

# APPENDIX C

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Infrastructure Asset  
Maintenance Guide

# 1 Introduction

For safe, reliable, and economically efficient operation, all infrastructure assets require a maintenance plan. A large percentage of the infrastructure assets in Nauru consist of engineered structures and complex equipment and require subject matter expertise to develop maintenance plans. It is therefore recommended that, the maintenance plan be developed as part of the engineering scope during procurement of equipment or construction and installation of assets. The maintenance guidelines in this appendix are very general and generic and will need to be tailored by a civil engineer to meet asset-specific requirements.

## 2 Infrastructure maintenance requirements—general

All infrastructure assets will require the following maintenance activities:

- a. **Scheduled inspections and minor maintenance:** Scheduled inspections and minor maintenance is required at regular intervals for minor repairs or replacement of degraded parts to avoid more serious damage and asset degradation. The scope and frequency of minor maintenance will vary, depending on the asset. Minor maintenance activities are covered through operations and maintenance (O&M) budgets.
- b. **Reactive maintenance:** Reactive maintenance involves repairing or replacing minor asset components when they fail in service to maintain asset functionality, meet the required service levels, and to prevent further asset degradation. The reactive maintenance is generally covered through operations and maintenance budgets but may occasionally involve capital expenditure, depending on the scope of required repairs.
- c. **Planned condition assessment:** Planned condition assessment is carried out by subject matter experts and is undertaken less frequently than scheduled inspections. It involves comprehensive assessment of all assets and their components to determine their physical condition and to reveal any need for major repairs or refurbishment or replacement of components and their timing (i.e. determining the need for roof replacement of a building).
- d. **Planned major repairs and refurbishment:** Planned major repair and refurbishment activities are performed in response to the repair/refurbishment needs identified through planned condition assessment and these are generally covered through capital budgets. When repairs or refurbishment of an asset is not considered economically efficient, the asset is retired from service and replaced.

Typical maintenance activities for various assets are described in the following sections, but for engineered structures and complex assets, these activities should be further detailed with input from subject matter experts.

## 3 Buildings maintenance

The maintenance plan for a building should be tailored to the building's specific design and construction; therefore, the maintenance plan should be developed at the same time a new building is being designed and constructed. It is important to keep a complete set of "as built"

drawings for the building and any changes made during major maintenance should be recorded on the drawings.

- a. Scheduled inspections and minor maintenance for buildings is recommended to incorporate the following activities, undertaken annually:
  - i. Grading inspection around the building foundation to confirm water is draining away from the foundations and raising the top soil level near foundations, where required.
  - ii. Inspection of foundations to identify structural cracks or concrete spalling.
  - iii. Inspection of masonry walls to identify cracks or damage to walls.
  - iv. Inspection of exterior walls and roof to identify all sources of water leaks into the building's interior and performing emergency repairs, where required, to prevent water ingress into the building.
  - v. Inspection of eaves and gutters to ensure they are not detached from the building or blocked by leaves or other debris. Repairs should be made where required.
  - vi. Inspection of floors and interior walls to identify any damage, which could affect functionality of the buildings, repairing when required.
  - vii. Inspection of doors and windows to identify warped frames or broken glass, repairing when required.
  - viii. Inspection of plumbing system to identify damaged plumbing fixtures, blocked or leaked drains or damaged pipes or defective pumps, repairing when required.
  - ix. Inspection of electrical systems including lighting fixtures, repairing when required.
  - x. Inspection of ceiling fans, air conditioners, identify extent of rust, inspect for proper operation, repairing when required.
- b. Reactive maintenance for buildings involves repairing specific building components when they fail to maintain the building's functionality and service levels and to prevent further impairment, i.e. replacing an air conditioner compressor after it has failed. Reactive maintenance could be triggered based on the findings of an annual inspection or planned condition assessment or any serious asset impairment reported by the asset users.
- c. Planned condition assessments for buildings are generally undertaken every five years or after a major cyclone. Assessments involve a comprehensive assessment of all building components to determine the physical condition of the components of a building and to assess their operating performance and remaining useful life. The condition assessment is undertaken to reveal any need for major repairs or refurbishment or replacement of components during the next five-year period, for example replacing a roof.
- d. Planned major repairs and refurbishment activities are undertaken in response to needs identified in the planned condition assessments.

## 4 Road maintenance

The maintenance plan for roads should be developed at the same time a new road is being designed and constructed. For keeping records and performing inspections and maintenance, the road network should be divided into sections of approximately one-kilometer lengths and records of inspections, maintenance and condition assessments be kept for each section. To plan for road maintenance, a complete set of “as-built” plans and records of all maintenance operations and observations will be needed. The as-built plans should contain photographic records, location, and observations of any unstable conditions in relation to the road location, location of culverts, and other drainage features, and outline any changes made to the road from the original plan.

Maintenance activities required during each of the four maintenance categories are listed below:

- a. Scheduled inspections and minor maintenance on roads are recommended on a two-year cycle. Recommended inspection and maintenance activities are listed below:
  - i. Inspect roads and footpaths to identify potholes, cracks, damaged curbs and swales, and clogged sumps that allow water to collect. Undertake emergency repairs, where required, to avoid more serious damage and degradation to the pavement.
  - ii. Inspect roads and footpaths to identify tree branches or brush overgrowth that may interfere with safe traffic flow or the safety of pedestrians and trim trees or overgrowth where required.
  - iii. Inspect roads for abandoned vehicles or debris left along the right-of-way that may pose a hazard to safe traffic flow. Remove the debris.
- b. Planned condition assessment, undertaken once every five years, is a comprehensive assessment of all roads and footpaths to determine the adequacy of the physical condition of the roads, curbs, drainage sumps and footpath, and assess need for resealing, repaving, or other repairs and the timing of these repairs.
- c. Reactive maintenance should be undertaken to repair potholes in roads, minor footpath defects that impact public safety, or clogged drainage sumps in response to public complaints. During pothole repairs, road surfaces should be reworked as necessary to provide a smooth, driveable surface, and a good crown or slope for drainage.
- d. Planned major repaving of roads or major repairs to footpaths, road curbs or drainage system involves repaving of the roads or major (capital) repairs to footpaths, road curbs or drainage sumps, found in poor or very poor condition. Some roads may need the base strengthened or reconstruction of concrete curbs. Rutting and loss of ballast often occurs during the rainy season use. A plan should be in place to provide ballast when necessary to maintain continued use of the road.

In case of unsealed roads, maintenance activities, involve:

- a. Planned condition assessment, undertaken once every five years, should identify any major impairments or the need to regrading the existing base or add gravel in locations with serious soil erosion where the gravel base has eroded.
- b. Reactive maintenance should fix and repair the road base in locations where repairs are needed immediately.
- c. Planned major regrading should also be undertaken. On the first pass, the grader should move material from the shoulder to a windrow in the center of the roadway. On the second pass, the blade should be centered on the windrow and continue working along the roadway. The blade should be adjusted to provide a slight slope or crown and should avoid cutting too deeply into the road surface.

## 5 Airport runway maintenance

To plan for the maintenance needs of the airport runway, keep a complete set of 'as-built' plans and records of all maintenance operations and observations. The as-built plans should contain complete history of the project from the planning stage to construction, with photographic records, location, and observations of any unstable conditions, wet areas that may have required additional excavation and replacement with more suitable ballast materials, and any major changes made to the original plan. The most valuable tool for the maintenance program is the knowledge and experience of individuals performing the maintenance.

Specific activities during each of the four types of maintenance categories include:

- a. Scheduled inspections and minor maintenance is recommended to be undertaken once a year. Recommended inspections and maintenance activities are listed below:
  - i. Inspect runway to identify potholes, cracks, and depressions in the surface that would interfere with safe landing or takeoff of aircraft and perform emergency repairs, as needed.
  - ii. Inspect runway to identify locations with poor water drainage that would lead to ponding on the surface during heavy rain and perform emergency repairs, where required, to avoid more serious damage and degradation to the pavement.
  - iii. Inspect runway to identify locations of brush overgrowth along the airstrip that may interfere with safe movement of aircraft and clear the overgrowth where required.
  - iv. Inspect airstrip markings and repaint surfaces where the markings have faded.
  - v. Inspect security fences to confirm their effectiveness in blocking entry of unintended animals and vehicles during aircraft movement.
- b. Planned condition assessment, undertaken once every three years, should comprehensively assess the physical condition of the pavement to determine its remaining useful life and the need for resealing or repaving and the timing of any

resealing. Air navigation equipment should be inspected by qualified contractors following strict procedures and schedules dictated by international aviation standards and safety protocols.

- i. Reactive maintenance should undertake repairs to the runway, the drainage system, or security fences to rectify identified defects and impairment.
- ii. Planned major repaving of the runway should be undertaken when its condition becomes poor or very poor.

## 6 Wharf and boat harbor maintenance

Maintenance for wharfs and boat harbors should be tailored to their specific design and construction; therefore, the maintenance plan should be developed at the same time as a new wharf, jetty, or channel is being designed and constructed. It is important to keep a complete set of “as-built” plans and records of all maintenance operations and observations.

The maintenance activities for wharfs and jetties require four types of maintenance activities:

- a. Scheduled inspections and minor maintenance should be undertaken once a year. Since the concrete structures in wharfs are generally based on complex designs, inspections should be undertaken using a plan developed by a subject matter expert (structural engineer). The following is check list of activities to be included in planned inspections and minor maintenance of the wharf and boat harbor:
  - i. Inspect concrete structures, including piers to identify and measure the size of surface cracks, spalling, rust staining, and exposed rebar
  - ii. Inspect steel members to identify and quantify the degree of corrosion, pitting, mechanical damage, or reduction in cross-section due to corrosion
  - iii. Inspect bumper pads to identify damage.
  - iv. Inspect paved areas to identify and benchmark surface conditions, pot holes, drainage condition etc.
  - v. Inspect mooring systems to confirm the buoy and its topside hardware, fenders, and chafing strips are in satisfactory condition and to verify that the mooring has not been dragged from its proper location.
  - vi. Inspect safety railings to identify any damage or corrosion.
  - vii. Inspect access channels to confirm adequate depth for safe ship movement to the port.
- b. Planned condition assessment of wharf structures, mooring systems, and approach channels should be undertaken by an engineer with expertise in marine structures, once every five years. This assessment should include both above- and under-water inspections, supplemented with non-destructive tests to benchmark the degree of corrosion on steel members, and degradation of concrete structures and to identify serious structural deficiencies and defects in structures, requiring structural repairs or refurbishment and renewal of structural components.

- c. Reactive maintenance involves site-specific repairs, refurbishment, or renewal to address deficiencies, prevent further impairment of structures, and to ensure the structures continue to meet the functional requirements.
- d. Planned major repairs involve repaving of the wharf surface or major repairs to structures or re-dredging of the channels to remove silt. The specifications for these repairs must be prepared by a subject matter expert with experience in marine structures.

## 7 Coastal protection structures

The maintenance activities for coastal protection structures, including sea walls or rock revetments, requires the following four types of maintenance activities:

- a. Scheduled inspections and minor maintenance should be undertaken annually and should include inspections and minor maintenance of both engineered and masonry sea walls, as well as rock revetments. Scheduled inspections and minor maintenance should consist of the following specific activities:
  - i. For engineered concrete sea walls or masonry walls, inspections should be undertaken annually to identify damage, either in form of structural cracks, concrete spalling, exposed re-bar, missing sections of masonry wall, or soil erosion at the base of the wall, caused by wave action or incidents of overtopping of the sea wall by strong waves.
  - ii. For rock revetments, annual inspections should determine if the rock revetments have moved from their original location or if earth under the structure has settled or eroded away, or if a section of the rock revetment has been washed away by wave action.
  - iii. Any minor damage that is repairable by using the maintenance budget and local resources should be repaired during routine maintenance.
  - iv. When severe structural damage is identified during visual inspections, it should be used a trigger to perform a more detailed inspection by a structural engineer.
- b. Planned condition assessments for the sea wall structures should be performed by an engineer, with expertise in marine structures and should involve detailed inspections, measurement of the extent of structural damage to the sea walls and development of a plan to repair the damage and address the deficiencies in order to prevent the degradation to the structures and to ensure they provide their intended functions. Mitigation measures may include reactive maintenance to be undertaken immediately to address public safety concerns or comprehensive mitigation measures as a permanent solution.
- c. Reactive maintenance involves immediate site-specific minor repairs, refurbishment or renewal to address deficiencies, prevent further impairment of structures, and to ensure the structures continue to meet the functional requirements, following plans developed in step (b).
- d. Planned major repairs and renewal of the sea walls comprehensively addresses all deficiencies to ensure the structures continue to meet the functional requirements, following plans developed in step (b).

## 8 Solid waste management facility



## 8.1 Landfill facility

A maintenance and management plan for the solid waste disposal site should be prepared by a subject matter expert and should cover:

- a. landfill inspections and reporting
- b. landfill planning and monitoring
- c. landfill deficiency corrective actions.

The maintenance plan should include:

- a. an inventory of required assets to be maintained
- b. quality standards to which assets are to be maintained
- c. maintenance procedures
- d. maintenance schedule
- e. methods for collecting data and reporting results related to environmental safeguards
- f. method to develop annual budgets and work programs
- g. method to determine and record the annual weight and volume of waste disposed using either weigh scales or estimates of volumes from truck tray measurements
- h. method for identifying and recording the hazardous wastes entering and leaving the site
- i. methods for groundwater and soil sampling near the landfill facility.

## 8.2 Medical waste incinerator

The medical waste incinerator is a specialised piece of equipment. A maintenance plan should be developed following the original manufacturer's recommendations for maintenance and the maintenance plan should be followed strictly. Table C-1 indicates the maintenance activities and their schedule, which should be included in the maintenance plan for the medical waste incinerator in Nauru.<sup>1</sup>

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<sup>1</sup> World Health Organization, Best Practices for Incinerators,  
[http://www.who.int/water\\_sanitation\\_health/medicalwaste/en/smincinerators3.pdf](http://www.who.int/water_sanitation_health/medicalwaste/en/smincinerators3.pdf)

**Table C-1: Medical waste incinerator maintenance schedule**

<i>Activity Frequency</i>	<i>Component</i>	<i>Procedure</i>
Hourly	Ash removal	Inspect and clean as required
Daily	Temperature, pollution monitors, if any	Check operation
	Underfire air ports	Inspect and clean as required
	Door seals	Inspect for wear, closeness of fit, air leakage
Weekly	Ash pit	Clean after each shift
	Latches, hinges, wheels, etc.	Lubricate if applicable
Monthly	External surfaces of incinerator and chimney (stack)	Inspect external hot surfaces. White spots or discoloration may indicate loss of refractory
	Refractory	Inspect and repair minor wear with refractory cement
	Upper/secondary combustion chamber	Inspect and remove particulate matter accumulated on chamber floor
Semi-annually	Hot external surfaces	Inspect and paint with high temperature paint as required
	Ambient external surfaces	Inspect and paint as required

## 9 Sewage treatment plant

A maintenance and management plan for the sewage treatment plant should be prepared by a subject matter expert and should cover:

- a. scheduled inspections and minor maintenance
- b. planned condition assessment
- c. the scope of reactive maintenance and planned major repairs should be based on the results of the planned condition assessment and recommendations of the subject matter expert.

The maintenance plan should include:

- i. an inventory of required assets to be maintained
- ii. quality standards to which assets are to be maintained
- iii. maintenance procedures
- iv. maintenance schedule
- v. methods for collecting data and reporting results related to environmental safeguards
- vi. method to develop annual budgets and work programs
- vii. method to determine and record the annual weight or volume of waste disposed using either weigh scales or estimates of volumes from truck box measurements
- viii. methods of groundwater and soil sampling near the sewage treatment facility
- ix. methods for measuring the level of obnoxious gases near the sewage treatment facility.

## 10 Motor vehicle fleet

All motor vehicles come with a vendor-recommended maintenance plan, requiring time-based and mileage-based maintenance activities, which should be strictly adhered to. Typical maintenance activities for motor vehicles are summarized below:

- a. Monthly inspections and corrective actions include:
  - i. Check all the lights, including headlights, brake lights, signal lights, and reversing lights, are working and replace any fused lamps.
  - ii. Check tire air pressure to confirm the tires are correctly inflated as recommended by manufacturer and fill tires when pressure falls below the recommended inflation level.
  - iii. Make sure the tires have sufficient tread and plan to replace worn tires.
  - iv. With the engine running, listen for any strange sounds, inside and out and investigate the sources of any abnormal noises.
  - v. Inspect the condition of all belts. Be aware of the life of the engine timing belt and make sure it is replaced before it fails.
  - vi. Check fluid levels—engine oil, transmission fluid, engine coolant, power steering, brake fluid, and wiper fluid—and top up when required. Look for any fluid leaks under the parked vehicle.
  - vii. Inspect batteries for any leaks or corroded connections.
- b. Fluid and filter changes should be undertaken according to manufacturers' recommendations, which are commonly time-based and mileage-based, including:
  - i. lubricating oil changes and oil filter changes
  - ii. air filter changes when they get dirty
  - iii. engine coolant flush and fill
  - iv. transmission fluid change.
- c. Tires, wheels and brakes should be assessed according to manufacturers' recommendations, which are typically condition-based, including:
  - i. rotating tires rotation and wheel balancing
  - ii. wheel alignments
  - iii. replacing brake pads and rotor reconditioning or replacement, when required.
- d. Engine tune-ups should be undertaken in line with manufacturers' recommendations, including changing spark plugs and spark plug cables when they are worn out or covered in buildup.
- e. Corrosion protection by reapplying protection to the vehicle's underside to protect against rust.

## 11 Boats and ferries

Boats (ships) are extremely complex form, spending most of the time in a corrosive ocean environment and require frequent maintenance and scheduled overhauls to remain operational.

The scope and frequency of maintenance work should initially be specified by manufacturers and then by companies that perform condition assessment of the boats.

A maintenance manual must be prepared by a subject matter expert for each boat, and should include:

- a. Recommended planned maintenance:
  - develop a checklist of inspections and maintenance activities to be undertaken onboard, indicating both the frequency and scope of maintenance activities
  - develop a checklist of inspections and maintenance activities to be performed at dock, indicating both the frequency and scope of maintenance activities.

Typical maintenance activities for large boats includes the following tasks:

- i. reconditioning of the hull, including blasting of surfaces to remove rust and repainting of the boat's hull, freeboard, superstructure, interior tanks and work areas
- ii. maintenance and major overhauls of the engine room machinery, i.e. diesel engines, turbines, generators, and pump stations, including checking and maintaining fluid levels for engine oil, engine coolant, inspecting batteries and connectors etc.
- iii. propeller and rudder repairs, modification and alignment
- iv. flushing, testing and installation of piping systems
- v. repairing or replacing outdated components of navigational systems and communication systems
- vi. structural modifications, if required e.g. cutting out existing steel structure and inspecting the condition of all belts. Be aware of the life of the engine timing belt and make sure it is replaced before it fails.

## 12 Telecommunications infrastructure

Initial generations of “state-of-the-art”, solid-state components and devices required significant adjustments by operations and maintenance personnel. The early solid-state telecommunications equipment was manufactured with external controls to allow adjustments (recalibration). However, modern equipment is less affected by its environment and most manufacturers have eliminated the external adjustment controls.

Under the current design, communication devices either perform as specified, or they must be replaced. Manufacturers have created “board level” systems with all necessary components required for a device placed on digital cards, commonly referred to as printed circuit boards.

Most communication system component hardware is constructed on a single printed circuit board that can easily be replaced by a qualified technician. The components are so small that

they cannot be repaired or replaced in the field. Replacing the entire board with the failed component saves time and money.

Most communications equipment is built with internal monitoring capabilities. Diagnostics are displayed in one of two general ways: external display on the equipment or via a diagnostics terminal (or a program on a PC). Most modems have LED indicator lamps to show that the device is functioning properly. A multiplexer or router will provide diagnostics via directly connected terminal, or through a device setup and management program on a PC.

Telecommunications devices, therefore, require the following types of maintenance activities:

- a. Reactive maintenance to replace defective components and devices by replacing digital circuit boards. It is also important to maintain a logbook of all maintenance activities, device failures, and replacement of defective cards in a database. Failure of climate control systems also require immediate attention and replacement. In the field, damaged cables should be replaced immediately.
- b. Planned minor maintenance is recommended to be undertaken once a year and it should include:
  - i. field verification of inventory to confirm the installed equipment against the database
  - ii. inspect connectors should for corrosion and clean them when required.
- c. Planned condition assessments should be undertaken once every five years and should include comprehensive condition assessments of the existing system capability against the current needs to see if the system should be replaced with the next generation of telecommunication devices. Failure rates should be also be reviewed to assess if the devices are still operating within acceptable levels.
- d. Asset upgrades should replace equipment when it has reached a poor or very poor condition.

## 13 Electricity infrastructure

The maintenance plan for electricity infrastructure should be tailored to the specific equipment design and construction; therefore, a maintenance plan should be developed at the same time a new asset is procured and installed. Maintenance plans must reflect the requirements specified by the original equipment manufacturer.

Maintenance activities required for major assets are described below:

### 13.1 Generating sets

Electricity generating sets are extremely expensive and maintenance-intensive assets. If they do not receive the required maintenance, their service life is significantly reduced. Therefore,

electricity generators require scheduled maintenance, strictly in accordance with the manufacturers' recommendations.

#### **a. Scheduled inspections**

Routine maintenance and inspections of generating plant should be performed daily and include:

- i. checking lubricating oil levels and leaks
- ii. checking coolant levels and leaks
- iii. inspecting exhaust pipes
- iv. inspecting fuel lines
- v. inspecting control batteries and testing voltages.

#### **b. Scheduled minor maintenance**

Planned minor maintenance activities include changing oil and oil filters, air filters, fuel filters, and coolant. Minor maintenance activities include:

- i. tasks recommended by the manufacturer once every 600 hours for medium-speed engines, i.e. changing oil and oil filters and air filters
- ii. tasks recommended by the manufacturer every 6000 hours for medium-speed engines, i.e. changing air fuel filters and coolant.

#### **c. Planned condition assessment and major maintenance**

Planned major maintenance activities include engine overhauls required after about 60,000 operating hours for medium-speed engines.

High-speed generators require more frequent maintenance, as specified by the manufacturer, due to their higher operating speed creating greater wear of moving parts.

## **13.2 Solar panels, inverters and batteries**

Because there are many types of solar panels, inverters, and batteries in use, the maintenance of the solar PV plant should be undertaken strictly in accordance with the manufacturers' recommendations in the operating manual. The following recommendations for maintenance are just general guidelines.

Solar panels and inverters are generally considered to be maintenance-free for a service life of 20 years and do not require any maintenance with the exception of planned minor maintenance.

#### **a. Scheduled routine inspections and minor maintenance (three-month intervals)**

The following maintenance activities should be undertaken once every three months:

- i. Wash the panels with water to remove dust, dirt, and bird droppings. Rub the panels with a soft sponge to remove bird dropping if required, do not use hard brushes or chemicals.

- ii. Inspect panel wiring to ensure connections are tight and wires are properly secured.
- iii. Monitor the panel output power.
- iv. Check the electrolyte level in the storage batteries and topped up when required.

**b. Planned detailed inspections and maintenance (annually)**

- i. Check the panels for defects in the modules such as cracks, chips, de-lamination, fogged glazing, water leaks, and discoloration. If any defects are found, note their location in a logbook, so they can be monitored in case further deterioration affects the modules' output.
- ii. Inspect solar panel mounting frames for damage or rusting and repaint surfaces, when required.
- iii. Inspect the inverter and remove any dust accumulated with a dry cloth. Confirm all the indicators such as LED lights are working and that the wires are not loose. Note that the charge controller should show the system is charging when the sun is out.
- iv. Check the wiring and conduits to confirm they are free from damage.

### 13.3 Overhead lines

**a. Scheduled detailed inspections and minor maintenance (three-year Intervals)**

- i. Undertake detailed inspections of poles to identify the following common deficiencies:
  - out of plumb, cracked or broken poles
  - excessive surface wear or scaling on steel poles
  - loose, cracked, or broken cross arms and brackets
  - woodpecker or insect damage, or bird nests
  - loose or unattached guy wires or stubs
  - guy strain insulators that are pulled apart or broken
  - guy guards that are out of position or missing
  - grading changes or washouts
  - indications of burning.
- ii. Undertake detailed inspections of pole-mounted distribution transformers to identify the following common deficiencies:
  - degree of transformer tank corrosion or rust and the need for repainting
  - ensure phase indicators and unit numbers match operating map (where used)

- oil leaks
  - flashed or cracked insulators
  - contamination or discolouration of bushings
  - ground lead attachments
  - damaged disconnect switches or lightning arresters
  - unattached ground wire on arresters.
- iii. Undertake detailed inspections of pole-mounted disconnect switches to identify the following common deficiencies:
- bent or broken bushings and cut-outs
  - damaged lighting arresters
  - unattached ground wire on arresters.
- iv. Undertake detailed inspections of pole hardware to identify the following common deficiencies:
- loose, rusted, or missing hardware
  - insulators unattached from pins
  - conductors unattached from insulators
  - insulators flashed over or obviously contaminated (difficult to see)
  - unravelled tie wires
  - broken or removed ground wire
  - removed or broken ground wire guards.
- v. Undertake detailed inspections of pole-mounted cables and conductors to identify the following common deficiencies:
- low conductor clearance
  - broken or frayed conductors or tie wires
  - exposed or broken ground conductors
  - broken strands, bird caging, and excessive or inadequate sag
  - insulation fraying on secondary conductors.



- vi. Undertake detailed inspections of vegetation growth near the lines to identify the following common deficiencies:
  - leaning or broken “danger” trees
  - growth into line of “climbing” trees
  - compromised accessibility
  - vines or brush growth interference (line clearance)
  - bird or animal nests.

### **13.4 Pad-mounted distribution transformers and ring main units (RMUs)**

All active electrical components in a distribution transformer and SF6-insulated RMU are sealed inside the tank. In the case of transformers, if corrosion has not resulted in an oil leak from the tank through to the welds or gaskets, the transformer does not require any maintenance of its internal parts. For RMUs, as long as the SF6 pressure gauge indicates the correct pressure, no maintenance is required. There are no maintenance facilities available in Nauru to repair internal components of transformers and RMUs. In case of an internal failure, the defective equipment must be replaced with a spare unit.

Maintenance activities for distribution transformers and RMUs include:

- a. Reactive maintenance for site-specific repairs of external parts or replacement of faulty units with a spare one to meet immediate needs.
- b. Planned minor maintenance, undertaken once a year, to complete the following tasks:
  - i. inspect to confirm the safety of power equipment
  - ii. clearing the equipment of dirt or debris, if required
  - iii. trim shrubs near the equipment
  - iv. paint rusted surfaces to avoid more serious damage to equipment.
- c. Planned condition assessment of equipment, should be undertaken once every five years.

The condition assessment of the transformer should include:

- i. testing of oil samples to assess condition of internal insulation
- ii. measuring insulation resistance with a megger
- iii. checking turns ratio to detect shorted coils.

The condition assessment of the SF6-insulated RMUs should include:

- i. inspecting for seals and gaskets of SF6 tanks
- ii. checking gas pressure and identifying sources of leaks
- iii. measuring insulation resistance.

- d. Planned replacement. There are no major repairs recommended for transformers and RMUs, when the condition assessment results indicate poor or very condition, the equipment will need to be replaced.

### **13.5 11 kV and low-voltage cables**

The 11 kV or low-voltage cables require no maintenance, other than replacement on failure. Some electric utilities conduct onsite tests to verify the remaining life of cables, but no reliable tests are available that could be performed cost effectively in Nauru.

For condition assessment of the cables, the following tasks should be undertaken:

- i. for all medium-voltage and low-voltage circuits, keep records of cable failures, indicating the type, location, and cause of the failure
- ii. plan to replace cables when the number of repeated failures on a circuit becomes excessive.

### **13.6 Revenue meters**

Maintenance activities for revenue meters include:

- i. reactive maintenance, which involves replacing non-working meters and resealing broken seals, when identified by meter readers
- ii. removing and resending the revenue meters for calibration, after the current calibration period expires.

# 14 Water supply systems

## 14.1 Rainwater harvesting systems

For rainwater harvesting systems, the following maintenance activities are required:

- a. Planned minor maintenance of rainwater harvesting system should be undertaken twice a year and should include:
  - i. cleaning and clearing all gutters of vegetation and leaves
  - ii. inspecting joints in pipes for leaks
  - iii. re-attaching and repairing any gutters and downpipes where rainwater is leaking
  - iv. cleaning the coarse filter, when a filter is used
  - v. identifying damaged or cracked roofs of below-grade water cisterns through which contaminated groundwater could leak into the water cistern, and make necessary repairs.
- b. Reactive maintenance should involve repairing and reattaching gutters and downpipes, whenever leaks are noticed.
- c. Planned major maintenance, performed annually, should include:
  - i. Partially drain the tank, leaving about 1000 liters of water. Add about half a bottle (125 ml) of plain, household-grade, unscented, and un-colored bleach (with 4% active chlorine) to water. The bottom and sides of the tank should be thoroughly scrubbed with this solution, using a brush. The remaining water and bleach solution should then be drained out of the tank and the tank refilled with water, left to settle overnight, before use. Proper hand and eye protection should be worn when handling chlorine bleach solutions.
  - ii. The water quality in tanks should be tested by the Ministry of Health and results compared against WHO water quality guidelines. Testing of water quality can guide when the tanks need to be cleaned or disinfected. The main focus of water quality tests should be microbiological testing such as thermos-tolerant coliform count *Escherichia coli* (*E. coli*) count, or simple hydrogen sulfide ( $H_2S$ ) test.
- d. Planned condition assessments should be undertaken once every five years and should include a comprehensive condition assessment of the water tanks and water storage cisterns.

## 14.2 Water desalination plant

Maintenance of the water desalination plant should be carried out strictly in accordance with the manufacturer's recommendations. Maintenance activities typically include:

- a. Reactive maintenance with day-to-day monitoring of the system operations, including the following tasks:
  - i. adjusting the pump
  - ii. inspecting and adjusting the chemical feed

- iii. leak detection and repair.
- b. Planned minor maintenance, including the following tasks:
  - i. replacing cartridge filter elements, once every two months
  - ii. backwashing the clogged membrane, once every four months
  - iii. instrument calibration and structural repair of the system on a planned schedule, according to the manufacturer's recommendations.
- c. Planned condition assessments should be undertaken once every five years and should include comprehensive condition assessments of the membrane and its replacement.

## 15 Fuel storage facility

The fuel storage facility in Nauru is managed by Vital FSM Petroleum Corporation, the subsidiary of a corporation with headquarters in the Federated States of Micronesia (FSM). Since the fuel storage facility must be maintained in strict compliance to international standards and because Vital FSM Petroleum Corporation is a subject matter expert in managing fuel storage facilities, it is recommended that Vital FSM Petroleum be asked to write a maintenance plan for the facility and implement it.

## 16 Maintenance cost estimates

The scope of maintenance activities varies significantly for different asset types, to achieve the desired objectives of:

- preventing premature asset impairment
- reducing the risk of in-service asset failures
- providing economically efficient asset operations, throughout the assets' life cycle.

The optimal level of maintenance required for an asset depends on a number of factors. Generally, assets that have a large number of moving parts experience a higher degree of wear and tear and, therefore, require more frequent and extensive maintenance. Similarly, assets that are routinely exposed to a corrosive environment, experience accelerated degradation of metal surfaces due to oxidation and, therefore, also require more extensive maintenance to restore the condition of corroded surfaces. The maintenance effort required for an asset also increases with the asset's service age. As assets age and approach the end of their typical useful life, they require significantly greater maintenance efforts, relative to brand new assets.

Based on the scope of maintenance activities required for different assets classes, the annual maintenance budget requirements should be calculated as percentage of the gross replacement cost of the assets, as indicated in the table below. The indicated costs are for routine maintenance, inspections, and minor emergency repairs and do not cover the cost of major component renewal.

Asset Class	Avg annual mtc Cost as % of Replacement Cost
Residential Building	1.0%
Office / Institution Building	1.0%
Sealed Roads - Surface maintenance	1.5%
Runway - Surface maintenance	1.5%
Motor Vehicle Light Duty	3.0%
Motor Vehicle Heavy Duty and Machinery	3.0%
Motor Boats	5.0%
Disel Generators	4.0%
PV Solar	2.0%
Electricity Distribution Assets	2.0%
Telecom Assets	2.0%
Coastal Protection Assets	2.0%
Miscellaneous Assets	2.0%

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