re-grading the existing gravel pavement and long life is based on replenishment of the gravel pavement through addition of fresh gravel and re-grading. The earth formation in case of both sealed and unsealed roads is assumed not to degrade with no investment requirements for renewal or replacement. The curbs, footpaths and drainage system are replaced as whole component when they reach the end of their life and they do not have any short-life components.

Based on the above listed assumptions, the typical useful life for the sealed and unsealed road components are indicated in Table E-7 and Table E-8, respectively. The typical life of footpaths is provided in Table E-9.

In Table E-7, for road surface and road pavement components, a “short life” and a “long life” is shown. This is because when the road surface reaches the end of its life, before application of a new seal, the existing road seal material is removed through a milling operation. But during the milling operation, 100% of original seal is not removed, but only the top portion of the seal is removed and the lower portion remains in service. Similarly, when the base pavement reaches the end of its service life, only a fraction of the original pavement is ripped and removed and the lower portion of the base pavement remains in service.

Table E-7: Typical useful life of components of sealed roads in Nauru

Road Components	Typical Useful Life (TUL) in Years			
	Short Life			Long Life
Road Formation	Road Formation (Earthwork)			
	Flat	Rolling	Steep	Steep
	N/A	N/A	N/A	N/A
Base Pavement	Base Pavement			
	Light	Standard	Heavy	Heavy
	50	75	100	200
Road Surface	Road Surface			
	Inferior	Standard	Superior	Superior
	15	20	25	75
Curb and Gutter	Curb and Gutter			
	None	One Side	Both Side	Both Side
	N/A	50	50	N/A
Drainage Sumps c/w Soak Pits	Drainage Sump c/w Soak Pits			
	None	One	Two	Two
	N/A	50	50	N/A

Table E-8: Typical useful life of components of unsealed roads in Nauru

Road Components	st (GRC) in Austra	Typical Useful Life (TUL) in Years			
		Short Life			Long Life
Road Formation	Road Formation (Earthwork)				
	Steep	Flat	Rolling	Steep	Steep
	110	N/A	N/A	N/A	N/A
Base Pavement	Base Pavement				
	Heavy	Light	Standard	Heavy	Heavy
	26	10	10	10	20

Table E-9: Typical useful life of footpaths in Nauru

Infrastructure Asset	Typical Useful Life in Years
Foot path	30

3.5 Condition assessment of roads

Condition assessment of roads and their components should be performed by a civil engineer or competent road inspector. Condition assessment of the roads and their components can be performed through visual inspections, by carefully examining the condition of the pavement surfaces, concrete curbs, footpaths and drainage system and taking into account the number of potholes per kilometer length of the road and their condition.

3.6 Roads remaining service potential

To determine the RSP of various road sections, the physical condition of all road components should be performed through condition assessment of the roads and all deficiencies are identified and assessed using Table E-1. Similarly, the maintenance history and degree of functional obsolescence related to the sealed and unsealed roads should be assessed using criteria provided in Tables E-2 and E-3. The results of these assessments should be combined through the algorithm shown in Tables E-10 and E-11, respectively, to determine the RSP for each section of sealed and unsealed roads.

Table E-10: Sealed roads—RSP calculation algorithm

Component	Formation Condition	Base Pavement Condition	Surface Condition	Curb and Gutter Condition	Drain Sump and Soak Pit Condition	Obsolescence Rating Condition	Mainteance History	Total	RSP
Max Rating	5	5	5	5	5	5	5		
Actual Rating	?	?	?	?	?	?	?		
Weight	1	3	12	1	1	1	1		
Actual Score	?	?	?	?	?	?	?	?	
Max Score	5	15	60	5	5	5	5	100	Actual Score/Max Score

Table E-11: Unsealed roads—RSP calculation algorithm

Component	Formation Condition	Base Pavement Condition	Obsolescence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5	5		
Actual Rating	?	?	?	?		
Weight	2	8	4	6		
Actual Score	?	?	?	?	?	
Max Score	10	40	20	30	100	Actual Score/Max Score

Table E-12: Concrete footpath—RSP calculation algorithm

Asset	Footpath Condition	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5		
Actual Rating	?	?	?		
Weight	16	2	2		
Actual Score	?	?	?	?	
Max Score	80	10	10	100	Actual Score/Max Score

3.7 Road capacity adequacy index

Road capacity adequacy index is expressed on a scale of 1 to 5 and indicates if the existing road network is sufficient to meet the current and immediate future needs or if an increase in road capacity is required through construction of new roads. Table E-13 provides the road capacity adequacy index criteria.

Table E-12: Roads—capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
100% of the existing buildings and vacant land parcels are connected with a reliable road network.	5	Very good
100% of the existing buildings and vacant land parcels requiring development in the next 5 years are connected with a reliable road network.	4	Good
100% of the existing buildings are connected with a reliable road network but all the vacant land parcels are not connected.	3	Fair
Less than 5% of the buildings are not accessible by reliable the road network	2	Poor
More than 5% of the buildings are not accessible by reliable the road network	1	Very poor

4 Airport runway

The airport runway in Nauru is approximately 2160 m long and 46.2 m wide. It has widened turning areas at each end. The airfield was originally constructed by the Japanese during the World War II as a military base. The last major upgrade to the runway was done in 1993, when it was extended and upgraded. The total length of the runway has grooves to a depth of about 5 mm and spaced at about 100 mm centres, 15 m either side of the centreline. These grooves help drain water off the runway as well as help improve the skid resistance of the runway.

There are two taxiways to facilitate aircraft in and out, each about 54 m long and 23 m wide. There is hardstand area to the west of the terminal building, which is about 120 m long and 57 m wide. There is also a carpark in front of the terminal building, which is about 60 m long and 20 m wide and there is a second carpark to the east of the main car park area, which is 20 m by 20 m. Directly to the south of these carparks (between the terminal building and the runway), and running parallel to the runway, is the main Ring Road.

4.1 Runway components and their functions

The runway has the following main components:

a. asphalt seal—surface layer
b. pavement base course
c. formation—earthwork grading.

The perimeter security fence is an additional infrastructure asset associated with safe operation of the runway. Although a number of navigation aids, including UHF/VHF radio, precision approach path indicator (PAPI) and wind direction indicator are important pieces of safety equipment for the runway, detailed discussion of their failure modes or maintenance is beyond the scope of this document.

The runway surface layer provides a hard, skid-free surface for safe aircraft landing and takeoffs. The paved surface also needs to be graded laterally, to allow rainwater to drain away from the runway centerline on apron, without causing ponding on the runway surface. The runway is grooved for about15 m on either side of centreline. Runway surface grooves, which are cut in the transverse direction to the pavement centerline, make a secondary contribution to drainage, but their main purpose is to increase friction between the pavement surface and aircraft tires, to reduce the possibility of hydroplaning, even when there is water on the runway. Runway grooving provides improved contact between aircraft tires and the pavement surface under the condition of standing water

The purpose of runway markings is to provide visual display to the aircraft pilots during daytime landing conditions. Runway markings indicate the beginning and end of the designated space for landing and takeoff under non-emergency conditions.

The security fence consists of a 1.2 m high chain link fence, supported on steel posts installed at 3 m intervals. While at most airports, the purpose of security fence is to provide a secure airside zone with restricted access to public, in Nauru, the security fence is designed mostly to keep the animals away from the runway.

4.2 Runway construction details

A full set of construction details and specifications for the runway must be maintained during the entire life cycle of the asset, including the depth of the base pavement and surface layer. The drawings showing construction details of the existing runway were not available for this project.

4.3 Common degradation modes for runway

Typical degradation for asphalt pavement are the oxidation of binding material, which gradually decreases pavement strength, and the pavement becomes brittle and develop longitudinal or lateral cracks, as shown in Figure E-8.

Figure E-8: Runway surface degradation due to cracks

If impurities in form of vegetation are present in the quarried material used for resurfacing, such vegetation decays and plucks out, leaving imperfections in the surface, as shown in Figure C-9.

Figure E-9: Runway surface degradation due to vegetation plucking-out

Similarly, if asphalt is paved over the base contaminated with vegetation, when the vegetation rots, failures appear in form of volcano cracks, which, as shown in Figure E-10, are much more serious because they extend through the entire surface layer into the base.

Figure E-10: Runway surface degradation due to volcano cracks

Resealing of asphalt pavement prevents moisture from penetrating its surface. It also substantially slows down the rate of oxidation of the underlying pavement. If the cracks in runway are resealed in a timely manner, it helps extend the service life of paving, but when the cracks are not resealed, the paved surfaces degrade more quickly.

For security fences, the common degradation is oxidation (rusting) of steel members with age, which gradually reduces the structural strength of the members, eventually leading to failure. Fence impairment may also be caused by damage due to motor vehicle accidents or due to vandalism.

4.4 Typical useful life

The typical life of runway components can vary broadly depending on the quality of surface and base pavement, number of flights per week, the type of aircraft, effectiveness of drainage and the quality and scope of preventative maintenance.

The runway surface renewal typically involves milling of the overlay AC with a fine-profile milling machine and resurfacing of the top layer. Because only the top part of the surface layer is milled and resurfaced, the lower level of AC (layer beneath the milled depth) is considered the long-life component and the milled depth is considered the short life component. The short useful life of the surface is the average time between the surface renewal treatments e.g. mill and replace for

AC or reseal with chip. The long useful life for the surface is the time between complete runway reconstruction and it is estimated to be about three times the renewal cycle.

Typical base renewal process is to rip and remake the top 200–300 mm depth of the base pavement. During re-pavement of the base, the sub-base (layer beneath the ripped depth) is considered the long-life component, as this layer of the base is not replaced, during renewal of the pavement base and the upper layer (which is ripped and removed) is considered the short-life component. The short useful life for the base is the average time between renewal treatments e.g. a rip and remake or granular overlay and the long useful life is the time between complete road reconstruction and it is estimated to be twice the base renewal cycle.

Based on the above listed assumptions, the typical useful life for the structural runway components are indicated in Table E-14. The typical life of the other assets associated with the runway, which are treated as independent assets in the asset register, is provided in Table E-15.

Table E-14: Typical useful life of main components of air strip in Nauru

Air Strip Components	Typical Useful Life (TUL) in Years	
	Short Life	Long Life
	Air Strip Formation (Earthwork)	
Air Strip Formation	N/A	N/A
	Base Pavement	
Base Pavement	75	120
	Air Strip Surface	
Air Strip Surface	25	75

Table E-15: Typical useful life of runway-associated assets

Infrastructure Asset	Typical Useful Life in Years
Navigation Aids PAPI	25
Navigation Aids—edge lighting	25
Chainlink fence	25

4.5 Condition assessment

Condition assessment of structural components of the air strip should be undertaken by a civil engineer. Condition assessments can be performed through visual inspections, by carefully examining the condition of the pavement surfaces supplemented by in-situ testing,[2] if required.

In-situ testing with dynamic cone penetrometer (DCP), e.g. Scala penetrometer or Drop Impact Hammer (Clegg Hammer), or Shear Vane and test pit and hand auger investigations, as shown in Figure E-11 can be used to further confirm the remaining strength of pavement.

Figure E-11: Tools to assess the remaining strength of runway pavement

4.6 Airstrip remaining service potential

To determine the RSP of the airstrip, the physical condition of the runway, taxiways, and hardstand areas should be performed through a condition assessment of the airstrip and its associated assets and all deficiencies identified and assessed using Table E-1. Similarly, the maintenance history and degree of functional obsolescence related to the airstrip and associated assets should be assessed using criteria provided in Tables E-2 and E-3. The results of these assessments are then combined through the algorithms shown in Tables E16, E-17, E-18 and E-19 to determine RSP for the air strip, navigation aids, edge lighting and the security fence, respectively.

[2] Foundation Investigation. Standard Test Procedures Manual. Saskatchewan Highways and Transportation.

Table E-16: Airstrip—RSP calculation algorithm

Component	Formation Condition	Base Pavement Condition	Surface Condition	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5	5	5		
Actual Rating	?	?	?	?	?		
Weight	4	4	8	2	2		
Actual Score	?	?	?	?	?	?	
Max Score	20	20	40	10	10	100	Actual Score/Max Score

Table E-17: NAVAID equipment—RSP calculation algorithm

Asset	NAV AIDS - PAPI Condition	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5		
Actual Rating	?	?	?		
Weight	12	6	2		
Actual Score	?	?	?	?	
Max Score	60	30	10	100	Actual Score/Max Score

Table E-18: NAVAID edge lighting—RSP calculation algorithm

Asset	NAV AIDS - Edge Lighting	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5		
Actual Rating	?	?	?		
Weight	12	6	2		
Actual Score	?	?	?	?	
Max Score	60	30	10	100	Actual Score/Max Score

Table E-19: Airstrip security fence—RSP calculation algorithm

Asset	Security Fence	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5		
Actual Rating	?	?	?		
Weight	12	6	2		
Actual Score	?	?	?	?	
Max Score	60	30	10	100	Actual Score/Max Score

4.7 Airport runway capacity adequacy index

The airport runway capacity adequacy index is expressed on a scale of 1 to 5 and indicates if the existing airport and runway has sufficient capacity to meet the current and immediate future needs of users or if additional airport or runways are required. Table E-20 provides an example of airport runway capacity adequacy index.

Table E-20: Airport runway—capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
The existing airport is conveniently located to fully meet the air travel needs of 100% of potential service users.	5	Very good
The existing airport is conveniently located to fully meet the air travel needs of more than 90% but less than 100% of potential service users.	4	Good
The existing airport is conveniently located to fully meet the air travel needs of more than 70% but less than 90% of potential service users.	3	Fair
The existing airport does not meet the air travel needs of more than 30% but less than 50% of potential service users with willingness to pay for the service	2	Poor
The existing airport does not meet the air travel needs of more than 50% of potential service users with willingness to pay for the service.	1	Very poor

5 Commercial port and boat harbor

The role of commercial port is to allow docking of ships and large boats to facilitate loading and unloading of cargo by allowing docking of large ships. When a reef blocks the pathway for a ship to reach the dock, channels are required to be cut through the reef to allow safe passage of the ship or boat to the rock.

The Port Authority of Nauru manages the main commercial wharf, located in Aiwo District. The existing wharf does not allow docking of ships next to the wharf. Ships are moored in the deep water, some distance away from the wharf, and are loaded and unloaded using freight boats, which are referred to as sea mules. Containers are transferred from the wharf to the freight boat, using the ship's crane and are lifted from the freight boat with help of a mobile crane stationed on the wharf.

The construction of a new wharf is currently ongoing, which would allow docking of the commercial freight ships at the wharf. It is strongly recommended that the company responsible for designing the wharf should also be asked to prepare detailed procedures for the wharf's condition assessment.

In addition to the main wharf, there is a small boat harbor in Anibare District, which is used as boat launching facility and is managed by the Fisheries Department.

5.1 Major components of the commercial port

Seaport wharves have the following major components:

a. structural supports
b. decking on horizontal surface and padding on vertical sea walls
c. mooring systems
d. approach channels.

Support structures commonly consist of foundations, steel reinforced concrete or concrete encased steel pillars and beams. Loading and unloading surfaces are generally paved with reinforced concrete. Vertical seawalls along the ocean are padded with cushions to prevent damage to boats and ships from collisions with concrete structures during docking. To allow the safe passage of ships to the dock, channels of sufficient depth and width are required to suit the size of boats and ships. Mooring systems allow securing of ships docked at the wharf, as well as mooring of the ships in deep water waiting for a berth at the wharf.

The boat harbor in Nauru only has structural support and decking and no mooring or approach channels.

5.2 Wharf construction details

Many different types of design and construction materials can be used in wharf construction. For asset management, it is extremely important that a full set of construction drawings and specifications for wharves be maintained for the entire life cycle of the wharf and boat harbors.

5.3 Common degradation for wharves

Typical degradation for wharf structures involve concrete spalling and rusting of steel rebar in structural members or corrosion of steel support pillars, as shown in Figure E-12.

Figure E-12: Example of structural corrosion at wharf

Because these structures are exposed to extremely corrosive conditions, anticipated high corrosion rates are taken into account during structural design and compensated with selection of greater safety margins. Degradation of structural strength also occurs due to metal fatigue induced by cyclic or dynamic loads. Degradation mechanisms related to metal loss and fatigue are typically time-dependent and determine the maximum service life of the wharves and jetties. Chain links used in mooring systems, which are required to carry high cyclic axial tension loading, also suffer from corrosion and weaken in strength over time.

5.4 Typical useful life

The typical useful life of components of the commercial port is indicated in Table E-21.

Table E-21: Typical life expectancy of components of commercial port

Commercial Port Components	Typical Useful Life (TUL) in Years	
	Short Life	Long Life
Pier / Sea Wall Structure	Pier/Sea Wall	
	80	N/A
Decking	Decking	
	40	N/A
Access Channel	Access Channel	
	20	80
Mooring Buoys	Mooring Buoys	
	20	N/A

Because the boat harbor is a relatively small concrete structure, for asset management and condition assessment, it is treated as the whole structure (rather than components) with a typical useful life of 50 years.

5.5 Condition assessment

Condition assessment of wharves should be performed by a structural engineer with experience in marine structures. All structural and non-structural defects affecting safety and operations are identified. Alternatives for mitigation of the defects are identified and cost estimates are prepared for the most attractive option.

5.6 Commercial port remaining service potential

To determine the RSP of the commercial port, the physical condition of the wharf structure, surface decking, mooring buoys, and access channels is performed through condition assessment of these components and all deficiencies are identified and assessed using Table E-1. Similarly, the maintenance history and degree of functional obsolescence related to the commercial port should be assessed using criteria provided in Tables E-2 and E-3. The results of these assessments should be combined through the algorithms shown in Table E-22 to determine RSP of commercial port. For the boat harbor, which is treated as a single component structure, RSP calculation algorithm is shown in Table E-23.

Table E-22: Commercial port—RSP calculation algorithm

Component	Pier / Seawall Condition	Decking Condition	Approach Channel Condition	Mooring Buoys Condition	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5	5	5	5		
Actual Rating	?	?	?	?	?	?		
Weight	6	3	3	3	3	2		
Actual Score	?	?	?	?	?	?	?	
Max Score	30	15	15	15	15	10	100	Actual Score/Max Score

Table E-23: Recreational boat harbor—RSP calculation algorithm

Asset	Boat Harbour Condition	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5		
Actual Rating	?	?	?		
Weight	16	2	2		
Actual Score	?	?	?	?	
Max Score	80	10	10	100	Actual Score/Max Score

5.7 Capacity adequacy index for commercial ports and boat harbors

The capacity adequacy Index for wharves and boat harbors is expressed on a scale of 1 to 5 and it indicates if the existing wharves or boat harbors have adequate capacity and are appropriately located to meet the current and immediate future needs of potential users or if additional wharves or harbor capacity is required. Table E-24 provides the capacity adequacy criteria for commercial ports and recreational boat harbors.

Table E-24: Commercial port and recreational boat harbor—capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
The existing wharves and boat harbors have adequate capacity and are conveniently located to fully meet the needs of 100% of potential service users.	5	Very good
The existing wharves and harbors have adequate capacity and are conveniently located to fully meet the needs of more than 90% but less than 100% of potential service users.	4	Good
The existing wharves and harbors are conveniently located to fully meet the needs of more than 70% but less than 90% of potential service users.	3	Fair
The existing wharves and harbors do not meet the needs of more than 30% but less than 50% of potential service users with willingness to pay for the service	2	Poor

Condition criteria	Capacity adequacy index	Interpretation
The existing wharves and harbors do not meet the needs of more than 50% of potential service users with willingness to pay for the service.	1	Very poor

6 Coastal protection—sea walls

Coastal protection in the form of sea walls or rock revetments protects coastal districts from flooding caused by ocean waves and, more specifically, to protect high-value assets, i.e. roads, buildings, aviation assets, electricity, or telecommunication assets from damage. Coastal protection is also provided to prevent shoreline erosion.

6.1 Coastal protection design and construction types

There are three types of costal protections commonly used,[3] but only the first two types are currently used in Nauru.

a. Immobile (rigid) structures

These are vertical, sloping or stepped structures, as shown in Figure E-13 and are constructed of mass concrete or reinforced concrete, grouted rock or blocks. They require a well-founded toe, on hard substrate to avoid scour and undermining. The structures must be strong to withstand high wave loading. Because they do not dissipate wave energy effectively (the structures are rigid and do not move), overtopping incidents are high.[4]

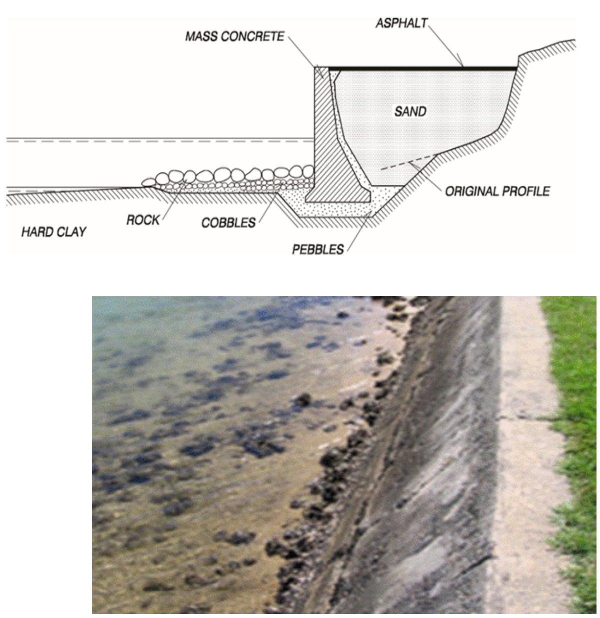


Figure E-13: Vertical sea wall—fixed structure

[3] Affordable Coastal Protection, Pacific Regional Infrastructure Facility (PRIF) and Tonkin & Taylor International Ltd.
[4] Affordable Coastal Protection, Pacific Regional Infrastructure Facility (PRIF) and Tonkin & Taylor International Ltd.

b. Semi-mobile structures

Semi-mobile structures are not firmly attached to ground and have the ability to move under wave pressure, which helps to dissipate some of the wave energy. If earth under the structure settles, the structure moves to new seabed location, without getting cracked or damaged. Semi-rigid structures are therefore better suited in regions with higher waves. Figure E-14 shows some example of the semi-rigid structures:[5]

- rock revetments
- sand-filled geotextile bags held under gravity.

In Nauru, there are a number of rock revetments sea walls in use, but no sand-filled bag protection is used currently.

Figure E-14: Semi rigid structures—sand-filled bags and rock revetments

c. Dynamic structures

Dynamic coastal protection structures involve artificial addition of sand or gravel to the coast to improve the capacity of a beach to act as a buffer against storm erosion or storm surge to protect the land behind. Sand replenishment or beach nourishment projects are examples of dynamic structures. When a wave strikes a dynamic structure, the structure moves to alter its shape and, in doing so, absorbs the wave energy. Dynamic materials continue to be moved over time with some loss of sand or gravel. Therefore, coastal protection using dynamic materials must include adequate build up to allow gradual material loss over time. Rock and gravel, which are also commonly used in mobile structures are generally less mobile than sand and therefore require less ongoing maintenance.

Dynamic structures are more suitable for lagoons, where the wave activity is modest, the sand loss would occur at a much faster rate if they are used along on sea coast and this is why this type of protection is not used in Nauru.

[5] Affordable Coastal Protection. Pacific Regional Infrastructure Facility (PRIF) and Tonkin & Taylor International Ltd.

6.2 Common degradation modes for coastal protection structures

a. Rigid structures

Rigid structures can break, but they don't bend. So, when the force from a storm surge exceeds the structural strength of the structure, it can cause damage to the structure in form of structural cracks. High waves can overtop the structure resulting in complete destruction of the sea wall. In general, rigid structures are less prone to gradual degradation in strength but can fail suddenly under storm surge.

b. Semi-mobile structures

Semi-mobile structures will bend but not break. They are less likely to suffer total failure during wave overtopping, but parts of the structure may get washed and displaced, requiring maintenance after each storm event.

c. Mobile structures

They undergo ongoing erosion and will require periodic rehabilitation. The timing of such rehabilitation depends on the strength of the wave activity.

6.3 Typical useful life of coastal protection structures

Coastal protection structures are self-sacrificing protective structures. There is no typical useful life for the three types of structures, because the life of the structure would be highly variable—dependent on the design used and wave activity. However, for the purpose of financial reporting and investment planning, the typical useful life shown in Table E-25 is proposed for different types of structures.

Table E-25: Typical useful life coastal protection structures

Infrastructure Asset	Typical Useful Life in Years
Sea Wall - Steel Reinforced Concrete	60
Masonry Wall of Rock (Std)	40
Masonry Wall of Rock (Superior)	50
Rip rap	40

6.4 Coastal protection structures—condition assessment

Condition assessment of the rigid structures can be carried out by a structural engineer through visual inspections, both above and below water. In case of significant damage to the structure, the remaining strength of the concrete would need to be determined through testing. When a portion of the soil from under the footings has washed away, the bearing strength of the soil may need to be examined.

Condition assessments of the semi-mobile and mobile structures can be completed by a civil engineer through visual inspections and dimensional measurements to determine the loss of material during a storm.

6.5 Coastal protection structures—remaining service potential

To determine the RSP of coastal protection structures, the physical condition of the structure should be performed through condition assessment of structures and all deficiencies are identified and assessed using Table E-1. Similarly, the maintenance history and degree of functional obsolescence should be assessed using criteria provided in Tables E-2 and E-3. The results of these assessments should be combined through the algorithms shown in Table E-22 to determine RSP of commercial port. For the boat harbor, which is treated as a single component structure, RSP calculation algorithm is shown in Table E-26.

Table E-26: Coastal protection structure—RSP calculation algorithm

Asset	Coastal Protection Structure Condition	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5		
Actual Rating	?	?	?		
Weight	12	6	2		
Actual Score	?	?	?	?	
Max Score	60	30	10	100	Actual Score/Max Score

6.6 Capacity adequacy index

The capacity adequacy Index for coastal protection infrastructure is expressed on a scale of 1 to 5 and indicates the percentage of vulnerable shoreline that is currently protected by the existing costal protection infrastructure. Table E-27 shows the proposed infrastructure capacity adequacy index for coastal protection infrastructure.

Table E-27: Coastal protection infrastructure—capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
The existing coastal protection infrastructure protects 100% of the vulnerable shoreline against anticipated storm surge during the next 10–20 years.	5	Very good
The existing coastal protection infrastructure protects <100%, ≥95% of the vulnerable shore line against anticipated storm surge during the next 10–20 years.	4	Good
The existing coastal protection infrastructure protects <95%, ≥75% of the vulnerable shoreline against anticipated storm surge during the next 10–20 years.	3	Fair
The existing coastal protection infrastructure protects <75%, ≥50% of the vulnerable shoreline against anticipated storm surge during the next 10–20 years.	2	Poor
The existing coastal protection infrastructure does not protect >50% of the vulnerable shoreline against anticipated storm surge during the next 10–20 years.	1	Very poor

7 Solid waste management

In the absence of a functional strategic management plan for solid waste management, Nauru has not committed sufficient financial resources to waste management in the past. Until the 1990s, there was no landfill site for solid waste disposal and household waste was buried in backyards or at the beach, thrown into the sea, or burned.[6] Waste collection services are now provided by Nauru Rehabilitation Corporation (NRC), through its Waste Management Division and they also manage a small landfill site, located on top of the hill, on previously mined land. The landfill site is located on top of an aquifer, and has no lining or leachate collection provision. The waste is burned first and then pushed into an old mined-out area and bulldozed and covered with a thin layer of soil.

Currently, there are no facilities to segregate recyclables from solid waste, although under a pilot project, financed by the Government of Japan, a small-scale waste transfer station was under construction at the landfill site. A significantly large number of buildings in Nauru, have asbestos roofing and lack of proper places for disposal of abandoned asbestos materials is a major concern for public health and safety.

[6] Asian Development Bank 2014. Publication Stock No. ARM146610-2, June.

The medical waste incinerator, installed at the hospital, was not working in 2018 and it is understood that medical waste is burned in open pit at the landfill site.

7.1 Solid waste infrastructure components

Main components of solid waste disposal system include:

- landfill site
- medical waste incinerator.

7.2 Construction details

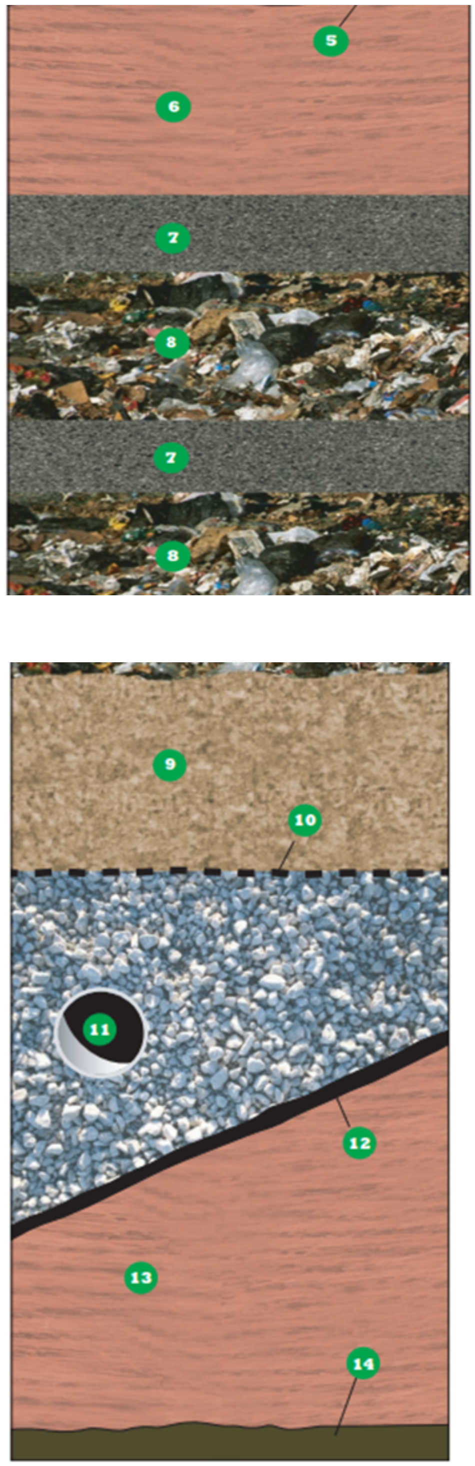
a. Landfill site

Ideal landfill sites are designed to minimize any environmental impacts, while providing a cost-efficient and long-lasting site for solid waste disposal. Figure E-15 shows the cross-section for a desirable landfill site design.[7] To protect the leachate created during decomposition of organic waste from seeping into the ground, a thick plastic liner made of high-density polyethylene (HDPE), commonly referred to as geo membrane, is installed at the floor of the landfill site. It is also common to install a compacted layer of clay above the native soil to support the liner in level position and to prevent leachate from leaking into the soil.

A perforated pipe is installed just above the liner to collect leachate and drain it into a sump pit, where it is collected for disposal. A geotextile fabric filter is installed above the leachate collection pipe to allow the leachate to flow through it, but prevent the solid waste from falling through and clogging the leachate collection pipe. Solid waste is dumped and compacted in layers, with each layer being covered by soil to prevent flies from getting into the waste and also to prevent objectionable odors. Venting pipes are also installed to vent out methane, which is produced by decomposing organic matter.

The landfill site in Nauru does not have the provision for collection of leachate or vent pipes and this may create some environmental issues if leachate overflows and contaminates the ground.

[7] Waste Management, Typical Anatomy of a Landfill, www.wm.com.



4 Drainage Layer
A layer of sand or gravel or a thick plastic mesh called a geonet drains excess precipitation from the protective cover soil to enhance stability and help prevent infiltration of water through the landfill cap system. A geotextile fabric, similar in appearance to felt, may be located on top of the drainage layer to provide separation of solid particles from liquid. This prevents clogging of the drainage layer.

5 Geomembrane
A thick plastic layer forms a cap that prevents excess precipitation from entering the landfill and forming leachate. This layer also helps to prevent the escape of landfill gas, thereby reducing odors.

6 Compacted Clay
Is placed over the waste to form a cap when the landfill reaches the permitted height. This layer prevents excess precipitation from entering the landfill and forming leachate and helps to prevent the escape of landfill gas, thereby reducing odors.

9 Leachate Collection Layer
A layer of sand or gravel or a thick plastic mesh called a geonet collects leachate and allows it to drain by gravity to the leachate collection pipe system.

10 Filter Geotextile
A geotextile fabric, similar in appearance to felt, may be located on top of the leachate collection pipe system to provide separation of solid particles from liquid. This prevents clogging of the pipe system.

11 Leachate Collection Pipe System
Perforated pipes, surrounded by a bed of gravel, transport collected leachate to specially designed low points called sumps. Pumps, located within the sumps, automatically remove the leachate from the landfill and transport it to the leachate management facilities for treatment or another proper method of disposal.

Composite Liner System

Working Landfill

7 Daily Cover
At the end of each working period, waste is covered with six to twelve inches of soil or other approved material. Daily cover reduces odors, keeps litter from scattering and helps deter scavengers.

8 Waste
As waste arrives, it is compacted in layers within a small area to reduce the volume consumed within the landfill. This practice also helps to reduce odors, keeps litter from scattering and deters scavengers.

Please Note: This illustration depicts a cross section of the standard environmental protection technologies of modern landfills. While the technologies used in most landfills are similar, the exact sequence and type of materials may differ from site to site depending on design, location, climate and underlying geology.

12 Geomembrane
A thick plastic layer forms a liner that prevents leachate from leaving the landfill and entering the environment. This geomembrane is typically constructed of a special type of plastic called high-density polyethylene or HDPE. HDPE is tough, impermeable and extremely resistant to attack by the compounds that might be in the leachate. This layer also helps to prevent the escape of landfill gas.

13 Compacted Clay
Is located directly below the geomembrane and forms an additional barrier to prevent leachate from leaving the landfill and entering the environment. This layer also helps to prevent the escape of landfill gas.

14 Prepared Subgrade
The native soils beneath the landfill are prepared as needed prior to beginning landfill construction.

(Not to scale)

Figure E-15: Ideal landfill design

b. Medical waste incinerator

Figure E-16 shows a typical medical waste incinerator[8], which commonly uses oil for fuel. The incinerator has a two-stage burner, which reduces the emission levels of harmful emission products. An incinerator has been procured and installed at the hospital inside a shelter, but it has not been commissioned, because it is missing some parts for the burner.

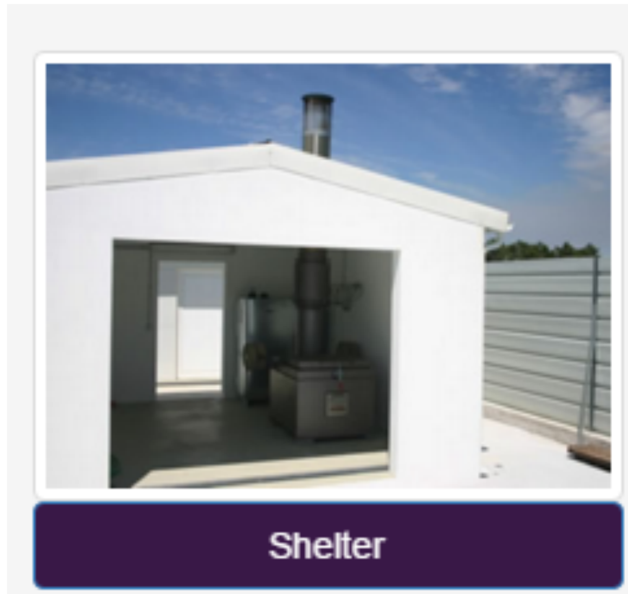


Figure E-16: Medical waste incinerator

7.3 Common degradation

a. Landfill site

In case of landfill, the only time-related degradation is the leakage of the leachate, which can contaminate the ground below. If waste is not promptly covered it can result in odors and flies getting into the waste and potentially spreading disease. The other degradation is filling the landfill site quickly, because land is a scarce asset on the island.

[8]Medical Waste Solutions. INCINER8 International, UK.

b. **Incinerator**
   For the incinerator, the common degradation is rusting of the enclosure, degradation of the seals and gaskets, degradation of the oil burner, and clogging of the filters.

7.4 Typical useful life

The typical useful life for the landfill site is dependent on the availability of land and the efficiency of the recycling program.

The useful service life of the incinerator will depend on how well it is protected against rust. If it is installed outdoors, its service life would be likely less than five years, but if it is installed inside an enclosure with suitable protection from salt spray, it should provide service life of about 10 years.

7.5 Condition assessment

The landfill site condition assessment techniques involves an environmental subject matter expert to inspect the landfill and evaluate the environmental impacts from landfill operations and where evidence of serious environmental impacts exist, provide mitigation alternatives and determine the cost for implementing the most effective and cost-effective solution(s).

The condition assessment of medical waste incinerator should be carried out by a subject matter expert, involving:

- visual inspections to determine the degree of corrosion
- visual inspections of door seals
- operational tests to confirm combustion temperature and emission levels.

7.6 Solid waste management infrastructure—remaining service potential

To determine the RSP of the landfill site and the medical waste incinerator, the physical condition of the assets should be assessed and all deficiencies identified and assessed using Table E-1. Similarly, the maintenance history and degree of functional obsolescence should be assessed using criteria provided in Tables E-2 and E-3. The results of these assessments should then be combined through the algorithms shown in Table E-28 and Table E-29 for the landfill site and medical waste incinerator, respectively.

Table E-28: Landfill site—RSP calculation algorithm

Asset	Land Fill Site Condition	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5		
Actual Rating	?	?	?		
Weight	14	4	2		
Actual Score	?	?	?	?	
Max Score	70	20	10	100	Actual Score/Max Score

Table E-29: Medical waste incinerator—RSP calculation algorithm

Asset	Medical Waste Incinerator Condition	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5		
Actual Rating	?	?	?		
Weight	16	2	2		
Actual Score	?	?	?	?	
Max Score	80	10	10	100	Actual Score/Max Score

7.7 Solid waste management capacity adequacy index

Solid waste site capacity adequacy index is expressed on a scale of 1 to 5 and indicates if the existing landfill site, collection, and recycling plant has sufficient capacity to meet the current and immediate future needs of residents or if an increase in landfill capacity is needed. Table E-30 shows the proposed infrastructure capacity adequacy index for solid waste management infrastructure.

Table E-30: Solid waste management infrastructure—capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
There is sufficient landfill capacity available to meet the user needs for > 40 years.	5	Very good
There is sufficient landfill capacity available to meet the user needs for >20, ≤40 years	4	Good
There is sufficient landfill capacity available to meet the user needs for >5, ≤20 years	3	Fair
There is sufficient landfill capacity available to meet the user needs for >2, ≤5 years	2	Poor
There is sufficient landfill capacity available to meet the user needs for ≤2 years	1	Very poor

8 Sewage treatment plant

Sewage treatment facilities currently available in Nauru are grossly deficient and fail to provide adequate capacity to treat the sewage waste produced by households.

At the household level, either a single compartment or two compartment septic tanks are commonly used in Nauru, as shown in Figure E-17.

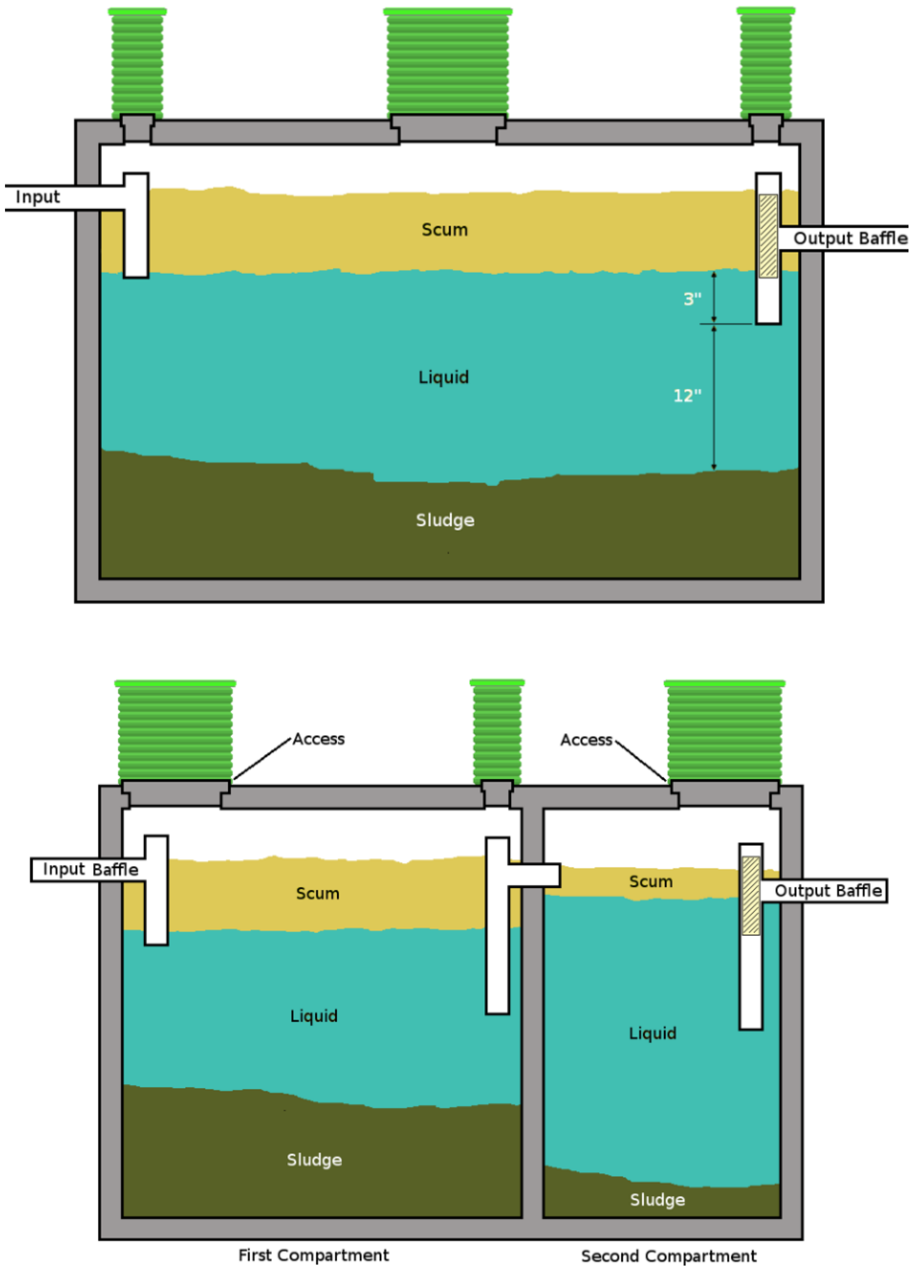


Figure E-17: Single and two compartment household septic tanks

Septic tanks provide some degree of primary treatment to sewage waste, where human waste is broken down by bacteria into methane gas and CO_2, before discharging the effluent to seepage drains. The two-compartment design is significantly more efficient than the single compartment design for primary sewage treatment, but both types of septic tanks need to be pumped out periodically. The waste from the septic tanks contains solids and liquids with unacceptably high level of pollutants and pathogens, which should not be discharged close to water source intakes. Until recently, sewage pumped from septic tanks and cesspits was disposed through a number of ocean outfalls that exist throughout the island, without any secondary treatment.

A few small-scale secondary sewage treatment plants have been built in Nauru recently, one of which is located at the Regional Processing Centre, where the sewage waste generated at the Regional Processing Centre buildings is treated. Similarly, a small-scale sewage treatment plant has been built at the hospital. The municipal sewage treatment plant in Nauru is a small plant in Meneng district, installed behind the Nauru Primary School building. It has insufficient capacity to handle the raw sewage that is brought to this site and has not been operating correctly for some time. The primary school discharges its sewage into a cesspit located nearby.

Nauru is in urgent need of a new sewage treatment plant of inadequate capacity for secondary treatment of sewage waste. Because sewage plants use a number of different technologies, it is strongly recommended that the company responsible for design of the sewage system, should also be asked to update the following sections related to sewage treatment plant and prepare detailed procedures for its condition assessment.

8.1 Sewage waste treatment plant components

There are two basic stages in the treatment of sewage waste: primary treatment stage and secondary treatment stage.

a. Primary sewage treatment plant

In the primary treatment stage, solids are allowed to settle and removed from wastewater. The secondary stage uses biological processes to further purify wastewater, before it is discharged.

Figure E-18 shows the flow diagram for the primary waste treatment stage.

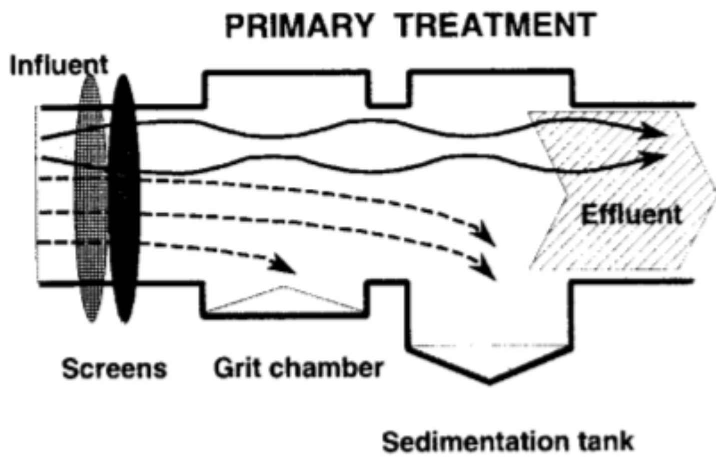


Figure E-18: Primary sewage treatment stage flow diagram

Sewage entering the primary treatment plant flows through a screen, where large floating objects that might clog pipes or damage equipment are removed. The screened sewage then passes into a grit chamber, where heavier objects, such as cinders, sand, and small stones settle to the bottom. At this stage sewage still contains organic and inorganic matter along with other suspended solids, in the form of minute particles and these are removed in a sedimentation tank. In the sedimentation tank, the flow speed is reduced, allowing the suspended solids to gradually sink to the bottom, in the form of primary biosolids or sludge. Biosolids are usually removed from tanks by pumping and these biosolids, after further treatment can be used as fertilizer, or disposed of in a landfill.

b. Secondary sewage treatment plant

Figure E-19 shows the flow diagram of the secondary sewage treatment plant.

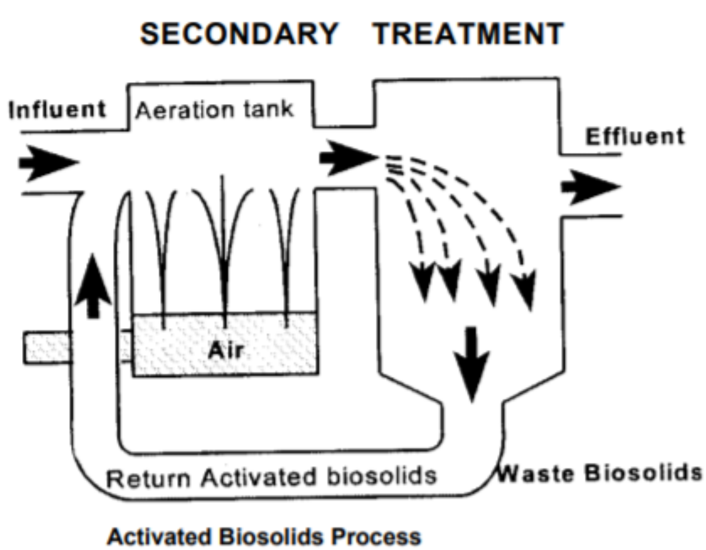


Figure E-19: Primary sewage treatment stage flow diagram

After effluent leaves the sedimentation tank in the primary stage, it either flows to or is pumped to the secondary treatment facility. The main components used in secondary treatment are the trickling filter and the activated sludge process. A trickling filter is simply a bed of stones from three- to six-feet deep through which sewage passes. Modern designs also use interlocking pieces of corrugated plastic or other synthetic media have in trickling beds. Bacteria gather and multiply on these stones until they can consume most of the organic matter. The cleaner water trickles out through pipes for further treatment. From a trickling filter, the partially treated sewage flows to another sedimentation tank to remove excess bacteria.

Some modern designs use the activated sludge process instead of trickling filters. After the sewage leaves the settling tank in the primary stage, it is pumped into an aeration tank, where it is mixed with air and sludge loaded with bacteria and allowed to remain for several hours. The activated sludge speeds up the work of the bacteria by bringing air and sludge heavily laden with bacteria into close contact with sewage.

The sludge, activated with additional billions of bacteria and other tiny organisms, is used again by returning it to the aeration tank for mixing with air and new sewage. From the aeration tank, the partially treated sewage flows to another sedimentation tank for removal of excess bacteria. To complete secondary treatment, effluent from the sedimentation tank is usually disinfected with chlorine before being discharged into receiving waters.

8.2 Construction details

There is significant variability in construction details of sewage treatment plants, depending on capacity and technology used. Therefore, this section should be completed when a new sewage treatment plant is designed for Nauru.

The main components of the sewage treatment plant include: bar screens, grit chamber, pre-aeration tank, primary settling tank, aeration tank, secondary settling tank, biological filters, sludge handler and pumps etc.

8.3. Common degradation

Sewage treatment plant has a number of components, which degrade over time. A majority of the tanks are made of steel, which is prone to metal corrosion. If large non-biodegradable and floating solids are not effectively removed by screens, it would lead to possible damage or unnecessary wear and tear, pipe blockages, and the accumulation of unwanted material that will interfere with the wastewater treatment process. When not maintained properly, the screens can get clogged, blocking the flow of effluent from one tank to the next. Bearings and bushings in pumps develop friction with age eventually leading to pump failures.

And if the volume of waste entering the sewage treatment plant exceeds its rating, it would allow less time for bacteria to breakdown the solid waste and will lead to unsatisfactory results.

An improperly functioning treatment plant would lead to the targets for total nitrogen, total phosphorus, or biochemicals in the effluent or foul odours (generally related to the presence of hydrogen sulphide) being met.

8.4. Typical useful life

The typical useful life of sewage treatment plant is 30 years.

8.5. Condition assessment

The sewage treatment plant condition assessment techniques involve inspecting the site by a sewage treatment subject matter expert to evaluate the condition of various components of the plant and their ability to meet the intended functions and where evidence of serious environmental impacts exists, evaluation of the mitigation alternatives and determining the cost for implementing the most effective and cost-effective solution.

8.6. Sewage treatment plant—remaining service potential

To determine the RSP of the sewage treatment plant, its physical condition should be assessed, and all deficiencies identified and assessed using criteria in Table E-1. Similarly, the maintenance history and degree of functional obsolescence should be assessed using criteria provided in Tables E-2 and E-3. The results of these assessments should be combined through the algorithm shown in Table E-31 to determine RSP of sewage treatment facility.

Table E-31: Sewage treatment plant—RSP calculation algorithm

Asset	Sewage Treatment Plant Condition	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5		
Actual Rating	?	?	?		
Weight	12	4	4		
Actual Score	?	?	?	?	
Max Score	60	20	20	100	Actual Score/Max Score

8.7. Sewage waste management capacity adequacy index

Sewage waste capacity adequacy index is expressed on a scale of 1 to 5 and indicates if the existing sewage treatment facilities and collection and pumping plant has sufficient capacity to meet the current and immediate future needs of residents or if an increase in sewage plant capacity is needed. Table E-32 shows the proposed infrastructure capacity adequacy index for solid waste management infrastructure.

Table E-2: Sewage waste management infrastructure—capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
There is sufficient landfill capacity available to meet the user needs for > 40 years.	5	Very good
There is sufficient landfill capacity available to meet the user needs for >20, ≤40 years	4	Good
There is sufficient landfill capacity available to meet the user needs for >5, ≤20 years	3	Fair
There is sufficient landfill capacity available to meet the user needs for >2, ≤5 years	2	Poor
There is sufficient landfill capacity available to meet the user needs for ≤2 years	1	Very poor

9 Motor vehicle fleet

9.1 Government-owned motor vehicles

Government-owned motor vehicles in Nauru can be divided into two main categories:

a. passenger vehicles—includes passenger cars and light duty pick-up trucks
b. medium- and heavy-duty engine trucks and speciality vehicles.

There are a number of government departments in Nauru that are responsible for managing the motor vehicle fleets for the departments.

9.2 Motor vehicle types and their main components

There are two main types of vehicles currently in use in Nauru.

a. Passenger vehicles

These are either gasoline- or diesel-fuel powered vehicles, including cars and light pick-up trucks or jeeps. The main motor vehicle components include:

- chassis or body
- engine
- transmission
- wheels and tires
- brakes
- instruments.

b. Medium- or heavy-duty engine vehicles

These are general-purpose vehicles with diesel engines and include dump trucks, loaders, excavators, fire trucks, school buses and other special purpose vehicles. The main components of medium- or heavy-duty engine vehicles include:

- chassis or body
- engine
- transmission
- wheels and tires
- brakes
- instruments
- hydraulic operating system for buckets, booms or dump trucks etc.

9.3 Common degradation

Motor vehicles use gasoline or diesel engines and power drives with many moving parts, including pistons in cylinders, cranks, bearings, and transmission systems, which continually wear in service and require periodic maintenance. Engine lubricating oil, engine cooling fluid, transmission fluids, brake fluids, fuel filters, oil filters, air filters become clogged in service and require periodic replacement. Gaskets and O-rings can develop leaks. Other wearing parts are the seals and bearings, brake pads, and rotors.

All steel parts used on motor vehicle chassis and body experience corrosion and rusting. Lubricants lose their viscosity under heat and need to be replaced at specified intervals. Water-cooled engines develop sludge in radiators, which reduces their cooling efficiency and when the engine is running at higher temperature, the degradation process is accelerated.

9.4 Typical useful life

The typical useful life of different types of motor vehicles in Nauru is indicated in Table E-33 and takes into account the corrosive environment.

Table E-33: Motor vehicles—typical service life

Passenger cars	100,000 km or 8 years
Medium- and heavy-duty trucks	50,000 km or 8 years

9.5 Condition assessment

Condition assessments of the motor vehicles are performed by a licensed motor vehicle mechanic and involve visual inspections to assess the extent of corrosion and wear, as well as testing the engine and drive train to confirm all components are in compliance with the vendor specifications to provide safe and reliable operation. The inspection report includes each of the following major components:

- engine and power train inspections and testing; including accelerator, fuel system exhaust, transmission, front/rear/spindles axles, clutch, CV joints, fluid leaks
- chassis and body, including structural integrity, hood latch, door latches & hinges, bumpers, windshield and windshield wipers and washer, windows, mirrors, seats, seat belts and airbags, mudguards etc.
- steering system, including steering linkage, rack and pinion, power steering system, king pin and ball joints, etc.
- suspension system, including leaf springs, struts and shocks, coil spring, torsion bar etc.
- braking system, including parking/emergency brake, hydraulic or air pressure system, vacuum system, drum brakes, disc brakes, shoes/pads, anti-lock etc.
- tires and wheels, including tread depth, tread section, sidewalls, wheels etc.
- electricals, including wiring, battery, switches, alternator, etc.
- lamps, including high beam and low beam lamp, tail lights, brake lights, turn signal and back up lamps etc.
- instrument cluster, including odometer, indicator lamps, horn etc.

9.6 Motor vehicle—remaining service potential

To determine the RSP of both light-duty and heavy-duty motor vehicles, the physical condition of the motor vehicle is assessed and all deficiencies are identified and assessed using criteria in Table E-1. Similarly, the maintenance history and degree of functional obsolescence should be assessed using criteria provided in Tables E-2 and E-3. The results of these assessments should be combined through the algorithm shown in Table E-34 for light-duty vehicles and Table E-35 for heavy-duty vehicles, to determine RSP of motor vehicles.

Table E-34: Light-duty motor vehicle - RSP calculation algorithm

Asset	Motor Vehicle Condition	Motor Vehicle Odometer Reading	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5	5		
Actual Rating	?	?	?	?		
Weight	6	6	2	6		
Actual Score	?	?	?	?	?	
Max Score	30	30	10	30	100	Actual Score/Max Score

Table E-35: Heavy-duty motor vehicle—RSP calculation algorithm

Asset	Motor Vehicle Condition	Motor Vehicle Odometer Reading (Operating Hours)	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5	5		
Actual Rating	?	?	?	?		
Weight	6	6	2	6		
Actual Score	?	?	?	?	?	
Max Score	30	30	10	30	100	Actual Score/Max Score

9.7 Capacity adequacy index

The capacity adequacy index for passenger vehicles is expressed on a scale of 1 to 5 and it indicates the percentage users, with need for a passenger vehicle to efficiently perform their official duties, are currently served by the existing passenger vehicle fleet. Table E-36 shows the proposed capacity adequacy index for passenger vehicles.

Table E-36: Passenger vehicle—capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
The existing passenger vehicle fleet serves the needs of 100% of potential users, requiring a passenger vehicle to efficiently perform their duties.	5	Very good
The existing passenger vehicle fleet serves the needs of <100%, ≥95% of potential users, requiring a passenger vehicle to efficiently perform their duties.	4	Good
The existing passenger vehicle fleet serves the needs of <95%, ≥75% of potential users, requiring a passenger vehicle to efficiently perform their duties.	3	Fair
The existing passenger vehicle fleet serves the needs of <75%, ≥50% of potential users, requiring a	2	Poor

Condition criteria	Capacity adequacy index	Interpretation
passenger vehicle to efficiently perform their duties.		
The existing passenger vehicle fleet does not fully serve the needs of >50% of potential users, requiring a passenger vehicle to efficiently perform their duties.	1	Very poor

The capacity adequacy index for medium- and heavy-duty utility trucks is expressed on a scale of 1 to 5 and indicates the number of hours during a year when a truck is required for a task, but not available due to fleet capacity constraints. Table E-37 shows the proposed capacity adequacy index for medium- and heavy-duty trucks.

Table E-37: Medium- and heavy-duty vehicles—capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
There are less than 100 hours in a year when a vehicle is not available when needed due to fleet capacity constraints	5	Very good
There are more than 100 but less than 200 hours in a year when a vehicle is not available when needed due to fleet capacity constraints	4	Good
There are more than 200 but less than 500 hours in a year when a vehicle is not available when needed due to fleet capacity constraints	3	Fair
There are more than 500 but less than 1000 hours in a year when a vehicle is not available when needed due to fleet capacity constraints	2	Poor
There are more than 1000 hours in a year when a vehicle is not available when needed due to fleet capacity constraints	1	Very poor

10 Boats

Two departments are responsible for managing this class of assets and these include:

a. Port Services - responsible for providing transportation service for freight destined for Nauru
b. Fisheries Department - responsible for patrolling the oceans to manage and protect the Government of Nauru’s interest in the fisheries industry.

10.1 Boat construction and components

The main components of a boat or ferry include:

- hull

- propulsion system
- communication and navigation equipment
- safety equipment
- anchoring equipment
- electrical systems.

A boat’s hull provides floatation to the boat. Most large boats are single-hulled (mono-hull design), but catamarans (with two hulls) and trimarans (with three hulls) are also used. A boat’s hull provides space for the engines and the propellers are attached to it. Hulls have to be meticulously designed, because they are subjected to stresses and strains and the failure of the hull will lead to sinking of the boat.

The propulsion system powers the boat to move it in the desired direction. The main engine generates power, which is transmitted to the propeller. The boats owned by the Government of Nauru use the propulsion system with diesel engines to drive the propellers. Steering is provided through rudders or changing the direction of the propellers.

Communication and navigation equipment include radios, telephones, computers, and radar systems installed in the control room to help with navigation at sea and provide direction and also permit precise ship movement during docking. Anchors are needed to hold the ship in one place and prevent it from being carried away by waves, when the ship has to be docked or kept in one place. And the electrical systems are needed to provide passenger comfort and also provide refrigeration. The electrical system consists of an auxiliary engine to produce electricity and the distribution system to supply electricity to various loads.

Safety equipment is provided to deal with emergencies including a fire on the boat or sinking of the boat.

10.2 Common degradation modes

A boat’s hull experiences progressive deterioration as a result of normal operational use and environmental influences. The common structural deterioration can be in the form of damage to coatings, corrosion, cracking, deformation, dents, and changes in material properties.

Coating degradation can take the form of coating cracking, blistering, rust, and flaking. Coating cracks appear when structural deformation exceeds the elongation of the paint film. Blisters appear when adhesion of the paint is lost and flaking occurs due the lifting of paint from surface.

Hull corrosion is the result of a chemical reaction between metal and the salt containing environment. Rust is generated from the part where an adhesion of paint film is insufficient and a paint film is broken. Since the initial rust is porous and hygroscopic, the range of rusting expands and the paint film is eventually destroyed. Cracks often originate from defect of welds. If such initial cracking is left undetected or not repaired immediately, it can grow into a crack that continues to propagate under repeated loads.

Ship structures can also be damaged by external forces such as falling cargo. Impacts with the quay or floating objects can produce dents and with repeated loadings, dents may gradually continue to increase in size.

The main and auxiliary engines of boats have many moving parts, including pistons in cylinders, cranks, bearings and transmission systems etc. that continually wear in service and require periodic maintenance. Engine lubricating oil, engine cooling fluid, fuel filters, oil filters, air filters become clogged in service and require periodic replacement. Gaskets and O-rings can develop leaks. Oil or fuel leakages from main or auxiliary power systems into the ocean can cause environmental harm. Communication and navigation systems include solid-state devices that can fail suddenly and the anchoring equipment loses its mechanical strength due to loss of steel during corrosion.

10.3 Typical useful life

The typical useful life of ships and sea worthy boats is 30 years and 15 years for small service boats.

10.4 Condition assessment

Condition assessment of the seaworthiness of boats and ships is a highly specialized activity. It should be performed by accredited organisations, equipped with adequate inspection and test facilities to assess the condition of the hull and the machinery, including the main engine. The condition assessment results should be written reports, with recommendations for required repairs for life extension or with recommendations for retirement of the boat when the repairs are not considered economical.

Condition assessment of hulls involves thickness measurements, structural strength evaluation, fatigue strength assessment, and assessment of corrosion protection systems for water ballast tanks and coated cargo tanks. Condition assessments of machinery involve reviewing operating records, visual inspections, functional tests, and measurement of machinery parameters, vibration measurements and oil sample analysis and ratings.

The condition assessment results for ships and boats are expressed by inspection agencies in a standardized format,[9] as follows:

Rating Grade 1: Very good condition—Items and systems examined and function-tested, found with no deficiencies affecting safe operation and/or performance. Documentation and maintenance practices considered good. No repair/renewal required.

Rating Grade 2: Good condition—Items and systems examined and function-tested, found with some minor deficiencies that do not affect safe operation and/or normal performance.

[9] Condition Assessment Programme, Lloyd's Register Marine.

Documentation and maintenance practices considered adequate. No immediate repair/renewal considered necessary.

Rating Grade 3: Satisfactory condition—Items and systems examined and function-tested, found with deficiencies not affecting safe operation and/or performance. Documentation and maintenance practices considered to be of a minimum standard. Some repair or renewal may be considered necessary.

Rating Grade 4: Unsatisfactory condition—Items and systems examined and function-tested, found with deficiencies significantly affecting operation or performance. Documentation and maintenance practices considered inadequate. Major repair or renewal required to reinstate serviceability.

The condition of the service boats can be assessed by taking into account the degree of corrosion of the boat's body and the condition of its engine and controls.

10.5 Remaining service potential

To determine the RSP of both seaworthy and service boats, the physical condition of the boat should be assessed using the criteria in Table E-1 and the results should be translated into one of the rankings in the table. Similarly, the maintenance history and degree of functional obsolescence should be assessed using criteria provided in Tables E-2 and E-3. The results of these assessments should be combined through the algorithm shown in Table E-38 to determine the RSP of the boat.

Table E-38: Seaworthy and service boats—RSP calculation algorithm

Asset	Boat Condition	Odometer Reading (Operating Hours)	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5	5		
Actual Rating	?	?	?	?		
Weight	6	6	2	6		
Actual Score	?	?	?	?	?	
Max Score	30	30	10	30	100	Actual Score/Max Score

10.6 Capacity adequacy index for boats

The capacity adequacy Index for sea worthy and service boats is expressed on a scale of 1 to 5 and is based on the boat's availability when needed. Table E-39 shows the proposed capacity adequacy index for seaworthy and service boats.

Table E-39: Boat fleet—capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
There are less than 100 hours in a year when a boat is not available when needed due to fleet capacity constraints	5	Very good
There are more than 100 but less than 200 hours in a year when a boat is not available when needed due to fleet capacity constraints	4	Good
There are more than 200 but less than 500 hours in a year when a boat is not available when needed due to fleet capacity constraints	3	Fair
There are more than 500 but less than 1000 hours in a year when a boat is not available when needed due to fleet capacity constraints	2	Poor
There are more than 1000 hours in a year when a boat is not available when needed due to fleet capacity constraints	1	Very poor

11 Telecommunication assets

From 1970 to 2009, public telecommunication services in Nauru were provided by the state-owned enterprise, Nauru Telecom, using Intelsat satellites and landlines. During the last 10 years of its mandate, the services provided by Nauru Telecom were of very poor quality. In particular, the dial-up access to the internet had become totally unreliable and very expensive, and the landlines installed in the 1970s were experiencing frequent breakdowns. In 2004, satellite communications were shut down for non-payment of subscription fees.

In June 2009, the government issued licenses to a private company, Digicel Nauru Ltd (Digicel), to provide mobile telephone (GSM) and basic internet access services, with provision for monopoly services for a period of two years. In August 2009, Digicel started providing mobile services. During this transfer of service provider, most of the existing telecommunications facilities of Nauru Telecom, including earth stations and network facilities, were abandoned due to their poor condition or obsolete functionality and Digicel installed its own network assets. From the original Nauru Telecom-installed equipment, most of the existing towers still remain in service and Digicel has been allowed to install their new equipment on these existing structures, under a lease agreement.

The two years monopoly status of Digicel ended in 2011 and the Government of Nauru decided to introduce competition in the telecommunications market, in a staged manner. As the first step in introducing competition, a new license was issued to Cenpacnet Inc. (Cenpacnet) for basic internet access business services. Cenpacnet previously operated an internet café at the Civic Center, but due to the monopoly status of Digicel, Cenpacnet was obliged to stop its operation. After receiving its license, Cenpacnet re-opened the internet café using Digicel's access network.

The Department of Telecommunications of the Government of Nauru has two divisions:

i. Regulatory Directorate, which oversees and regulates the services provided by private telecom companies

ii. Information & Communications Technology (ICT), which serves as the network aggregator for all governmental LAN connections, including Ministry of Finance, Transportation, Media, Hospital and Health Centers and Internet Gateway for Schools, University, Police and Airport. ICT is responsible for managing all government-owned telecom assets.

11.1. Telecommunications infrastructure components and their functions

The main assets used in the telecommunication system can be divided into the following categories:

a. telecommunications switching devices
b. telecommunications transmitting and receiving devices
c. landline connections
d. buildings (the asset management strategy is covered in Section 1).

11.2. Construction details

Telecommunication switching devices are installed indoors in climate-controlled rooms and consist of solid-state devices, including transistors, capacitors, microprocessors, etc. Telecommunications transmitting and receiving devices include antennas and satellite dishes and are installed on high towers and masts. These devices are connected to indoor-mounted switching devices through copper or fiber optic cables. Landline connections to residential and commercial buildings are provided through cooper and fiber optic cables, installed in underground ducts.

11.3. Common degradation modes

Communication system hardware is made of solid-state components, the operating characteristics of which change over time. It is difficult to see small-scale changes because there are no moving parts; however, all of the components, including transistors, capacitors, microprocessors, etc. that make up the solid-state devices used in telecommunication systems do change and eventually lose their performance tolerances. When a large number of these components start operating at less than specified performance, the overall system or device no longer performs as required and the end of life for that device is reached.

A large percentage of communication hardware devices commonly fail either during, or just after, installation and commissioning. These failures can be the result of manufacturing defects, commonly referred to as “birth defects”, when the manufacturing testing process fails to identify a manufacturing error, or substandard component. However, the leading cause of near-term failures is the result of improper installation or operation. Installation failures are commonly caused when technicians fail to familiarize themselves with the manufacturer’s recommendations. Sometimes, installation technicians try to use shortcuts to reduce the installation time, or because they have installed similar equipment and believe that there are no differences between devices manufactured by different companies. Another common error is to assume that there won’t be differences between old and new versions of the same device.

On a long-term basis, most failures are the result of electronic component aging, through cyclical heating and cooling, as a result of which component performance degrades and they fail to meet original specifications. Systems will either fail, or develop substandard functional characteristics. Telecommunications equipment is also sensitive to over-voltages and can fail when subjected to lightning strikes, switching power surges, and connection of electrical power to a communications port. The reliability of solid-state electronic components is often measured in terms of mean-time-between-failures (MTBF). As solid-state devices age, MTBF starts decreasing and eventually reaches a level below acceptable performance.

Technical obsolescence is often the main reason due to which telecommunication devices reach the end of their service life. Due to fast changing technology, data processing speed and the need for speed and bandwidth is continually increasing and as a result most telecommunication products and devices becomes obsolete within about 10 years.

11.4. Typical useful life

Due to technology obsolescence, telecommunication devices have a short typical useful life of about 10 years. The antenna towers have a typical useful life of 30 years.

11.5. Condition assessment techniques

For telecommunication systems, commonly used condition assessment techniques include:

a. Monitoring the rate of component and equipment failure over the recent past. Failure rates in electronic component industry are commonly measured and monitored in terms of MTBF. MTBF is measured in units of time, i.e. hours or minutes and is calculated as follows.

$$MTBF\ (in\ hours) = \frac{Total\ Number\ of\ hours\ in\ a\ year}{Number\ of\ equipment\ failures\ in\ a\ year}$$

Let us assume you have 20 equipment failures on your telecommunication network during the past year. MTBF can be calculated as:

$$MTBF\ (in\ hours) = \frac{8760}{20} = 438 \text{ Hours}$$

A low MTBF indicates poor condition of equipment.

b. Because technical obsolescence is often the main reason due to which telecommunication devices reach the end of service life, telecommunication assets' condition assessment also includes checking and confirming to what degree the existing technology is meeting customer needs.

11.6. Telecommunication equipment—remaining service potential

To determine the RSP of both indoor- and outdoor-mounted telecom equipment as well as for antenna towers, the physical condition of the asset is assessed and the results are translated into one of the rankings in Table E-1. Similarly, the maintenance history and degree of functional obsolescence should be assessed using criteria provided in Tables E-2 and E-3. The results of these assessments should be combined through the algorithm shown in Table E-40 and Table E-41 to determine the RSP of the telecom equipment and antenna towers, respectively.

Table E-40: RSP algorithm—telecommunications infrastructure

Asset	Telecom Equipment Condition	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5		
Actual Rating	?	?	?		
Weight	8	8	4		
Actual Score	?	?	?	?	
Max Score	40	40	20	100	Actual Score/Max Score

Table E-3: RSP algorithm—telecommunications antenna towers

Asset	Antenna Tower Condition	Absolence Rating	Mainteance History	Total	RSP
Max Rating	5	5	5		
Actual Rating	?	?	?		
Weight	10	4	6		
Actual Score	?	?	?	?	
Max Score	50	20	30	100	Actual Score/Max Score

11.7. Telecommunication infrastructure capacity adequacy index

Telecommunication infrastructure capacity adequacy Index is expressed on a scale of 1 to 5 and indicates if the existing wireless and wired network is sufficient to meet the current and immediate future needs or if an increase in network capacity is required. Table E-42 provides an example of telecommunication network capacity adequacy index.

Table E-42: Telecommunication infrastructure—capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
100% of the users in need of service are connected with a telecommunications network and there is 25% spare capacity available.	5	Very good
100% of the users in need of service are connected with a telecommunications network and there is 15% spare capacity available.	4	Good
100% of the users in need of service are connected with a telecommunications network and there is 5% spare capacity available.	3	Fair
Less than 10% of the potential users in need of service cannot be connected to telecommunications network due to capacity constraints	2	Poor

Condition criteria	Capacity adequacy index	Interpretation
More than 10% of the potential users in need of service cannot be connected to telecommunications network due to capacity constraints.	1	Very poor

12. Electricity generating and distribution plant

Nauru Utilities Corporation (NUC), one of the state-owned enterprises has the responsibility for managing and operating the electricity assets of Nauru. One hundred percent of dwellings in Nauru have access to electricity.

Under ADB- and World Bank-financed capacity development initiatives, NUC was able to develop and implement a modern asset management strategy, which covers measurement and benchmarking of asset performance, reliability-centered asset maintenance, and prioritization of investments into asset renewal and replacement based on asset condition and risk of failure in service. Therefore, this section for the electricity assets is quite generic and has been written only to provide a complete set of asset management strategies for all national assets.

Use of this document for condition assessment of assets will also ensure that a uninform, objective criteria is applied for prioritizing investments into asset maintenance, renewal and replacement across all sectors.

12.1 Electricity infrastructure components and their functions

The main assets used on Nauru's electricity generation and distribution system are listed below:

a. diesel generating sets, including medium-speed and high-speed generators
b. solar photo voltaic (PV) generation plant
c. distribution transformers
d. overhead distribution lines
e. overhead load break switches
f. underground cables
g. underground switchgear (ring main units)
h. revenue meters.

Diesel generators are the main source of power generation in Nauru, and the diesel engine generation is supplemented by generation from the renewables, in the form of PV solar plant, to conserve diesel fuel use.

The distribution system carrying the power from generating plant to electricity users is installed on overhead pole lines, although there are some sections where underground cables are also used. Pole-mounted load break switches in conjunction with fuses or pad-mounted switchgear with vacuum breakers (ring main units) provide means of over-current protection, switching, and isolating. Distribution transformers are installed either on poles or on concrete pads. Low voltage cables carry power from distribution transformers customer premises. Revenue meters measure energy use by customers for settlement.

12.2 Construction details

The power generating plant uses medium-speed, water-cooled, diesel generators. Pole lines carry 11 kV overhead conductors on top, with underbuilt low voltage distribution lines in the form of aerial bundled conductors. Direct buried, low voltage cables are also used to carry power from either the distribution transformers or low voltage lines to customer premises. Most of the revenue meters are of solid-state design.

12.3 Common degradation modes for power plant

a. Generating sets

Figure E-20: Diesel generating set

Diesel generating sets use reciprocal engines for prime mover and they have a finite service life. Just like motor vehicle engines, moving parts, including pistons in cylinders, cranks, bearings etc. continually wear in service and require periodic maintenance. Engine lubricating oil, engine cooling fluid, fuel filters, oil filters, air filters become clogged with service and require replacement. Gaskets and O-rings develop leaks. Other wearing parts are the seals and bearings that are in constant contact with the rotating shaft.[10]

All steel parts experience corrosion and rusting. Lubricants lose their viscosity under heat and need to be replaced at specified intervals. Water-cooled engines also develop sludge in radiators, which reduces their cooling efficiency and when engine is running at higher temperature, it accelerates the degradation process. Diesel engine is directly coupled to the

[10] ABB Synchronous Generators, *User's Manual*.

electrical generator through the shaft and misaligned couplings can substantially increase the degree of mechanical wear. Generators with higher than normal vibration levels are an indication of alignment problems, non-uniform air gap, bearing damage, loose fastening, or rotor imbalance.

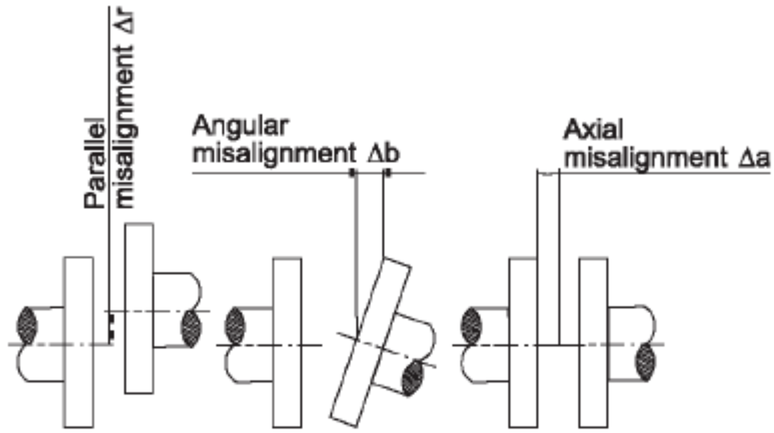


Figure E-21: Misaligned couplings increase equipment wear

The electrical windings of rotating electrical machines are subjected to electrical, mechanical and thermal stresses, all of which result in insulation degradation. Useful service life of electricity generators often depends on the insulation durability. Particular attention should be paid to rotor wear and tear, because even small damages in the rotor can lead to severe damages in the stator, which are extremely expensive to repair.

Generators are equipped with Automatic Voltage Regulators (AVR) and this device continuously monitors the output voltage and automatically initiates corrective actions to maintain the terminal voltage of the generator constant. AVRs also control the operation of the synchronous generator within pre-set limits. Any problems with AVRs' operation can affect the output voltage, resulting in serious power quality problems.

b. Solar PV generating plant

The solar photovoltaic (PV) plant consists of solar panels mounted on the roof with hardware. DC output from the PV panels is changed to AC through an inverter and AC output of the inverter is connected to the grid. When DC storage batteries are used, output of the panels is connected to the batteries and the output form battery is connected to the inverter.

Solar panels degrade with service and their output begins to decrease significantly after service life of about 20 years. There are different types of storage batteries in use, including sealed lead acid batteries, Nickel cadmium batteries and Lithium ion batteries. Battery life is determined by the number of deep charge discharge cycles and can vary from four to eight years.

Both solar panels and electricity storage batteries contain hazardous materials and require a disposal plan, when these assets reach the end of their service life.

Figure E-22: Roof-mounted solar PV penetration

The traditional crystalline silicon PV modules, which are more commonly in use, are made of outer glass cover (approximately 65% of mass), aluminum frame (approximately 20%) of mass, ethylene vinyl acetate encapsulates (approximately 7.5% of mass), polyvinyl fluoride substrate (approximately 2.5% of mass), and the silicon solar cells (approximately 4% of mass). Although the traditional silicon panels, as described above do not contain any hazardous components, because production of these components from mining to purification, uses processes that are not environmentally friendly and produce a lot of hazardous waste during manufacture, there is a great emphasis being placed to recycle the solar panels rather than sending them to landfills.

The modern, thin-film solar panels use less objectionable processes during their manufacture, but they use materials such as cadmium telluride, copper indium gallium selenide (CIGS) and cadmium sulfide. So each of these technologies uses compounds containing the heavy metal cadmium, which is both a carcinogen and a genotoxin, meaning that it can cause inheritable mutations. And these panels should certainly not go to the landfill sites.

Over 90% of the components in solar panels are recyclable and can be salvaged and reused in manufacture of new solar panels. It is recommended that when the solar panels reach the end of their service life, one of the recycling companies is contacted to determine if they are willing to receive products that are being disposed of. A list of the companies that currently provide recycling services is provided in Table E-43. A more detailed and current list of the solar panel recycling companies can be obtained from the footnote reference.[11]

[11] https://www.enfsolar.com/directory/service/manufacturers-recycling.

Table E-43: Solar panel recycling companies

Company Name	Location	Website	Phone Number
Cellnexx Energy Limited	United Kingdom	www.cellnexx.co.uk	+44 1724 304001
ECS Refining	USA	www.ecsrefining.com	+1 800 4699278
Envaris GmbH	Germany	www.envaris.de	+49 30 2888493110
Eiki Shoji Co., Ltd.	Japan	www.eikishoji.co.jp	+81 3 57460531
First Solar, Inc.	USA	www.firstsolar.com	+1 419 6626899
Jiangsu Juxin Energy Silicon Technology Co., Ltd.	China	yangzhou090011.11467.com	+86 136 45253850
SB Energy Sarl	France	www.sbenergy.fr	+33 3 28442712
Suzhou Jingshang Solar New Energy Technology Co., Ltd.	China	www.hualijiaxiao.com	+86 512 89168588

Commonly used storage batteries include lead acid batteries, Nickel metal hydride batteries, and Lithium ion batteries. Based on the capacity considerations required in Nauru, lead acid batteries are most likely to be used in Nauru. This battery is virtually the same as that used in motor vehicles and contains two hazardous components—lead and sulphuric acid. There are four lead acid battery recycling plants in Australia and it is recommended that when batteries reach the end of their service life, arrangements are made to ship the batteries (in appropriate packaging as recommended by the recycler) to one of the following recycling plants:

Company: Australian Refined Alloys Pty Ltd
Suburb/Town: Alexandria
State/Territory: NSW
Website: http://www.enirgi.com/projects/emg-ara.aspx

Company: Simstar Alloys Pty Ltd, Australia (Previously called Australian Refined Alloys Pty Ltd)
Suburb/Town: Laverton North
State/Territory: VIC
Website: http://www.nyrstar.com/operations/Pages/otheroperations.aspx

Company: Hydromet Lead Acid Battery Recycling Plant
Suburb/Town: Unanderra
State/Territory: NSW
Website: http://www.hydromet.com.au/

Company: Renewed Metal Technologies Pty Ltd
Suburb/Town: Bomen
State/Territory: NSW

Website: http://www.enirgi.com/projects/emg-rmt.aspx

c. Overhead lines

Overhead lines consist of structural supports in the form of wood, concrete or steel poles, insulators, conductor, hardware and many other pieces of equipment installed on lines. Poles provide the support structures for overhead lines to maintain the required clearances between live conductors and grounded objects, for safe and reliable operation of power supply system. In case of wood poles, the most critical degradation involves fungal decay of wood or damage caused by wildlife. Poles are most susceptible to fungal decay at and around the ground line, where wood can absorb water from the surrounding earth. Pole rot can also begin at the top of the pole. To slow down the decay of wood poles, they are commonly treated with preservatives before installation. In addition to the wood decay, external damage to poles can also be caused by termites or woodpeckers. Deformation of boltholes can also result in failure of the structure and the live conductors falling on ground. Bolts also can become loose, elongated, bent, cracked, sheared and broken. Steel poles degrade due to corrosion, which is more pronounced in Nauru due to saltwater spray from ocean. Concrete poles may degrade due to spalling or accidents with motor vehicles.

Porcelain or polymer insulators are commonly used on overhead lines. Degradation and eventual failure can result from the loss of either dielectric or mechanical strength. Mechanical loading on suspension or post insulators consists of a combination of tensile, torsional, cantilever, vibration and compression forces. Contamination of insulator surface with salt spray from ocean can induce flashovers resulting in dielectric failure of insulators. Typical damage to polymer insulators includes cuts, splits, holes, erosion, tracking, or burning of the rubber shed and sheath material. Electrical flashovers can cause both external and internal damage to porcelain and composite insulators.

Both aluminium-conductor steel-reinforced cable (ACSR) and all aluminium conductors (AAC) experience degradation due to corrosion of strands. While steel strands begin to rust more rapidly, aluminium strands are also susceptible to corrosion from salt spray. Overloaded line conductors, operating beyond their thermal capacity, can suffer from a loss of tensile strength due to annealing at elevated operating temperatures. Phase-to-phase power arcs can result from conductor galloping during severe storm events, resulting in broken strands, strand abrasion, bird caging or burn damage.

d. Distribution transformers

Three major factors generally contribute to the degradation of distribution transformers:

- deterioration of the transformer's solid insulation and insulation oil
- contamination of the bushings (terminals), which can lead to a flashover
- rusting and corrosion of the tank, because once the tank has corroded through it can allow the moisture laden air to enter into the otherwise sealed tank, thus contaminating the insulation system which leads to transformer failure.

Transformer oil consists of hydrocarbon compounds that degrade with time due to oxidation, resulting in formation of moisture, organic acids and sludge. The oil oxidation rate is a function of operating temperature. Increased acidity and moisture content in insulating oil causes accelerated degradation of insulation paper. Formation of sludge adversely impacts the cooling efficiency of transformer, resulting in higher operating temperatures and further increasing the rate of oxidation of both the oil and the paper. Distribution transformers commonly fail when the age weakened insulation system is subjected to a voltage surge.

As long as the transformer tanks provide a sealed environment to the interior components, transformer generally provide a service life ranging from 30 to 40 years, depending on the load level. However, in coastal area with corrosive environment, transformer tanks generally rust through creating pinholes through welds, allowing the transformer to breathe moisture, which degrades the insulation, causing transformer failure. Exposure to corrosive ocean spray plays a big role in causing accelerated aging of transformers.

e. Pole-mounted and pad-mounted switchgear

In case of pole mounted switches, switchblades, and operating mechanisms are the critical components that degrade with time. Misaligned or poorly surfaced contacts can result in excessive arcing during switch opening or closing, resulting in further deterioration of the blades. Corrosion can cause rusting of the links and pins in operating mechanism reducing the blade movement speed.

For pad-mounted switchgear, vacuum interrupters and SF6-insulated ring main units are commonly used. As long as the integrity of interrupter seals is maintained, the equipment provides reliable, trouble free service for up to 30 years. But if the tanks degrade due to rust and develop pinholes, insulation system in the current interrupting chamber degrades, causing failure of the RMU. In Nauru, the rate of deterioration of steel tanks is very high due to the prevailing corrosive environmental conditions near ocean and moisture ingress into the insulated unit leads to the end of life for the equipment.

f. Cables

The main degradation for 11 kV XLPE cables is formation of water trees and deterioration of insulation under partial discharge activity. Presence of moisture and impurities in the insulation system accelerate the insulation degradation due to water treeing. Insulation degradation and cable failures can be accelerated if cable jacket is damaged allowing moisture to enter into the insulation system. Cable degradation can also occur due to overheating under overloading or short circuit conditions. Overstressing of insulation during voltage surges can also lead to cable failures.

Polymeric insulation is very sensitive to partial discharge activity. It is therefore very important that the cable, joints and accessories are discharge free when installed. Partial discharge testing is, therefore, an important and useful test for these cables. Water treeing is the most significant degradation process for polymeric cables.

12.4 Typical useful life

Table E-44 indicates the typical useful life of electrical equipment under operating conditions in Nauru.

Table E-44: Typical useful life of electrical equipment

Electricity assets	Typical construction type	Component makeup	Typical service life (years)
		Whole component	**Whole component**
Generators	Diesel fuel, medium Speed	100%	60,000 hours, 7 years, life extendable with overhaul
Generators	Diesel fuel, slow speed	100%	25,000 hours, 3 years, life extendable with overhaul
PV Solar Panels	Fixed axis	100%	25
Transformers	Diesel fuel, high speed	100%	30
Overhead Lines	On wood, steel or concrete poles	100%	30
Pole mounted Switches	Cutouts or gang operated, load break	100%	30
11 kV Underground Cables	XLPE, tape shield, cables	100%	30
Low Voltage Cables	XLPE insulated cables	100%	60
Pad-mounted Switchgear	Ring main units	100%	30
Revenue Meters	Solid state	100%	10

12.5 Condition assessment techniques

a. Generators

For generators, condition assessment techniques include:

- visual inspections and testing: performed during each of the planned scheduled maintenance in accordance with the manufacturer's recommendations to identify deficiencies, including excessive noise, vibrations, operating temperature, extent of corrosion on external components, leaking gaskets, cooling components and identification of parts requiring replacement
- infra-red thermal scan to identify overheating components
- monitoring of operating hours since last overhaul
- monitoring of average demand (kW)
- monitoring of fuel consumption and oil consumption and its comparison against normal benchmarks.

b. PV solar panels

For PV solar panels, condition assessment techniques include:

- visual inspections and testing: performed during each of the planned scheduled maintenance in accordance with the manufacturer's recommendations to identify deficiencies and identification of components requiring replacement, physical damage to panels, extent of corrosion of support structures, contamination of panel surfaces with dirt, leaves or debris
- infra-red thermal scan to identify hot spots
- testing to measure panel output.

c. Distribution transformers

For distribution transformers, condition assessment techniques include:

- visual inspections: performed at three-year intervals to rank condition of external components, including degree of corrosion, on transformer tank, oil leaks, and condition of bushings
- infra-red thermal scan to identify hot spots
- test results of insulating oil
- monitoring service age
- monitoring average loading (kVA) or operating temperature.

d. Overhead lines

- visual inspections: line patrols performed at three-year intervals to identify deficiencies, including line clearances, hardware corrosion, condition of insulators, condition of support structures and guys
- observing below grade degradation of poles through partial excavation of surrounding soil
- non-destructive testing of wood poles to identify internal rot
- infra-red thermal scan to identify hot spots
- checking line loading and load balance among phases.

e. Overhead load break switches

- visual inspections and operating tests, performed at three-year intervals to identify deficiencies: including checking alignment of blades, looking for signs of arcing, friction-free movement of operating mechanism, corrosion of hardware
- infra-red thermal scan to identify hot spots.

f. 11 kV Switchgear (RMUs)

For RMUs, condition assessment techniques include:

- visual inspections: performed at five-year intervals to rank condition of external components, including degree of corrosion, SF6 pressure gauge readings and condition of bushings
- insulation resistance measurements with megger and comparing them against new equipment condition

- monitoring the service age.

g. 11 kV and low-voltage cables

For XLPE insulated cables condition assessment techniques include monitoring:

- the number of failures per year per km of installed cable, which are not related to accidental dig-ins
- service age of the cable.

h. Revenue meters

Revenue meters condition assessment techniques include monitoring the service age of the meter seals since last calibration.

12.6 Electricity infrastructure capacity adequacy index

The electricity infrastructure capacity adequacy index is expressed on a scale of 1 to 5 and indicates if the existing generating plant and distribution network is sufficient to meet the current and immediate future needs or if an increase in generating plant or network capacity is required through construction of new distribution lines or additional generators. Table E-45 provides an example of electricity capacity adequacy index.

Table E-45: Electricity infrastructure—capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
100% of the existing consumers are connected with a reliable distribution network and there is 25% spare generating capacity available above the peak demand.	5	Very good
100% of the existing consumers are connected with a reliable distribution network and there is 15% spare generating capacity available above the peak demand.	4	Good
100% of the existing consumers are connected with a reliable distribution network and there is 5% spare generating capacity available above the peak demand.	3	Fair
Less than 5% of the potential consumers are not connected to distribution network and/or load shedding is occasionally required due to capacity constraints	2	Poor
More than 5% of the potential consumers are not connected to distribution network and/or load shedding is frequently required (almost daily) due to capacity constraints.	1	Very poor

13 Water supply infrastructure

In most locations, ground water in Nauru is not potable due to its contamination by sewage and ocean water during high tide periods. Therefore, there is a strong need that water is harvested from rooftops of private and government buildings and stored.

Water volume collected through harvesting is limited, due to poorly designed and constructed roofs and gutters. To further aggravate the problem, septic tanks without a concrete floor can get flooded during high tide areas, exposing the below grade water cisterns to risk of contamination, particularly because the cisterns have cracks in floors, walls and ceilings.

To alleviate this problem, above grade HDPE plastic water tanks are used by households. Although above grade tanks occupy significant amount of space, causing further congestion on already congested land, they are a necessity to protect the water supply.

To supplement the rain-harvested water, purified water through desalination plant is distributed to households by NUC, using water tankers.

13.1 Water supply components

Main components of rainwater harvesting system and water desalination plant are discussed below:

a. Rainwater harvesting system

Rainwater harvesting system has the following components:[12]

- gutters installed along the building facia, which collect water from the roof
- water tanks to store water
- down-pipes that carry the water from the gutters to the storage tank
- course filter at the tank inlet.

b. Desalination plant

The process of desalination removes salt and minerals from seawater to make it fit for drinking. Desalination plants can use a number of different technologies to remove salt from water. Desalination plants, working on the principle of reverse-osmosis, are used in Nauru. This is a modern and energy efficient technology for water desalination.

This system has the following key components:

a. **Pre-treatment:** Incoming water is pre-treated by passing it through a membrane that removes suspended solid particles. During pre-treatment, pH level is adjusted and a

[12] Harvesting the Heavens, Guidelines for Rainwater Harvesting in Pacific Island Countries.

threshold inhibitor is added to control scaling caused by constituents in water, such as calcium sulphate.

b. **Pressurization:** In this section water pressure of the pre-treated feed is increased by a pump to an operating pressure appropriate for the membrane and the salinity of the feed water.

c. **Separation:** When water passes through the permeable membranes, they inhibit the passage of dissolved salts while permitting the desalinated water to pass through. Applying feed water to the membrane assembly results in a freshwater product stream and a concentrated brine reject stream. Because no membrane is perfect in its rejection of dissolved salts, a small percentage of salt passes through the membrane and remains in the water.

d. **Stabilization:** The clean water produced from the membrane assembly usually requires pH adjustment and degasification before being transferred to the distribution system for use as drinking water. The product passes through an aeration column in which the pH is elevated from a value of approximately 5 to a value close to 7. This water is discharged to storage tanks.

13.2 Construction details

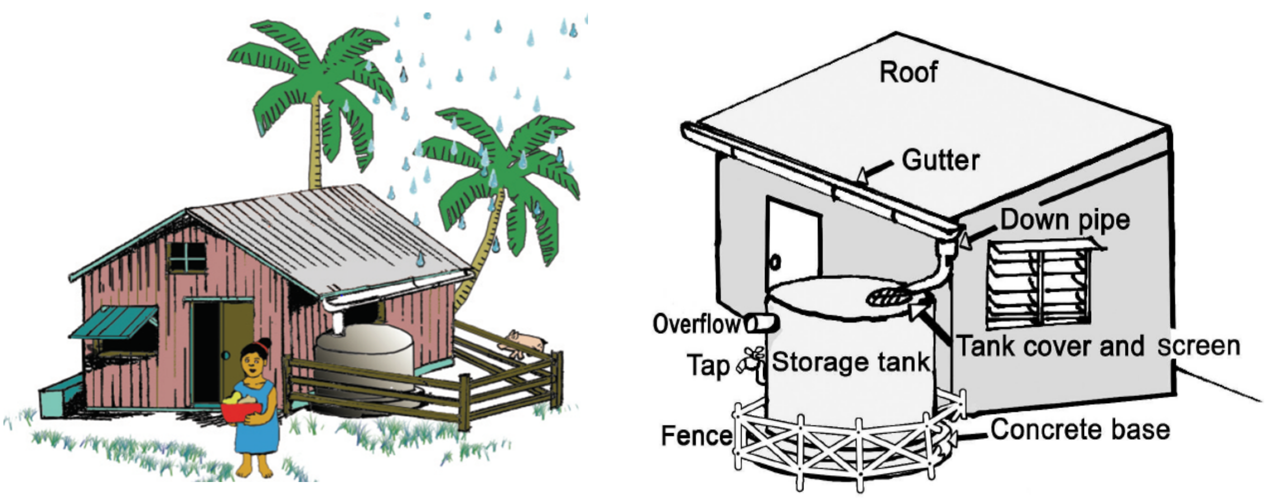


Figure E-23: Rainwater harvesting—system components

In rain harvesting systems, gutters made of plastic are attached to the building fascia with nails and a plastic downpipe collects the water from the gutters and delivers it into the storage tank through gravity.

Figure E-24 shows the construction details of a desalination plant, with reverse osmosis technology.

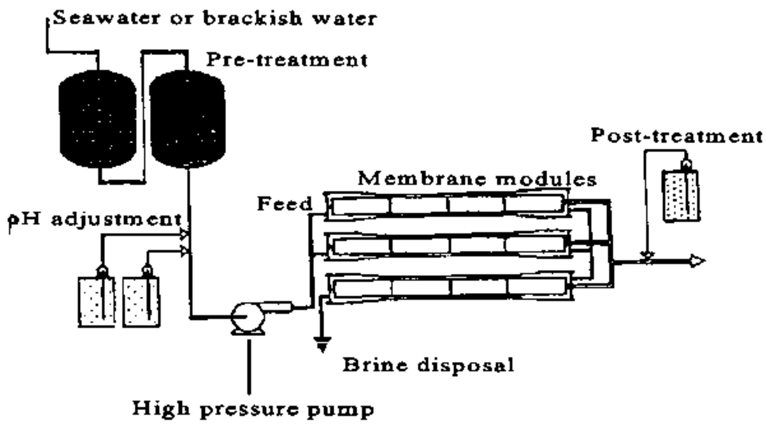


Figure E-24: Water desalination plant (reverse osmosis)

13.3 Common degradation modes

In a rain harvesting system, there are two potential degradations: first impacts efficiency of water collection and the second impacts quality and safety of water supply.

Over time, gutters can get separated from the roof resulting in water loss. Downpipe connections to gutter or tanks can become loose resulting in water leaks. Gutters or downpipes can also get choked with leafs thus resulting in overflowing gutters and loss of water. Concrete cisterns can develop cracks resulting in water leaks. Plastic storage tanks can be damaged if hit with a heavy sharp object or can be blown over (when empty) under strong wind conditions.

The larger risk, with water storage systems is the contamination of water supply. Bacteria of faecal origin can cause diarrhoea and other life-threatening diseases (e.g. typhoid fever). Water collected from raised roof catchments is likely to be better protected against contamination from human faecal matter. However, wind-blown dust particles, birds, reptiles and cats can carry human faecal pathogens from ground level onto roof catchments. Animals can also deposit their own faeces on such surfaces increasing the risk of contamination. Pathogenic bacteria may be attached to animal or bird droppings falling on the roof.

Below grade water cisterns are more vulnerable to water contamination from sea water or sewage. When toilet pits get flooded during high tide periods, with sea water rising through coral gravel under soil, water stored in cisterns with cracks can get contaminated.

If water entering the tank is not filtered, tree leaves can enter the water tank. Tree leaves and other organic materials provide nutrients for microorganisms to flourish and taint the water.
The main operational problem with reverse osmosis units is fouling. Fouling is caused when membrane pores are clogged by salts or suspended particulates. It limits the volume of water that can be treated before cleaning is required. Membrane fouling is corrected by backwashing

or cleaning, once every four months. The cartridge filter elements require replacement about every eight weeks.

13.4 Typical useful life

The typical useful life for assets used in water harvesting system is about 20 years. The typical useful life for assets used in water desalination plant is about 20 years. The life of the membrane used in reverse osmosis plant is about five years.

13.5 Capacity adequacy index

Capacity adequacy Index for water supply system is expressed on a scale of 1 to 5 and it indicates if the existing water harvesting and supplementary desalination plant has sufficient capacity to meet the current and immediate future needs of residents or if an increase in water supply capacity is needed. Table E-46 provides an example of water supply infrastructure capacity adequacy index.

Table E-46: Water supply infrastructure—capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
The existing water supply system has adequate capacity to meet the needs of 100% residents all year around with 10% reserve capacity	5	Very good
The existing water supply system has adequate capacity to meet the needs of 100% residents all year around with no spare capacity	4	Good
The existing water supply system has adequate capacity to meet the needs of <100% residents and ≥98% residents all year round	3	Fair
The existing water supply system has adequate capacity to meet the needs of <98% residents and ≥85% residents all year round	2	Poor
The existing water supply system has adequate capacity to meet the needs of <85% residents all year round	1	Very poor

14 Fuel storage facility

The above ground fuel storage facility, located in on a hill, approximately 35 m above sea level and inside a fenced yard in Aiwo district, receives all different forms of fuel, including diesel, petroleum and aviation fuel and stores it for distribution. The fuel storage facility is currently managed by Vital FSM Petroleum Corporation, the subsidiary of a corporation with headquarters in the Federated States of Micronesia (FSM).

14.1 Fuel storage facility components

Main components of fuel storage facility include:

a. fuel storage tanks
b. fuel transport pipes from ocean tankers to storage tanks
c. fire protection system
d. security fencing.

14.2 Construction details

As shown in Figure E-25, the facility has a total of nine fuel storage tanks, numbered T1 through T9. The dimensions, storage capacity, year of construction and current usage of the storage tanks is indicated in Table E-47.

Figure E-25: Aerial view of the storage facility

Table E-47: Storage tank capacity and current usage

Fuel Storage Tank	Current Use	Diameter (m)	Height (m)	Capacity (ML)	Year of Construction
T1	Automotive Diesel Oil	29.3	14.9	9.57	1977
T2	Automotive Diesel Oil	12.2	14.5	1.67	1977
T3	Unleaded Petroleum	12.2	14.8	1.67	1977
T4	Aviation Fuel	12.2	14.8	1.67	1977
T5	Aviation Fuel	12.2	14.8	1.67	1977
T6	Out of service	12.2	14.4	1.67	1977
T7	Fuel Oil	8.9	8.9	0.54	1977
T8	Out of service	9	8.6	0.55	1977
T9	Slops (Sea water mixed oil)	4	5.5	0.09	1977

Although the infrastructure is about 40-year-old, such infrastructure when well maintained and protected against corrosion, can provide a useful service life exceeding 60 years.

Fuel is received from the ships moored off the reef through one of two permanent pipes of 200 mm diameter, which run a distance of approximately 1.2 km from the storage facility to the conveyor gantry, located on shore, near RONPHOS ship loading facility. The pipes are equipped with sampling points and sight glasses to allow visual identification of the product.

Fuel delivery from the ship is dependent on the ship pumping, as there is no storage or pumping infrastructure in the harbor. As the same delivery pipe may be used to pump different types of fuel, sea water is used to flush the pipes after each operation and pipes are left filled with sea water when not in use, to protect them against fire hazard. One of the tanks, T-9, is dedicated to receive fuel contaminated sea water and the fuel is recovered from it after water settles down at the bottom of the tank.

Fuel is transferred from the storage tanks to the road tanker by steel pipeline and pumps located outside of the tank farm bund area. Three separate pipelines deliver Diesel, Unleaded Petrol and Jet A-1 to individual pumps.

14.3 Common degradation

For the fuel storage tanks and security fence and sprinkler system pipes, which are made of steel, the main degradation is oxidization (rusting) of the tanks walls and steel bolts.

Fuel leaks, vandalism, sabotage or terrorist attack are other risks that can lead to catastrophic accidents and destruction of this asset class.

14.4 Typical useful life

The typical useful life for assets used in fuel storage facility is about 60 years. Typical useful life for fire protection system and security fence is about 20 years.

14.5 Fuel storage facility condition assessment

Because the fuel storage facility is managed by an experienced, privately owned company with subject matter expertise, during the condition assessment, the government's role is to ensure that the facility is being audited regularly and is in full compliance of the recommendations made by auditors.

14.6 Capacity adequacy index

The capacity adequacy Index for fuel storage facility is expressed on a scale of 1 to 5 and it indicates if the existing fuel storage facility has sufficient capacity to meet the current and immediate future needs of residents or if an increase in fuel storage capacity is needed. Table E-48 provides an example of fuel storage facility infrastructure capacity adequacy index.

Table E-48: Fuel storage facility infrastructure—capacity adequacy index

Condition criteria	Capacity adequacy index	Interpretation
The existing fuel storage facility has adequate capacity to meet the needs of 100% residents all year around with 10% reserve capacity	5	Very good
The existing fuel storage facility has adequate capacity to meet the needs of 100% residents all year around with no spare capacity	4	Good
The existing fuel storage facility has adequate capacity to meet the needs of <100% residents and ≥95% residents all year round	3	Fair
The existing fuel storage facility has adequate capacity to meet the needs of <95% residents and ≥85% residents all year round	2	Poor
The existing water supply system has adequate capacity to meet the needs of <85% residents all year round	1	Very poor

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