GREEN STORMWATER INFRASTRUCTURE GUIDANCE MANUAL

LIFE IP Programme 2014-2020

LIFE 16 IPE/MT/000008 – *"Optimising the Implementation of the 2nd RBMP in the Maltese RIver Basin District"*

Co-financing rate: 65% European Union, 40% National Funds

Ministry for Public Works and Planning

June 2022

TABLE OF CONTENTS

Executive Summary

Green Stormwater Infrastructure (GSI) is the name given to solutions which emulate natural processes for the management of stormwater. GSI solutions provide greater long-term benefits than conventional or grey stormwater solutions which seek to dispose of stormwater in the easiest and fastest possible way. GSI solutions reduce the volume of downstream runoff and manage stormwater at source. GSI solutions refers to a range of decentralized stormwater management practices and technologies, such as rainwater harvesting systems, green roofs, trees, infiltration systems, pervious pavements, etc.

Malta has a long history of sustainable rainwater management, particularly through the harvesting of rainwater in cisterns. However, over the last decades, this sustainable practice, which was a primary source of freshwater supply, has lost ground to other less sustainable means of obtaining freshwater (such as groundwater extraction) leading to an under-investment, if not an abandonment, of GSI technologies. Unfortunately, stormwater is sometimes perceived as a nuisance, a waste product, that is to be immediately diverted using pipes, culverts, tunnels, etc. and channelled into roads, valleys, or the sea. The renewed need to sustainably manage stormwater and groundwater, compounded by the effects of climate change, is leading to a renewed interest in GSI. The Ministry for Public Works and Planning acknowledges the need for a local Guidance Manual for GSI.

The purpose of the GSI Guidance Manual for the Maltese Islands is to serve as a resource for planners, *periti*, designers, regulators, policy makers, etc., and provides professional guidance in the evaluation, selection, siting, permitting, design, construction, operation, and maintenance of best management practices (BMPs).

The Guidance Manual should provide for effective selection of the most appropriate type of GSI for different projects, and the tools necessary to formulate an outline design of the most appropriate GSI, with preliminary calculations on sizing, water recovery, and, space and budgetary considerations (including maintenance).

Globally, various international expert organizations have developed detailed GSI Design Manuals. However, given the very particular local circumstances of a densely populated island state in a semi-arid climate, one cannot adopt a ‘copy-and-paste’ approach as this would be very limiting in its efficacy, feasibility and ease of execution.

This Manual is a determined attempt to identify, describe and promote GSI technologies that work best for Malta, including the optimisation of traditional rainwater harvesting systems and the introduction of innovative compact infiltration systems. The Manual should assist in the rediscovering of rainwater as a precious resource and henceforth promotes sustainable stormwater infrastructure for big or small, new-build or retrofitting projects.

Preamble

The Guidance Manual is prepared by the Ministry for Public Works and Planning with the external assistance of Sustech Consulting (*Inġ.* Marco Cremona and *Perit* Philip Grech). It is co-financed by the European Union under the LIFE project *Optimising the implementation of the 2nd RBMP in the Malta River Basin District* (LIFE-IP RBMP-MALTA), which project is co-ordinated by the Energy and Water Agency (EWA) within the Ministry for the Environment, Energy and Enterprise. The Manual is intended to serve as a resource for planners, designers, regulators, policymakers, etc. The aim of the Manual is to support responsible decisions about GSI in Malta.

The solutions for sustainable stormwater management presented and described herein take into consideration Malta's particular characteristics of being a densely populated island state with a semi-arid climate, with limitations on space, the issue of seasonality of rainfall and the competition faced from other sources of water.

For the Manual to address the national needs for sustainable stormwater management, consideration is given to:

1. Recognise Malta's unique geographical, climatological, hydrological, and social characteristics;
2. Examine and describe the Maltese experience with GSI technologies over the centuries;
3. Identify, list, and rank the driving forces for GSI in Malta; and,
4. Identify the limitations with GSI systems in Malta.

The preparation of the Manual was carried out over a 16-month period with the invaluable input of several consultees, which are listed in **Appendix 10.01**.

1.00

What is Green Stormwater Infrastructure (GSI)?

Infrastructure is the term used for basic installations, utilities, and structures (such as roads, bridges, buildings, water and sewerage systems) that are essential for the well-being of communities. In order to function properly, all infrastructures must be maintained, repaired, or replaced at the end of their life cycle. During their life, infrastructures need to be monitored for possible required enhancements or other alterations because of changing circumstances.

The above considerations apply also for stormwater infrastructure.

It may be appropriate to define (water) runoff at this stage. ***Runoff*** is the flow of water occurring on the ground when rainwater can no longer sufficiently infiltrate the ground. Runoff occurs because impervious areas (such as rooftops and roadways) do not allow water to soak into the ground, or when the natural ground's capacity for infiltration through the surface is saturated.

The management of runoff has grown in significance with the increase of land development and urban sprawling, and climate change is affecting the expected efficiency of the infrastructure.

Runoff is sometimes perceived as waste to be disposed of; it causes flooding, results in physical damage, and if contaminated, is harmful for public health and the environment. At the same time, the element of runoff, namely rainfall, is a precious commodity and a vital natural source of freshwater.

If left unmanaged, or inadequately managed, runoff can be a health and flood hazard and cause of water pollution. Community leaders and decision makers are faced with making decisions on how to best manage stormwater in their communities. Often such decisions are forced on communities as a reaction to developments upstream of their localities, or after developments have been built.

Traditional ***grey stormwater infrastructure*** is designed to move urban stormwater away from the built environment and includes kerbs, gutters, drains, piping, and collection systems. Generally, traditional grey infrastructure collects and conveys stormwater from impervious surfaces, such as roadways, parking areas and rooftops, into a series of piped or channelled systems that ultimately discharge untreated stormwater into a nearby water body, which can be a river, a lake or, in the case of Malta, valleys and ultimately the sea.

On the other hand, ***green stormwater infrastructure (GSI)*** is designed to mimic nature and capture rainwater where it falls, reversing (at least in part) the sealing effect of impervious development. It refers to a range of decentralized stormwater management practices and technologies, such as rainwater harvesting systems, green roofs, trees, rain gardens and pervious pavements, that capture and infiltrate rain where it falls, thus reducing stormwater runoff while replenishing the quantity and improving the quality of receiving water bodies.

While there are different scales of GSI, such as large swathes of land set aside for water drainage, this guide mainly focuses on GSI's benefits within the urban context, and in particular addresses the requirements in coherence with the local context.

GSI aims to imitate the natural drainage of a site before development. It gives equal consideration to controlling water quantity, improving water quality, providing opportunities for amenities and improving biodiversity. Similar to a natural catchment, a combination of drainage features (also known as *components*) work together in sequence to form a management train. The management train controls both flows and volumes, as well as treating runoff to improve water quality. The fundamental principle is to slow down the movement of runoff to reduce its impact further down the catchment, capture for use or infiltrate into the ground.

GSI is nothing new. It has been nature's way of dealing with rainfall since time began. At its simplest, rain falling on land may evaporate or drain into the ground, nourishing the soils, or else flows overland into ponds, ditches, watercourses and rivers, sustaining habitats and replenishing water bodies. It is only comparatively recently with the advent of higher forms of civilisation that the balance of this natural water cycle has been disrupted.

Modern urban development with its buildings, roads and other impervious surfaces has increasingly altered the way that rainwater finds its way into pervious ground and watercourses. There tends to be less pervious ground available for infiltration and less vegetation for evapotranspiration in urban areas. When rain falls on impervious surfaces, much more of it turns into runoff (in some situations, by a magnitude of 10 or more), which can cause flooding, pollution, and land erosion.

Unfortunately, for the last decades, urban runoff has been allowed to be collected and channelled into roads or to the sanitary sewers. Conveying water away as quickly as possible from a development may adequately protect it from flooding but increases the risk of flooding occurring downstream. This unsustainable approach to water drainage, together with the potential effects of a changing climate, can contribute to serious consequences on life, buildings and the environment.

Moreover, the local sanitary sewerage system is not sized to take rainwater flows, and this practice is illegal. The overloading of sanitary sewers with runoff is a prime source of urban pollution and other hazards. The overloaded sanitary sewers often backflow into buildings introducing wastewater, the uplifted manhole covers are a hazard to traffic, while leaks drain into the foundations of roads.

Research has shown that if we do not change the way we design our urban areas and manage runoff more effectively, the above-mentioned incidences are going to get more frequent and severe. Climate change projections for Malta predict it is likely that while overall rainfall would decrease, heavy rainfall storms would become more frequent increasing flood risks. The projections also predict that Malta's groundwater reserves would come under more stress. A policy of augmenting the separate sewers capacities and/or dispose of runoff into the sea to try to cope with the higher risks of flooding is unsustainable, unaffordable, and a loss of prime resource.

GSI is more sustainable than conventional water drainage methods as it mitigates many of the adverse effects that stormwater runoff has on the environment. GSI reduces and treats runoff at its source while also provides multiple community benefits such as:

- Reducing runoff flows, thereby lessening flood risks;
- Minimising runoff flows which could otherwise exacerbate flood risks and impair water quality
- Encouraging natural groundwater recharge (as appropriate) and so reduce the negative impacts on water bodies, and land;
- Improving community aesthetics;
- Encouraging more neighbourhood socialization;
- Providing habitats for wildlife and opportunities for biodiversity enrichment;
- Improving economic prosperity by increasing the value of land and providing jobs opportunities; and,
- Decreasing the economic and community impacts of flooding, thereby delivering environmental, social, and economic benefits.

Instead of conveying runoff underground in piped systems, onto roads or valley watercourses, GSI provides the opportunity to create attractive places and visible routes for rainwater to permeate the built environment and connect people with rainwater. Drainage components on the surface provide valuable wildlife habitats and increase biodiversity as well as provide opportunities for environmental education.

The ability of such practices to deliver multiple environmental, economic, and social benefits or services has made GSI increasingly popular in recent years. In addition to reducing polluted runoff, GSI practices can also positively impact energy consumption, air quality, carbon reduction and sequestration, land values, recreation and other elements of community health and vitality that have monetary or social value. Moreover, GSI practices provide flexibility to communities faced with the need to adapt infrastructure to a changing climate.

	Reduces Stormwater Runoff											Improves Community Livability						
Benefit	Reduces Water Treatment Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding	Increases Available Water Supply	Increases Groundwater Recharge	Reduces Salt Use	Reduces Energy Use	Improves Air Quality	Reduces Atmospheric CO_2	Reduces Urban Heat Island	Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture	Improves Habitat	Cultivates Public Education Opportunities
Practice										CO_2								
Green Roofs	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes	Yes
Tree Planting	Yes	Yes	Yes	Yes	No	Maybe	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Bioretention & Infiltration	Yes	Yes	Yes	Yes	Maybe	Maybe	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe	No	Yes	Yes
Permeable Pavement	Yes	Yes	Yes	Yes	No	Maybe	Yes	Maybe	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes
Water Harvesting	Yes	Yes	Yes	Yes	Yes	Maybe	No	Maybe	Maybe	Maybe	No	No	No	No	No	No	No	Yes

Yes Maybe No

Figure 1: GSI benefits and practices

Figure 1 gives a snapshot of the benefits that can be accrued from some GSI practices. Some technologies deliver benefits in some respects (e.g., increase water supply) while others deliver other benefits (e.g., increase recreational opportunity).

Some technologies may work well in particular locations, others not so well, or don't work at all. The suitability or not depends on the priorities of the area/community, the lack or abundance of water resources, the precipitation pattern (in terms of total precipitation, seasonal distribution, and intensity), the availability of land for installation of GSI, the ground conditions, as well as the community's experience with a particular technology (which can be positive or negative, or none at all).

However, GSI can be designed to fit all developments and projects, as there are a wide range of components available to meet each site's specific requirements, opportunities, and constraints.

This applies both to ***new-build*** schemes and, importantly, to ***retrofitting*** GSI to existing developments or urban spaces.

GSI can be either ***hard constructed*** systems or ***soft landscaped*** features, ranging from pervious paving or small, hard edged water features to large scale ponds and dry detention basins, as well as more engineered components such as green roofs and below ground attenuation storage systems. Many GSI components use a combination of both hard and soft landscape features.

2.00

Properties of GSI

GSI manages stormwater runoff by several methods. The techniques (described more fully in **Chapters 8.01 - 8.13)** involve aspects of:

- Storage;
- Infiltration;
- Absorption;
- Treatment.

A GSI technique often involves more than one of the above aspects at the same time.

For example, a vegetated system, designed to reduce runoff, collects water, binds it in its roots and leaves (storage and absorption) while excess water diffuses into the substrate (infiltration) and incorporates evapotranspiration. On the other hand, a rainwater harvesting system may include pre-treatment (such as a sedimentation pit) and storage.

Storage

GSI storage techniques involve the most straightforward accumulation of incident rainfall for eventual direct reuse, especially in situations of water scarcity and where the price of water determines that this is the most advantageous use. Storage techniques may also alternatively provide a buffer to protect downstream environments by release at a controlled rate. Storage can be underground, as is commonly the case in Malta, at ground level or in above-ground tanks or butts. The choice is determined by the environment of the intervention, such as the cost and availability of land, the rate of evaporation, and the cost of infrastructure.

Given that the current local building code has a prescriptive recommendation on the amount of direct rainwater storage to be incorporated in every building development (see **Chapter 6.05**), the Manual discusses the options with various scenarios of this management in detail (see **Chapter 8.01**).

Infiltration

GSI infiltration recognises that the development of the ground entails sealing it, replacing a pervious surface into an impervious one, thereby reducing natural infiltration. Infiltration techniques seek to reverse the process by making the ground safely permeable to water without endangering the overlying structure and also without polluting the receiving water bodies and flow paths. This is done by a variety of systems, such as compact infiltration systems (CIS), soakaways, swales, filter drains, and pervious pavements.

Every adopted infiltration system must effectively perform both the requisites of structural stability and groundwater protection. Drainage is critical to the stability of any structure on land, e.g., a cracked road performs as a pervious pavement in dissipating water to the base, undermining the road itself and leads to its further degradation. A controlled and well-engineered drainage system will avoid this.

In each of these techniques, the function of the buffer within the infiltration system is crucial as it has to allow for the time necessary to allow for the water to dissipate to the unsaturated zone of the underlying aquifer. Naturally, controls have to be kept on the quality of the influent water; in this regard, data from the local situation (**Appendix 10.03**) has consistently shown that runoff in urban areas is generally of good quality for infiltration into the aquifers. However, specific treatment is recommended to runoff from known sources of pollution, e.g., runoff from car parks. Heed must be given to infiltration projects in rural areas, as the runoff may be high in dissolved nutrients originating from agricultural activities.

Absorption

GSI techniques can innovatively use nature to take up water and provide amenities and attractive environments. Green roofs, trees, and many other planned softscapes in relation to developments can effectively reduce runoff while generating spaces and volumes which are features in themselves. The vegetative growth not only provides spaces for nature to flourish in what would be otherwise roof tops, roadsides, or hard surfaces but also creates shade, provides insulation and improves air quality. The proper engineering of such techniques is vital. Plantings on a roof with failed waterproofing or insufficient strength can lead to damp and/or structural damage, and uncontained roadside root zones can damage pavement foundations and/or underlying utilities.

Treatment

Direct treatment of the influent runoff can be designed in relation to the pollutants which require to be controlled. Runoff from car parks can be treated in purposely designed oil and grit separators allowed to go onto indirect infiltration or for direct use as second-class water. They are usually installed underground as part of road/forecourt constructions. Reactors, made up of tanks, can also be used for biological and chemical water treatment where space is readily available.

3.00

Characteristics of the Maltese Islands

Malta has unique specific characteristics among European countries due to it being:

- A miniscule EU Member State adopting mainstream EU policies;
- An island state that has to be self-sufficient in freshwater
- Situated in the middle of the Mediterranean Sea with a semi-arid climate, just north of the Sahara Desert. It has no lakes or rivers. Annual precipitation is low and very unevenly distributed with most of the rain falling between September and February, while the remaining months are relatively or absolutely dry; and,
- One of the most densely populated and highly urbanised countries in the world.

The following describes the specific characteristics to be kept in mind when determining which GSI technologies are best suited for Malta.

Basic Facts about Malta

The Maltese archipelago consists of three inhabited islands; Malta, Gozo and Comino, and several uninhabited islets scattered around the shoreline of the major islands. Its location is about 96 km south of Sicily (Italy) and 290 km north of Tunisia (between 35° 48’ and 36° 05’ N and 14° 11’ to 14° 35’ E).

The total surface area is about 316 km^2 and the perimeter of the shoreline of mainland Malta is 136 km while that of Gozo is 43 km.

The Maltese Islands currently have a population exceeding 500,000, up from 445,000 in 2015. Indications are that this trend would continue in the short and medium term, which would impose further pressures on the socio-economic and socio-cultural structures of the country, with significant added strains on the water resources.

With a population density exceeding 1500 inhabitants/km^2, Malta is among the most densely populated countries of the world. Consequently, more than 30% of the country’s surface area is built-up, which is highest in Europe (Belgium follows at a distant 13%).

The number of families is on the increase, and the average size of the family is getting smaller. Consequently, there has been a shift in the type of dwellings being built, with blocks of apartments (customarily with heights of approximately 4 - 5 storeys) replacing townhouses, some of which had gardens and cisterns. The construction of numerous apartment blocks has resulted in some previously classified small towns and villages now becoming homes to tens of thousands of inhabitants within decades – the conurbation of St. Paul’s Bay/Qawra/Buġibba being a very clear example of such urban sprawl and increased density. Although the rate of home ownership in Malta is still high, the number of dwellings being rented – primarily but not exclusively to foreigners – has increased substantially.

The Maltese economy is becoming increasingly service oriented triggering more construction (or refurbishment/enlargement) of hotels and offices. The continual increase in the number of vehicles led to a massive investment in road infrastructure in the last few decades.

The dramatic increase in urban development in the last decades has drastically altered the physical characteristics of the landscape, increasing the sealing of land and, thereby, reducing infiltration processes. The consequence has been a decrease in natural groundwater recharge. There is an obvious need to effectively manage the consequential increase in runoff generation to reduce flood risks while at the same time safeguard and where possible augment the freshwater sources.

Weather and Climate

Malta's weather and climate are strongly influenced by the sea and have very Mediterranean characteristics, akin to southern Italy or southern Greece. The summers are hot and dry, the autumns are warm and sporadically wet, and the winters are typically short and cool with regular rainfall. The annual mean temperature is 18ºC and the monthly averages range from 12ºC to 31ºC.

The annual mean precipitation during the period 1961 - 1990 was 553 mm (**Table 1**). Approximately three-fourths of the total annual rainfall falls between October and March. The months of June, July, and August are normally quite dry and the length of the dry season in summer is longer than in, for example, southern Italy.

Rainfall depth (mm)	J	F	M	A	M	J	J	A	S	O	N	D
Average monthly rainfall	88	62	38	24	9	3	1	7	50	81	83	104
Maximum monthly rainfall	256	188	112	118	54	28	18	105	267	230	319	303
Minimum monthly rainfall	9	5	0	1	0	0	0	0	0	0	3	15

Table 1: Average, maximum and minimum monthly rainfall depth 1961 - 1990 (MET Office, Luqa station)

Total rainy days, of any intensity, are between 50 and 120 days/year and on average 80 days/year. The maximum number of rainy days per month is around 20, although the average value is in the range of 0 - 15 (**Table 2**).

Rainy days (No)	J	F	M	A	M	J	J	A	S	O	N	D
Average monthly rainy days	13	11	8	6	3	1	0	1	4	9	11	15
Maximum monthly rainy days	22	20	17	13	11	6	3	5	13	18	20	22
Minimum monthly rainy days	4	3	1	1	0	0	0	0	0	0	1	6

Table 2: Average, maximum and minimum monthly rainy days during the period 1961 - 1990 (MET Office, Luqa station)

Effective rainfall events (depth ≥ 5 mm), producing significant runoff, contribute 85% to the annual average rainfall depth (around 470 mm). The number of effective rainy days is between 10 and 45 days/year and on average 30 days/year. The maximum number of effective rainy days per month is around 12 (**Table 3**).

Effective rainy days (No)	J	F	M	A	M	J	J	A	S	O	N	D
Average monthly effective rainy days	5	4	2	1	1	0	0	0	2	4	4	6
Maximum monthly effective rainy days	12	11	7	5	3	1	1	3	8	10	11	12
Minimum monthly effective rainy days	1	0	0	0	0	0	0	0	0	0	0	1

Table 3: Average, maximum and minimum monthly effective rainy days during the period 1961 - 1990 (MET Office, Luqa station)

The characteristics of the semi-arid Mediterranean climate that are of relevance to water management include:

- Variability in interannual rainfall;
- High-intensity, short-duration rainfall events;
- Seasonal scarcity of precipitation when the water requirements of the agriculture and tourism sectors are highest (namely from June to August);
- Frequent occurrence of low rainfall years resulting in a reduced input to groundwater recharge; and,
- Frequent occurrence of high rainfall years, resulting in an increased input to groundwater recharge.

Evapotranspiration

The potential evapotranspiration calculated by the Penman formula using 1947 - 1989 climatological data for the Maltese Islands is 1390 mm (albedo = 0.2) with an interannual variability of 3%.

Preliminary estimates of actual evapotranspiration rates have been calculated on the basis of daily rainfall values recorded at Luqa Meteorological Office (1948 – 1998) using the models developed by Bureau de Recherche Géologique et Minière (BRGM, 1991)[1]. These estimates indicated that actual annual evapotranspiration varied between 197 and 402 mm, or 36 - 89 % of the measured annual rainfall.

Geology and Aquifers

The Maltese Islands are mainly composed of three porous and fissured limestones (the Upper Coralline Limestone, the Globigerina Limestone and the Lower Coralline Limestone, sequence by age, with the Lower Coralline Limestone being the oldest formation) (**Figure 2**). The Upper Coralline Limestone is separated from the other two by a relatively thin layer of clayey and marly material (the Blue Clay formation).

[1] BRGM, 1991. Study of the freshwater resources of Malta, Bureau de Recherche Geologique et Miniere, France

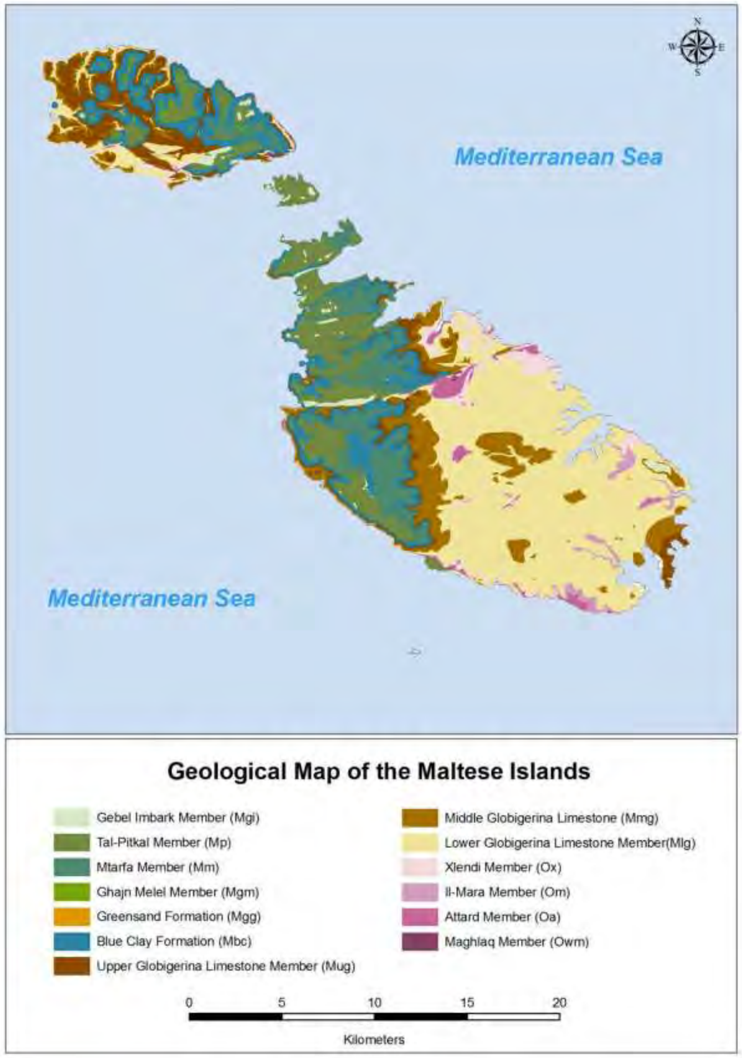


Figure 2: Geological Map of the Maltese Islands illustrating the prevalence of Upper Coralline Limestone and Globigerina Limestone. The Lower Coralline Limestone lies beneath the Globigerina Limestone.

The lithological different natures of these formations together with their geological position give rise to two broad aquifer types:

- The upper (perched) aquifers in the Upper Coralline Limestone and
- The lower (mean sea-level and coastal) aquifers in the lower limestone units (porous and fissured Globigerina and/or Lower Coralline Limestone).

There are sixteen hydro-geologically separate aquifer blocks on the Maltese Islands (**Figure 3**). The largest and most important aquifer is the Mean Sea-Level Aquifer of Malta (MT001) which has an area of 216.6 km^2, followed by the Mean Sea-Level Aquifer of Gozo (MT013, 65.8 km^2) and the Rabat-Dingli Perched Aquifer (MT002, 22.6 km^2).

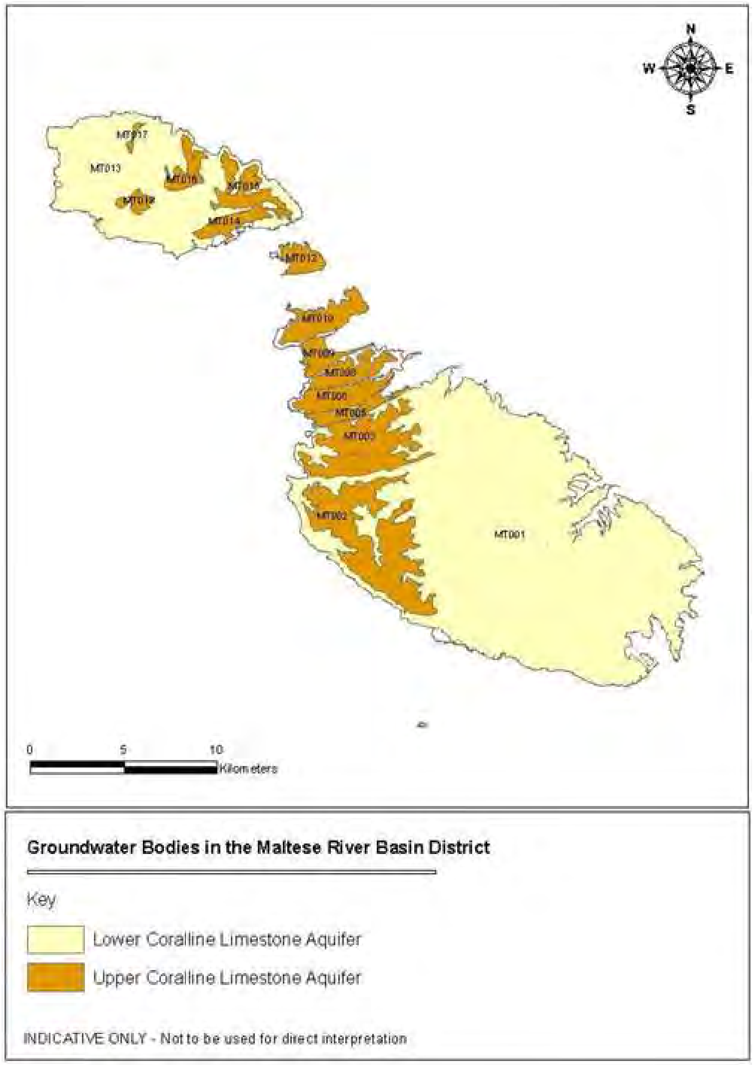


Figure 3: The aquifers in the Maltese Islands

The Mean Sea-Level Aquifers

The mean sea-level aquifers exist because part of the precipitation infiltrates into the soil and the underlying geology and moves downwards to reach sea level. At this point, the freshwater floats on the denser saline water to form a ‘lens’. These groundwater bodies are therefore in direct contact with seawater both in the horizontal and in the vertical direction, making them highly prone to the intrusion of saline waters through natural diffusion processes and also in response to extraction activities (**Figure 4**).

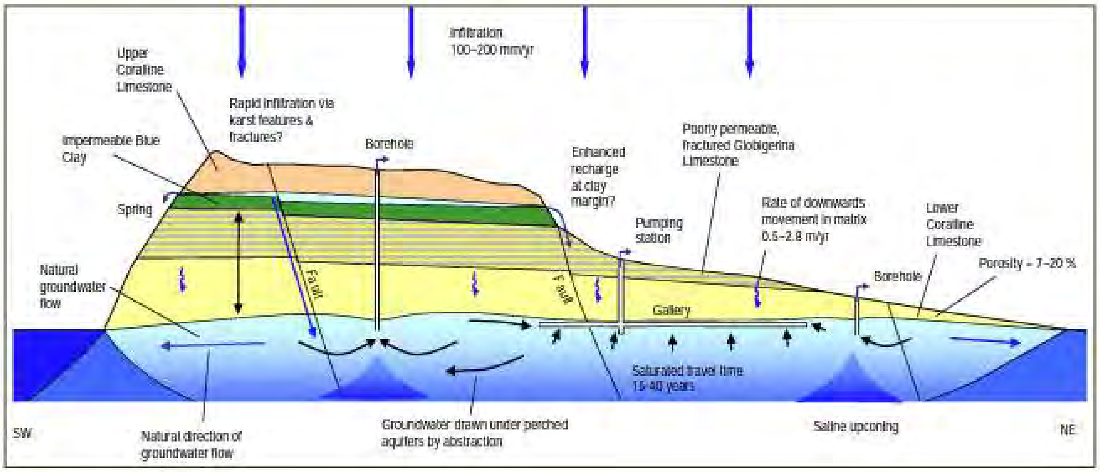


Figure 4: A conceptual model of the Mean Sea-Level Aquifer of Malta

It is important to note that transmission is slow in places where the geology is not fractured. Dating tests have indicated that residence times in the saturated zone are in the range of 15 - 40 years. The unsaturated travel time are long in the thicker parts of rock strata.

The height of the water table above sea level is controlled by abstraction and is presently up to only 3 m in places. This means that here the aquifer is protected by the overlying strata, rather than being confined in a hydraulic sense. Abstraction also leads to upconing of saline groundwater and an increase in salinity.

The 2nd Water Catchment Management Plan states that the mean sea-level aquifers are in a poor quantitative status (i.e., in deficit) because abstraction rates exceed recharge. They are also in a poor qualitative status due to seawater intrusion related parameters and contamination by Nitrate.

The Perched Aquifers

Like the mean sea-level aquifers, the perched aquifers arise because part of precipitation infiltrates the soil and the bedrock and percolates downwards. However, in this case, the vertical movement is intercepted by the impervious Blue Clay geological formation, and the aquifer exists in the Upper Coralline Limestone lying above the Blue Clay formation (**Figure 5**).

These aquifers are of limited saturated thickness and are present in the areas where the Upper Coralline Limestone outcrops. It is believed that the presence of fractures in the Upper Coralline Limestone formation results in a short residence time. These aquifers are not in contact with the sea, so seawater intrusion is not possible.

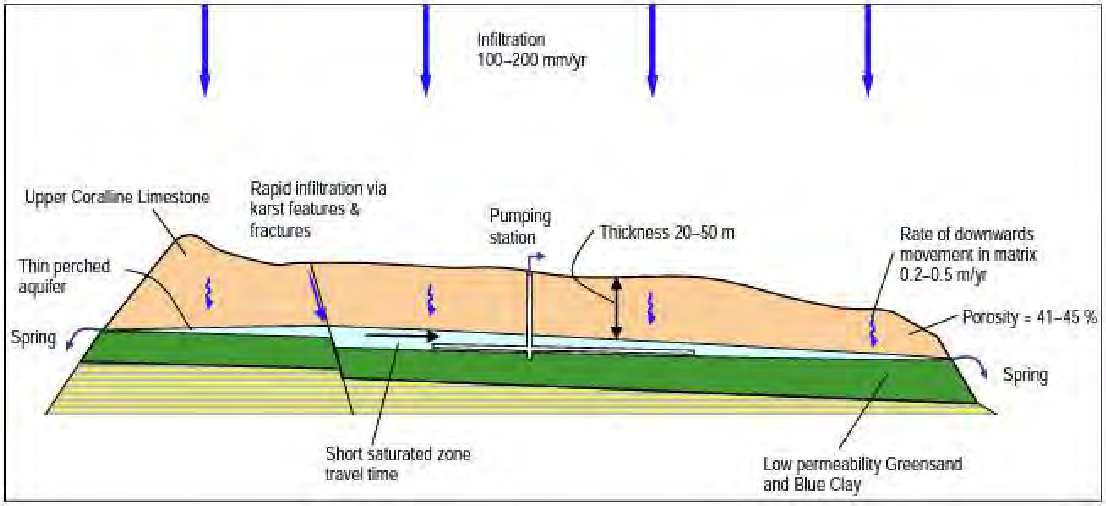


Figure 5: A conceptual model of a perched aquifer

The 2nd Water Catchment Management Plan states that while the perched aquifers are in a good quantitative status (i.e., in surplus), they have a poor qualitative status primarily due to Nitrate contamination.

Malta is tilted towards the North-East, with the high-lying areas (and cliffs) being on the west and south-west coasts. This, coupled with the fact that the most common rock formation – Globigerina Limestone – is soft, has resulted in faults being enlarged into narrow valleys. This has ensured that many valleys are essentially aligned along or subparallel to the SW - NE faults with most of the runoff flows being directed down this tilted terrain. Steep gradients contribute to short times of concentration for these catchments to discharge of the runoff. **Figure 6** shows the elevation profile of Malta. Malta's land morphology is strictly related to differentiated erosion of rock formation and to structural patterns.

Malta does not have any natural surface water bodies. The physical characteristics together with the uneven distribution of rainfall do not allow for the formation of natural perennial surface water bodies.

Malta however does have several dry valley systems (**Figure 7**).

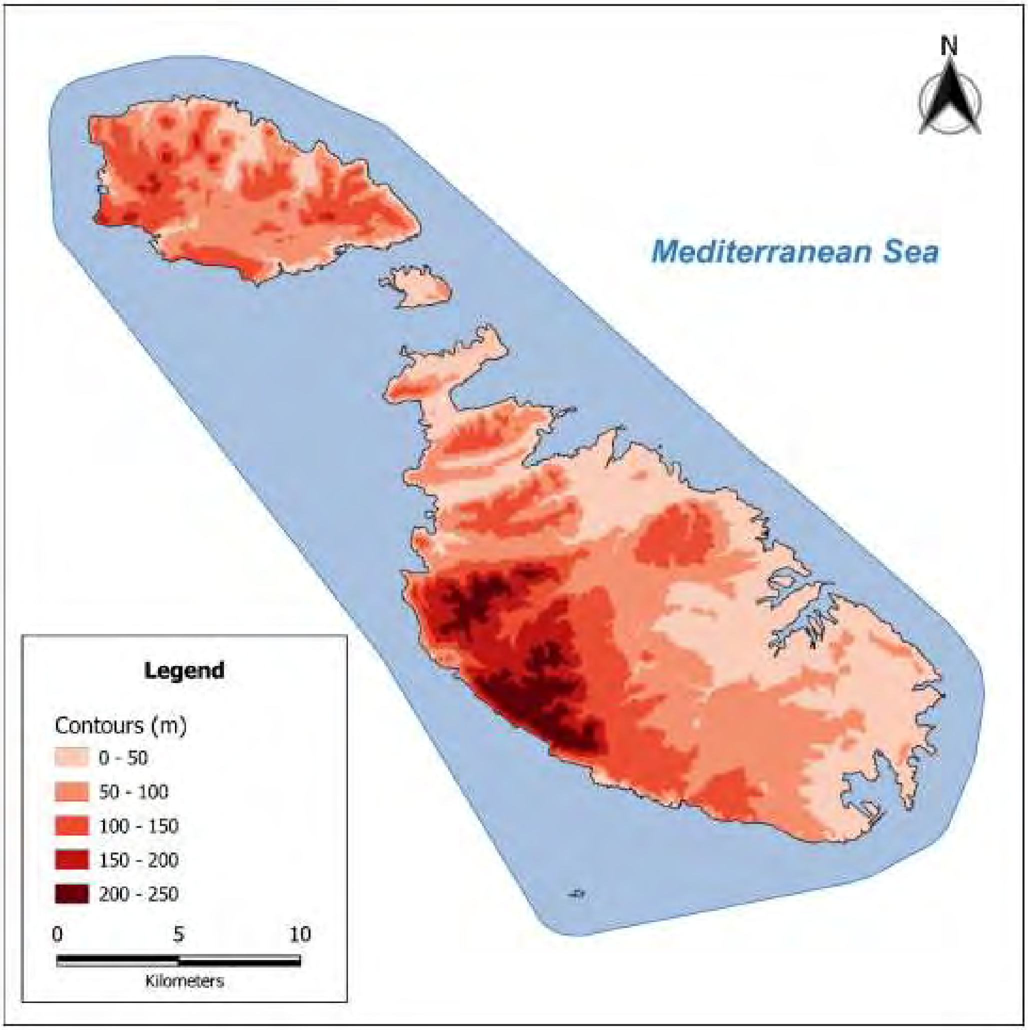


Figure 6: Elevation profile (topography) of Malta (EWA)

These dry valley systems act as conveyance channels for runoff that accumulates following a rainfall event. Runoff flows along valleys' watercourses and is quickly discharged into the sea. As a result of this rapid discharge into the sea, there is no surface storage and no runoff overtopping the valleys' banks onto the surrounding land. The opportunity for aquifer recharge without interception, capture and storage is low.

Over the years, some of these dry valley systems have been built up and the watercourses incorporated into the main roads. This results in runoff flowing through the main roads once the watercourses are reactivated following a rainfall event, resulting in significant damage to buildings and infrastructure, and disrupting mobility.

Figure 7: Map showing location and orientation of major valleys in mainland Malta (the marks in red denote the location of dams spanning across the valleys for water attenuation, retention, and recharge)

Development and Urbanisation

Although agricultural areas still make up the most part (51%) of mainland Malta, urban development, and the intensification of same within existing urban areas is increasing at a constant rate and now covers 30%. In some catchments, built-up areas make up more than 80%, making them very susceptible to flash floods. As shown in **Figure 8**, most of the urban areas in mainland Malta are concentrated on the eastern part correlating with the locations of the low-lying areas. Natural vegetation areas account for 18% while industrial areas occupy 6%.

Gozo is mostly covered by agricultural areas, almost 58%, whereas urban development accounts for 22% of land use and is primarily located in the centre. The rest of the Gozitan territory is occupied by natural vegetation for 19% and industrial areas (less than 1%).

The Maltese Islands have a population exceeding 500,000, resulting in a population density of over 1500 inhabitants/km^2, placing among the most densely populated countries of the world. Mainland Malta is more densely populated than Gozo. About 92% of the population of mainland Malta lives in the eastern and southern parts.

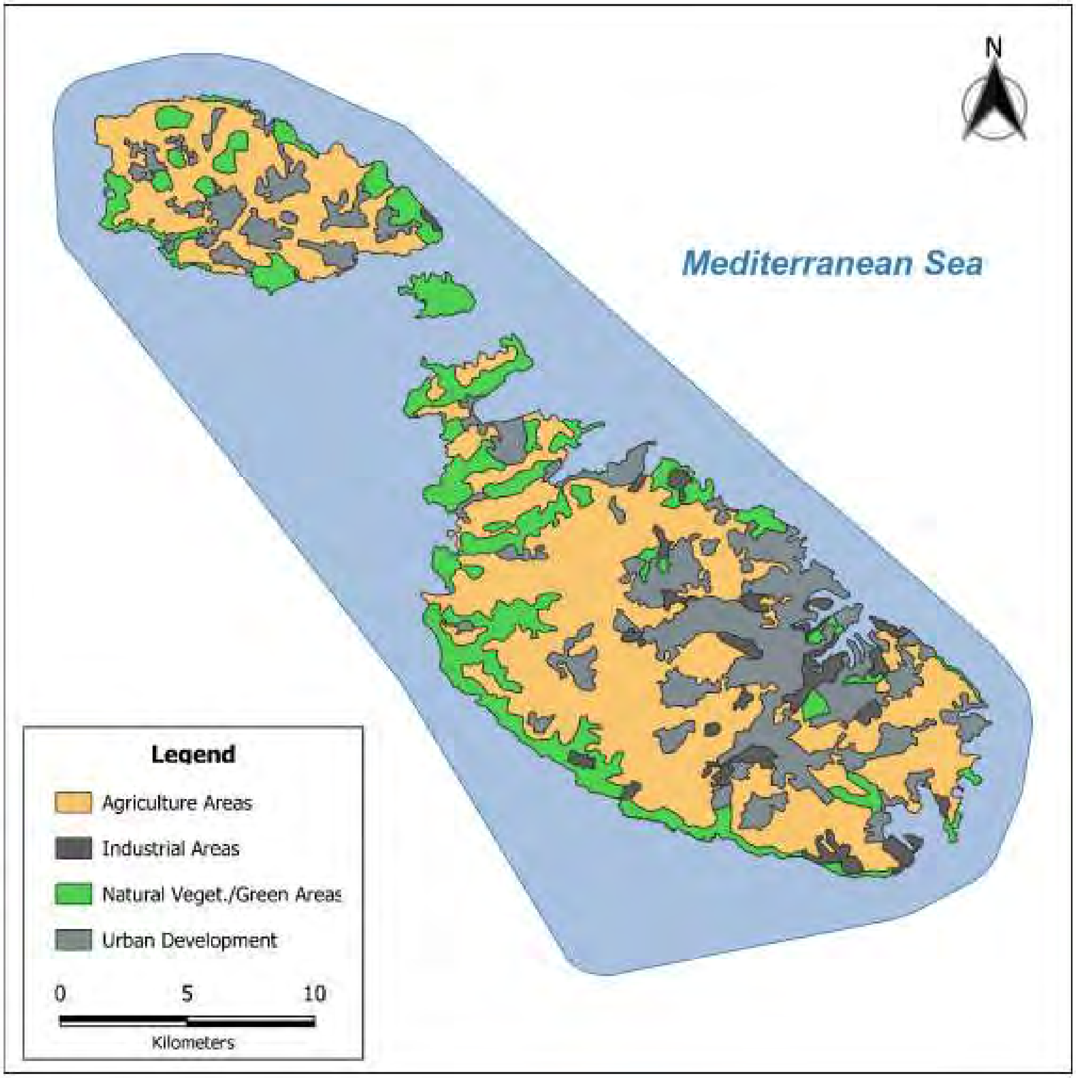


Figure 8: Map of land use in Malta (Corine Land Cover, 2018)

Apart from the precipitation, the runoff process varies according to the land use, soil type, antecedent moisture conditions, land slope, interception, capture, diversion, storage, infiltration, evaporation, and transpiration. The proportion of built-up areas within local catchments vary considerably from 5% to 90%. The runoff in rural areas is limited by the land morphology, good water absorption properties of the soil and infiltration into the ground, antecedent moisture conditions, evaporation, transpiration, diversions, interception by furrows, walls, dams, etc., capture, and storage. In developed areas, the runoff that is lost to the sea is reduced by the construction and maintenance of roadside soakaways, and the construction, maintenance and use of rainwater harvesting structures.

Estimates of the annual volume of runoff are discussed in **Chapter 5.01**.

4.00

History of GSI in Malta

The practice of rainwater harvesting in land management and ancillary to buildings has long been practised in Malta to establish onsite freshwater sources. Before the development of freshwater conveyance systems, communities strove to be completely self-sufficient in water use, and in areas where there were no springs, this meant emphatic priority for the collection of rainwater wherever and however possible. Consequently, many rainwater harvesting storage systems were built all over the country.

In Neolithic times it is known that many settlements had excavated underground water tanks to establish a water source. The most renown series of the earliest works are the series of tanks at Qrendi near the Mnajdra temples known as the Misqa tanks (**Figures 9** and **10**).

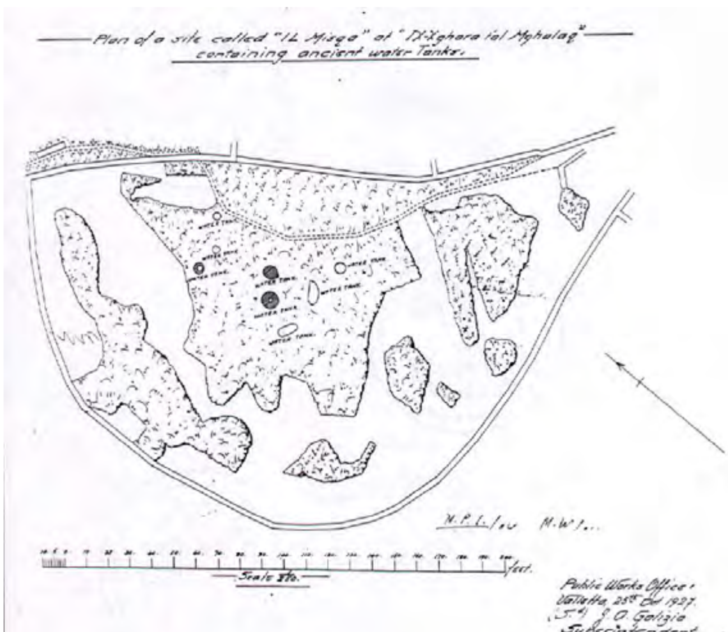


Figure 9:

Layout of the Misqa tanks

Figure 10:

Two views of Misqa tanks

During the building of Valletta in the 1500s, the "Officium Commissariorum Domorum" (Housing Office) codified the requirement for the rainfall of each building to be stored on site[2]; the site itself was often open quarried for the basic stone material used for the building erected onsite and the hollowed-out void became the cistern. Other wells were bell shaped and dug out of the rock. The reservoir at Saint John's Co-Cathedral (**Figure 11**) illustrates this former type, where the building was actually built up from an excavation to achieve the ground levels which were altered from the pre-existing topography. A typical excavated cistern in cross section is shown in **Figure 12.**

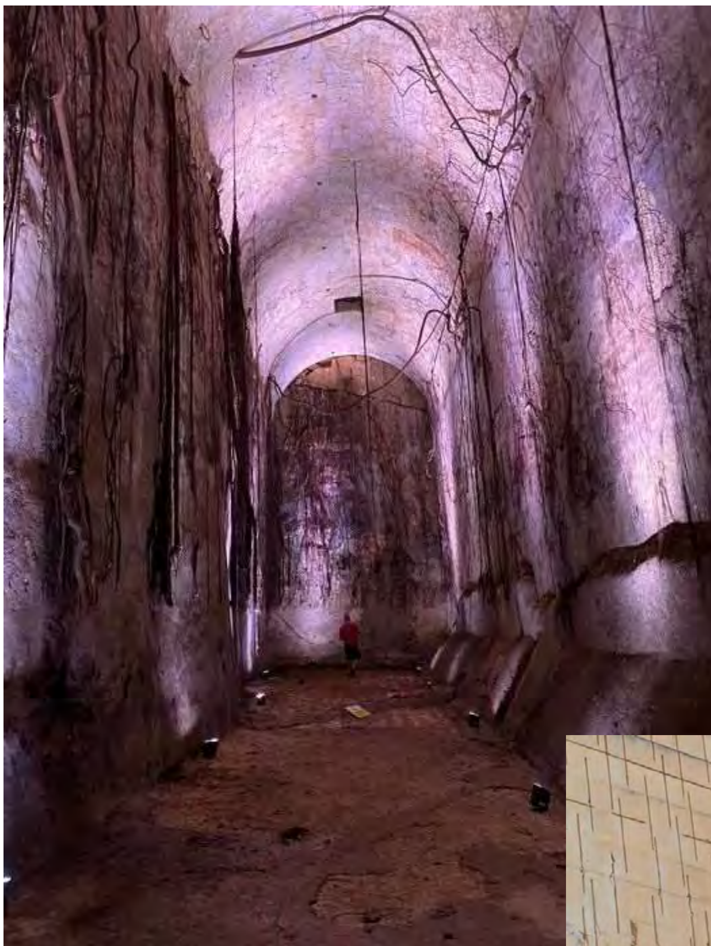


Figure 11:

Internal view of reservoir at Saint John's Co-Cathedral in Valletta (*Il-Ġibjun* Facebook)

Figure 12:

Cross section of rock excavated cistern (domestic) on side of a stone quarry

[2] Chapter 5 translation "Everyone is obliged to have one cistern in his house and a place for his needs."

The almost complete national dependence on harvested rainwater changed when a series of springs in Fiddien and Buskett were collectively channelled through the Wignacourt Aqueduct to Valletta in 1615 (**Figures 13** and **15**). This aqueduct also serviced communities on its route such as Santa Venera and Ħamrun. Another aqueduct was brought into service in 1845 to convey water from springs in Fawwara to Cottonera (**Figure 14**).

Figure 13: Wignacourt Aqueduct

Figure 14: Fawwara Aqueduct

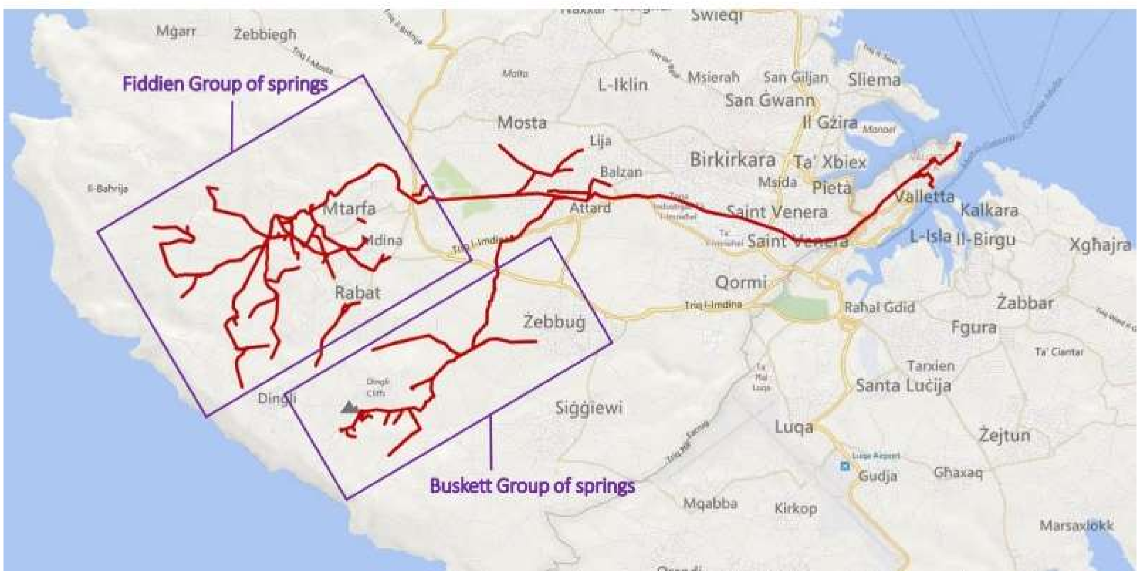


Figure 15: Wignacourt Aqueduct and linked springs (Brian Restall)

In the 19th century, attention was directed towards the harvesting of stormwater flowing in major valleys. Sir Osbert Chadwick who worked in Malta from 1883 to 1897 instigated the construction of a series of impounding dams in Wied il-Qlejgħa. The objectives were to intercept, capture, store and infiltrate runoff to the unsaturated zone of the underlying aquifers and provide water supply for irrigation (and also for human consumption, but the latter was not executed). These dammed areas serve as public amenities and are habitats for flora and fauna (**Figure 16**). Dams as GSI are reviewed in **Chapter 8.10**.

Figure 16: Two views of impounded runoff water in Wied il-Qlejgħa

With the passage of time and the introduction of national systematic extraction of groundwater through pumping stations and boreholes (in the 1960s and 1970s), the dependence on cisterns for water supply decreased. Existing cisterns and reservoirs were bypassed and abandoned and thus their buffer effect on flooding was lost. Their intensity of construction decreased especially in the successive building booms. Consequently, the mitigating effect of rainwater harvesting in reducing rainfall running to waste has decreased drastically. With the introduction of additional water supply systems after 1982 with the application of reverse osmosis desalination technology on a large scale, the rate of abandonment of rainwater harvesting systems became exponential. However, there is historic evidence that flood prone areas such as Birkirkara and Msida have long been subject to such conditions (**Figures 17** and **18**).

Figure 17:

Flooding in Birkirkara, 1915

(Louis Cardona)

Figure 18:

Flooding in Msida, 1951

(Tony Terribile)

A number of interventions to reduce water runoff going to waste were initiated in the late 1970s, as part of the Government project "Risq il-Widien". Valleys and watercourses were cleared, and fords and many low dams were built. Several soakaways, which collected water from arterial roads and the airport and allowed it to percolate into the unsaturated zone, were introduced. Examples still in use of these are at Gudja, Żebbuġ, Msida and Ħas-Saptan (**Figures 19, 20, 21** and **22**). Some of these failed to drain properly (due to improper siting, lack of maintenance, lack of ownership) and became semi-permanent small water bodies, attracting flora and fauna (see **Chapter 8.11**). Others function normally and are also temporary sources of water (e.g., Żebbuġ).

Figure 19:

Soakaway at Żebbuġ

Figure 20:

Soakaway at Msida

Figure 21:

Soakaway at Ħas-Saptan

Figure 22:

Soakaway at Gudja

5.01

Quantity of Stormwater Runoff in Malta

GSI is a means of converting a problem (runoff and the consequential damage and disruption) into an opportunity and a resource (useable freshwater, which is a scarce commodity in a dry country such as Malta where the groundwater reserves are under stress and in deficit).

The sustainable management of rainwater alleviates pressure from groundwater systems by:

- Providing an easily accessible source of freshwater for second-class purposes (e.g., for flushing of toilets) and
- Increasing groundwater recharge with water that is very low in Nitrate and Chloride, the major contaminants of concern in Malta's groundwater systems.

However, the latter statement only holds if it can be ascertained that:

a) The ***quantity*** of stormwater in Malta is such that the better management of runoff can make a significant difference in Malta's water balance and

b) The ***quality*** of stormwater is sufficiently good to:

- Be a suitable substitute to groundwater (or mains water, which is partially derived from groundwater) for direct use and/or
- Be used for groundwater recharge (replenishment).

Chapter 3.00 describes Malta's precipitation patterns (553 mm yearly average), the bulk of which falls within a relatively short period between October to March.

Notwithstanding the fact that the catchment area is only 316 km^2, and the annual precipitation is low when compared to other countries in Europe, the volume of yearly rainfall still amounts to almost 175 million m^3, which represents more than five times the total volume of water produced by the Water Services Corporation (WSC) from its desalination and groundwater sources[3].

The 74.6 mm of rain that fell during a morning storm event on the 25 November 2021 provided an estimated 23.6 million m^3 of freshwater – which is a considerable amount. Although it is unrealistic to design systems that can manage all this rainwater within few hours for good use, the percolated rainwater can make a positive difference to the groundwater systems of Malta.

The volume of runoff generated in different catchment areas varies according to the land use, soil type, antecedent moisture conditions, land slope, interception, diversion, storage, infiltration, evaporation, and transpiration (apart from the precipitation). The proportion of built-up areas within catchments may vary from 0% to 100% and it is not uncommon to have built-up areas making up more than 80% of a catchment in Malta.

In developed areas, the runoff that is lost to the sea is reduced by the construction and maintenance of roadside soakaways, and the construction, maintenance and use of rainwater harvesting structures.

[3] WSC 2020 production: desalination: 20.2 million m^3, groundwater 14.5 million m^3. WSC Annual Report 2020

The amount of runoff is limited by the land morphology, good water absorption properties of the soil and infiltration into the ground, and runoff interception by furrows, walls, dams, etc. in rural areas.

National Runoff Volumes: Previous Estimates

The FAO Malta Water Resources Review 2006 estimates that ***14%*** of the annual average precipitation ends up as surface runoff to the sea. This represents 24 million m^3 per year and includes the runoff that is generated both in urban and rural areas.

Similarly, the Preliminary Flood Risk Assessment Final Report, Malta Resources Authority (MRA), May 2013 estimates that, based on an average annual rainfall of 550 mm, 24 million m^3 of water ends up as surface runoff to the sea. This represents ***14%*** of precipitation.

The 2nd Water Management Catchment Plan states that for the mean sea-level aquifer systems, losses due to runoff amount to ***10%*** of precipitation, while for perched aquifer systems, which predominantly lie in rural areas where the runoff retention capacity of the karstic (garigue) surface is high, losses amount to 2%.

Calculation of National Runoff Coefficients Using Land Use Data

Given these discrepancies in estimates for annual runoff, it is considered necessary to calculate runoff from recent land use data.

Figure 23 shows the computation for the runoff generated during a year with average precipitation (553 mm) using:

- Recent land use data (Corine Land Cover, 2018) and
- Runoff Coefficients derived from different international sources and adapted for Malta’s particular situation of few but intense storms (which results in higher-than-average runoff coefficients).

Description of Land Use	Area	Assumed component		Runoff Coefficient					Runoff Generated			
	ha	Urban	Non-urban	Hard-surfaced	CFLIRE (1)	Soft-surfaced	CFLIRE (2)		m³/year	m³/year	%flow	%area
Continuous urban fabric	413	95%	5%	0.9	0.85	0.2	0.55	**0.73**	1,671,933			
Discontinuous urban fabric	6,720	75%	25%	0.9	0.85	0.2	0.55	**0.60**	22,343,611			
Industrial or Commercial Units	749	85%	15%	0.9	0.85	0.2	0.55	**0.67**	2,759,999			
Port areas	265	95%	5%	0.9	0.85	0.2	0.55	**0.73**	1,071,699			
Airports	404	50%	50%	0.9	0.85	0.2	0.55	**0.44**	978,105	**29,893,099**	75%	30%
Mineral Extraction sites	332							**0.05**	91,933			
Dump Sites	64							**0.10**	35,458			
Construction Sites	27	50%	50%	0.9	0.85	0.2	0.55	**0.44**	64,839			
Green Urban Areas	177	50%	50%	0.9	0.85	0.2	0.55	**0.44**	427,649			
Sport & leisure facilities	217	20%	80%	0.9	0.85	0.5	0.55	**0.37**	447,872			
Non-irrigated arable land	673	0%	100%	0.9	0.85	0.1	0.55	**0.06**	204,678			
Vineyards	53	5%	95%	0.9	0.85	0.1	0.55	**0.09**	26,565			
Complex cultivation patterns	1,257	5%	95%	0.9	0.85	0.1	0.55	**0.09**	629,130			
Agriculture and natural vegetation	14,419	5%	95%	0.9	0.85	0.1	0.55	**0.09**	7,216,180			
Coniferous forest	67					0.2	0.55	**0.11**	40,586	**9,899,070**	25%	70%
Mixed forest	139					0.2	0.55	**0.11**	84,572			
Sclerophyllous Vegetation	4,796					0.1	0.55	**0.06**	1,458,603			
Sparsely vegetated areas	772					0.1	0.55	**0.06**	234,938			
Salines	25					0.05	0.55	**0.03**	3,820			
	31,569							Runoff	39,792,170	m3/year		

Legend:

CLFIRE (1) - Correction For Low Intensity Rain Events for hard-surfaced areas

CLFIRE (2) - Correction For Low Intensity Rain Events for soft-surfaced areas

Incident precipitation	174,575,409	m3/year
Runoff generated	39,792,170	m3/year
National Runoff Coefficient	**0.23**	

Deduced National Averaged Runoff Coefficient	Urban	Rural
	0.58	0.08

Figure 23: Runoff coefficient computation

From this data, it is calculated that:

- 30% of Malta's surface area is built up, while the remaining 70% is either agricultural land or natural habitats;
- The averaged runoff coefficient for urban areas is 0.58 while that for rural areas is 0.08
- The runoff generated in urban areas is 29.9 million m^3 a year (75.1% of the total runoff);
- The runoff generated in rural areas is 9.9 million m^3 a year (24.9% of the total runoff);
- The total runoff generated is 39.8 million m^3 a year, for an annual precipitation volume of 174.6 million m^3 a year (translating in a national averaged runoff coefficient of 0.23, i.e., ***23%*** of precipitation ends up as runoff).

This calculation for national runoff generation represents the volume of runoff that is generated ***at source*** e.g., on roofs, on roads, in fields etc. It is ***NOT*** the volume of runoff that is lost to the sea, because some of the runoff is subsequently intercepted and contributes towards groundwater recharge.

This explains why the 23% figure is significantly higher than the 10 - 14% estimated runoff losses to the sea in previous studies.

Intercepting and Harvesting of Runoff

Not all runoff is lost to the sea, because there exist:

- Several cisterns beneath buildings collecting rainwater falling on roofs;
- A significant number of roadside reservoirs and soakaways collecting stormwater from arterial and country roads;
- A good number of dams spanning across valleys;
- Several rainwater harvesting systems in industrial and commercial establishments, and public buildings (including soakaway in Mater Dei Hospital); and
- Many kilometres length of walls bordering fields intercepting and retaining the soil (and the runoff).

This infrastructure intercepts, captures and stores runoff for direct use or for percolation. There is no information on the condition, efficacy and efficiency of this stormwater infrastructure, or on watercourses flows. So, it is not possible to accurately establish the proportion of runoff that is currently being intercepted and not ending in the sea. Hence, the discrepancy and uncertainties in the estimations.

Harvesting of Runoff from Urban Areas

Runoff generated in urban areas is conventionally harvested in:

- Underground rainwater cisterns built within buildings which collect the rainwater falling on the roofs and other impervious areas and
- Soakaways and reservoirs collecting stormwater runoff from roads.

The Census of Population and Housing 2011[4] found out that 36% of occupied dwellings had a cistern. The Census did not investigate whether the cisterns in occupied dwellings were in

[4] Census of Population and Housing, 2011 Final Report - NSO 2014

use, and the extent of use. The Census also established that only 4% of the occupied apartments/flats/penthouses had a cistern, while representing 29% of the residential housing by type. Since 2011, a number of previously occupied townhouses (having a 62% probability of having a cistern) have made way to apartment blocks lacking a cistern which implies that rainwater harvesting infrastructural capacity in residential dwellings has decreased further. This would be confirmed when the results of the Census of Population and Housing 2021 are published. **Appendix 10.05** provides a more detailed analysis of the data from the Census of Population and Housing 2011.

A study, carried out in 2014 by Sustech Consulting on behalf of the Valletta 2018 Foundation, established that only 15.2% of residences in Valletta had a cistern. Moreover, only 34% of residences having a cistern (5.2% of total residences) used the collected rainwater. This denotes that approximately 95% of the rain falling on residential rooftops in Valletta ends up in the sanitary sewers or runoff.

Rainwater Harvesting in Reservoirs and Soakaways

The physical condition, the infiltration performance (for soakaways) and the use (for reservoirs) of soakaways and reservoirs are not known.

The capacity of open roadside reservoirs and soakaways was estimated at 250,000 m^3 [5] in 2006. **Table 4** shows a 2005 list of public reservoirs and soakaways, with a total estimated capacity of 130,000 m^3, with information on the size, capacity, location and whether it is open (unroofed) or closed (roofed).

Soakaways percolate water into the ground and have the ability to capture and make available for percolation more water than their actual storage capacity providing more storage volume.

Harvesting of Runoff in Rural Areas

Runoff generated in rural areas is traditionally harvested in:

- Small above-ground rainwater reservoirs in fields filled by runoff collected from roads lying at a higher elevation;
- Small underground cisterns filled by runoff collected from water-saturated fields and rural buildings; and
- Roadside reservoirs and soakaways filled by runoff collected from roads.

Stormwater Harnessing for Irrigation

Before borehole drilling technology was widely introduced locally in the 1970s, unless served by spring water, most of Malta's horticultural produce was rainfed in autumn and winter, and barely irrigated in the late spring and summer months. The extension of extensive cultivation of agricultural produce onto spring and summer was then only possible through the collection of runoff.

The Census of Agriculture 2001 found 9,069 agricultural reservoirs in existence. The capacities of these reservoirs were not recorded. **Figure 24** shows the period of construction of these reservoirs. More than 50% of these reservoirs were built before 1977, with less than 9% of the reservoirs in use in 2001 being constructed in the 10 years prior. The loss of interest

[5] FAO Malta Water Resources Review 2006

in the capture of runoff coincided with the advance of borehole drilling for private abstraction of groundwater.

RESERVOIR	WIDTH	DEPTH	LENGTH	M^3	LIMITS_OF	USE	ROOF
WIED HAS-SAPTAN	0	0	0	20457	GUDJA	OPEN	NO ROOF
SAN GAKBU - STA. LUCIA	0	0	0	13638		CLOSED	
TA QALI (TRAINING GROUND)	45.5	2.8	69.8	12274	MOSTA	OPEN IRRIGATION OF FOOTBALL GROUNDS	NO ROOF
TAS-SALIB	17	9	42	6426	RABAT	CLOSED	
MOSTA HOUSING ESTATE	20.5	4.5	63	5812	MOSTA	CLOSED IRRIGATION	CONCRETE
ZEJTUN (HOUSING EST.)	19.3	4.4	66	5605	ZEJTUN	CLOSED IRRIGATION	CONCRETE
BARRANI (SOAK PIT)	20	5	54	5400	TARXIEN	OPEN DISCHARGED TO AQUIFER	NO ROOF
STA. LUCIA	22	3	71	4686	STA. LUCIA	SUPPLY OF S. GAKBU T. PLANT	NO ROOF
MARSA ROUNDABOUT	32.8	3.5	38.1	4374	CEMETRY - MARSA	OPEN NO USE	NO ROOF
MSIDA VALLEY ROAD	27.4	2	73.6	4033	MSIDA	OPEN IRRIGATION	NO ROOF
BARRANI 2	22	3	51	3366	TARXIEN	OPEN IRRIGATION	NO ROOF
CHURCHILL CLUB - MSIDA	18	3	61	3294	MSIDA	OPEN IRRIGATION	NO ROOF
ROAD RES 3	20.9	3.5	43.6	3189	MARSA / LUQA	OPEN NO USE	NO ROOF
PROVVIDENZA	16	1.7	51.5	2273	SIGGIEWI	OPEN IRRIGATION	NO ROOF
HLAS "A"	19	4	28.8	2189	ZEBBUG	OPEN IRRIGATION	NO ROOF
TAL- BARRANI	35.5	1.2	51.2	2181	TARXIEN	OPEN IRRIGATION	NO ROOF
HAL SAFLIENI (TAX-XEWK)	4.7	6	10.8	1909	TARXIEN	CLOSED IRRIGATION	CONCRETE
TARXIEN BY PASS (CEMETRY)	64.5	2.3	12	1780	PAOLA	OPEN SUPPLY OF S. GAKBU T. PLANT	NO ROOF
ROAD RES 1 GARIBALDI RD.	15.3	2.2	52.6	1771	MARSA / LUQA	OPEN IRRIGATION	NO ROOF
QORMIJA	25.8	2	32	1654	GHAJN TUFFIEHA	OPEN IRRIGATION	NO ROOF
A.20 MARSA IND. EST. (SHOE FACTORY)	0	0	0	1637	MARSA	CLOSED	
MARSA IND. EST. PLASTIC FACTORY LTD.	11.6	3.5	39.8	1616	MARSA	OPEN NO USE	NO ROOF
TA QALI 2	13.5	4	29.5	1593	MOSTA	CLOSED IRRIGATION OF FOOTBALL GROUNDS	CONCRETE
BAHRIJA (LARGE)	12	2.1	62	1500	BAHRIJA	OPEN IRRIGATION	NO ROOF
ROAD RES 2	17.1	1.5	56.2	1442	MARSA / LUQA	OPEN IRRIGATION	NO ROOF
MQABBA BY-PASS	17.1	1.8	45.1	1388	MQABBA BY-PASS	OPEN IRRIGATION	NO ROOF
TA QALI 1	11.8	4	29.3	1382	MOSTA	CLOSED IRRIGATION OF FOOTBALL GROUNDS	CONCRETE
WIED INCITA (RABAT RD.)	18.4	1.5	48.8	1347	ZEBBUG	OPEN IRRIGATION	NO ROOF
M.M.U. SCHEMBRI STREET	0	0	0	1137	HAMRUN	CLOSED	
VERDALA (GOVT. HOUS. EST.)	0	0	0	1137	COSPICUA	CLOSED	
TA QALI 3	10.6	4	26.3	1115	MOSTA	CLOSED IRRIGATION OF FOOTBALL GROUNDS	CONCRETE
SILG	20.7	2	26.5	1097	M'XLOKK	OPEN IRRIGATION	NO ROOF
ZEBBIEGH	15.2	1.3	51.5	1018	ZEBBIEGH	OPEN IRRIGATION	NO ROOF
PARIS HOUSING ESTATE	10.1	4.5	26.6	903	TA PARIS	CLOSED IRRIGATION	CONCRETE
ST. THOMAS BAY	8.5	4	25	845	ZEJTUN	CLOSED	CONCRETE
MRIEHEL (TAL HLAS P.S ROAD)	15.3	1.5	30	818	MRIEHEL	OPEN NO USE	NO ROOF
HAL FARRUG	10	1.3	61	793	MQABBA	OPEN IRRIGATION	NO ROOF
RESERV. "C" 13TH DEC. RD.	8	2	48	768	MARSA	CLOSED IRRIGATION	CONCRETE
RESERV. "A" 13TH DEC. RD.	8	2	40	640	MARSA	CLOSED IRRIGATION	CONCRETE
RESERV. "B" 13TH DEC. RD.	8	2	40	640	MARSA	CLOSED IRRIGATION	CONCRETE
HANDAQ	13.7	2	19.8	553	SIGGIEWI	OPEN IRRIGATION	NO ROOF
SAN NIKLAW "A"	12.3	1	23.1	409	ZEJTUN	OPEN	NO ROOF
GADDAFI GARDENS	0	0	0	227	PAOLA	CLOSED	
BAHRIJA (SMALL) (NEW RD.)	10.4	2.7	14	221	BAHRIJA	OPEN IRRIGATION	NO ROOF
MARFA RIDGE (L-AHRAX)	3.5	3.5	15.7	192	MELLIEHA	CLOSED IRRIGATION	CONCRETE
BELT IL- HAZNA	0	5.1	0	0	FLORIANA	OPEN	NO ROOF
BIR MIFTUH 1	0	0	0	0	GUDJA	OPEN	NO ROOF
BIR MIFTUH 2	0	0	0	0	GUDJA	OPEN	NO ROOF
GHALLIS	3.7	2.7	17.9	0	SALINA	CLOSED IRRIGATION	CONCRETE
HEMSIJA	0	0	0	0	RABAT	OPEN	NO ROOF
KORDIN	0	0	0	0	PAOLA	CLOSED	
NEAR LEATHER FACTORY	20.6	3	22.2	0	MARSA	OPEN FLOOD RELIEF	NO ROOF
SAN NIKLAW 2 (ZEJTUN QUARRY)	0	4	0	0	ZEJTUN	OPEN IRRIGATION	NO ROOF
ST. HELEN'S GATE 2	0	0	0	0	COSPICUA	CLOSED	
STABAR - (CENTRAL SUPPLY)	0	0	0	0	QORMI	CLOSED NO USE	CONCRETE
				130,729			

Table 4: 2005 list of public reservoirs and soakaways (WSC)

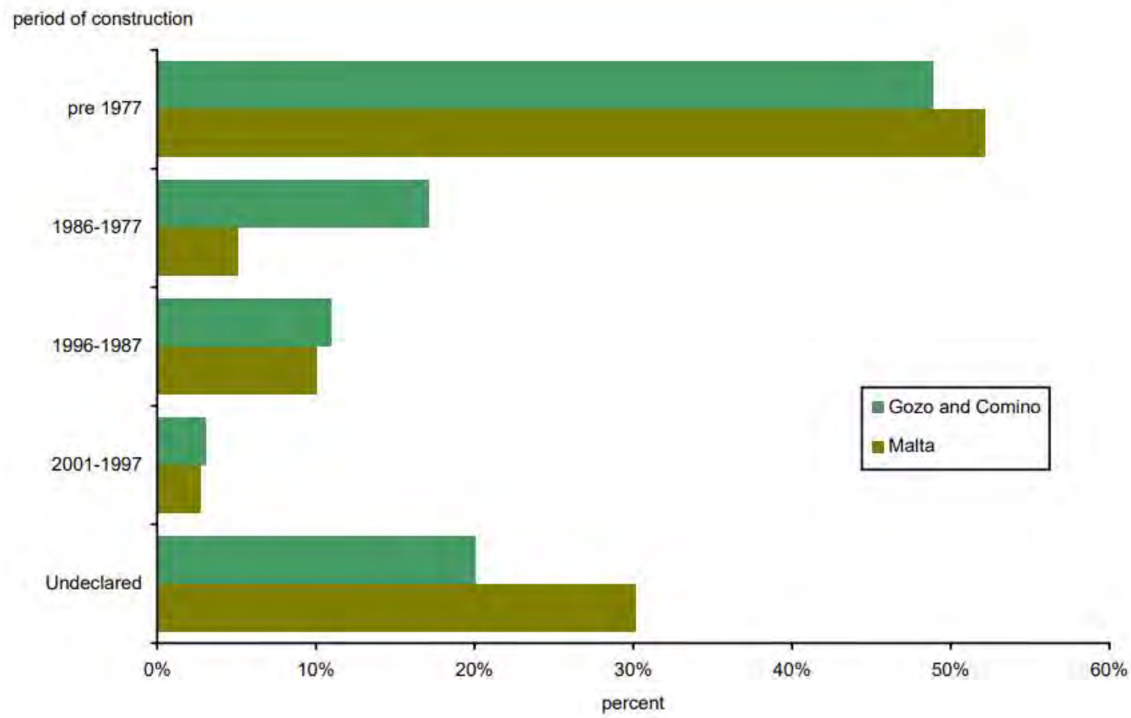


Figure 24:

Percentage distribution of agricultural wells/reservoirs by period of construction and island (Census of Agriculture 2001)

Figure 25 depicts the percentage distribution of water sources for irrigation[6] in 2010. Slightly more than half of the farms with access to water sources had on-farm collection of surface water, 31% had on-farm groundwater extraction, and 2% had supply of reclaimed water.

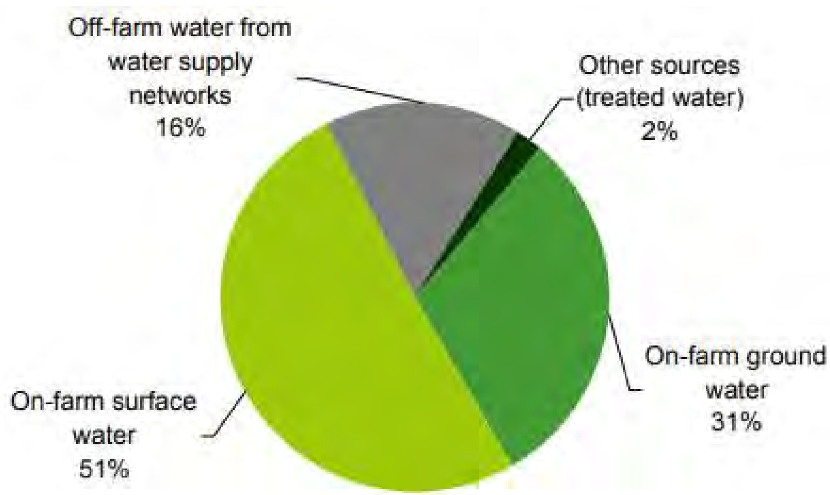


Figure 25:

Percentage distribution of source of water by type for irrigation: (Census of Agriculture 2010)

[6] Census of Agriculture 2010

Harvesting of Runoff in Dams

Dams, mostly built in the 19th century and the start of the 20th century, serve to slow down the flow of, capture and store runoff along valleys, supporting percolation and providing water for irrigation.

The total storage capacity of dams constructed across valleys is estimated at 154,000 m^3. [7]

A study carried out in 2004 by the then Ministry for Rural Affairs and the Environment (MRAE) states that in 1993 there were a total of 18 dam systems with a total capacity of 37,000 m^3 that were no longer in use and notes that “this number is likely to have increased since then (i.e., between 1993 and 2004)”.

Like soakaways, dams have the ability to store more water than their actual storage capacity because they are designed to percolate part of the stored water into the ground, providing more storage volume.

Major rehabilitation works were undertaken in 1997 and 2021 on the Wied il-Qlejgħa dams, while rehabilitation and upgrading works have been carried out in 2004 - 2006 on major dams including those of in Wied il-Għasel and Wied il-Kbir valleys. The dams at Wied il-Mielaħ were rehabilitated in 2007.

In 2022, Wied il-Għasel valley was rehabilitated through the *RainWiin* project, which works included the cleaning of debris and silt deposits which have accumulated over the years and the construction of new dams to increase the storage capacity by 45,000 m^3.

[7] FAO Malta Water Resources Review 2006

5.02

Quality of Stormwater Runoff in Malta

The quality of stormwater is an important determinant in the management of stormwater.

The quality of stormwater not only dictates the types of GSI that can be used but also defines the possible end use of the water. Water quality determines whether the stormwater can be used directly (e.g., irrigation) and whether it can be used as recharge without treatment, or recharge with treatment, and if treatment is required, the level of treatment required.

The bigger the disparity between the quality of the stormwater and the quality of the water that is needed for the intended use (e.g., irrigation, groundwater recharge), the more complex and expensive is the treatment technology. Indeed, if the disparity is large, it may not be financially or economically feasible to install any GSI at all.

The quality of stormwater differs from one source to another. The quality of stormwater collected from roads (which may also have a contribution from roofs and from surcharge of sanitary sewers) differs from stormwater collected from rural areas (with possibly nutrient/pesticide content), and latter differs from (usually cleaner) stormwater collected from roofs.

The quality of stormwater also varies with the intensity of the storm event, and whether the storm event follows or precedes another/other storm/s, since the earlier storm would have washed away any atmospheric depositions that would have settled on the surfaces. Severe storms may also result in surcharging of sanitary sewers, whose sewage turns the stormwater septic.

The quality of the stormwater depends on the nature of the catchment areas, which can be broadly categorised as urban, rural, or a mixture of both.

The runoff generated in **developed areas** may be mainly subdivided as originating from:

- Roofs of dwellings (either without or with pets with access to the roof);
- Roofs of buildings where there is no industrial activity or storage of materials on the roofs;
- Roads and car parks where there are possibilities of contamination by hydrocarbons and combustion products; and,
- Roofs or surfaces subject to industrial activity which may result in the contamination of runoff by chemicals, heavy metals, hydrocarbons, etc.

The quality of runoff generated in **rural areas** is characterised by the intensity of the agricultural activities in the respective catchment. High intensity cultivation results in surplus nutrients, fertilizers and pesticide residues in the soil being carried away by the runoff, which generally flows along watercourses in valleys, which flow may be intercepted by dams. Interception, capture and storage by dams allows for the direct use of the water (primarily for irrigation,) and for groundwater recharge.

Data on stormwater quality is limited to a few studies pertaining to individual catchments. This data gap is a significant water management issue and is being addressed through **Measure KNO 3** of the 2nd Malta Water Catchment Management Plan.

Appendix 10.03 is a comprehensive and thorough description of information on the quality of stormwater.

Summary of Results of Research and Tests

Urban Runoff

From the research carried out during the course of developing this Guidance Manual, and from the supplementary runoff sampling and tests carried out in October 2021 and January 2022, it transpires that contrary to perception, urban stormwater, despite the high traffic loading, and occasional surcharging of sanitary sewers during extreme storm events, is not exceptionally contaminated and manifests generally low concentrations of heavy metals (including Lead), Fluoride and PAHs (Polycyclic Aromatic Hydrocarbons).

The results of the tests carried out in 2021 and 2022 on stormwater in soakaways compare well with the tests carried out in 2006.

Samples of runoff collected from roofs of schools in densely populated heavy-traffic urban areas between January and April 2012 also showed very low concentrations of heavy metals, Total Organic Carbon (TOC) and Total Petroleum Hydrocarbons (TPH).

Urban runoff does not contain high levels of Chloride and Nitrate which are the major contaminants of groundwater in Malta.

These results, though not exhaustive, indicate that urban stormwater is not exceptionally contaminated, thus facilitating the construction of infiltration systems such as soakaways, pervious pavements, filter strips and other means of indirect groundwater recharge in urban areas (e.g., compact infiltration systems).

Rural Runoff

Studies carried out on the quality of runoff flowing along valleys present a rather negative picture. The runoff is severely contaminated with nutrients (particularly Nitrate) originating from over-fertilization and leaching from animal wastes. The high level of Nitrate in groundwater is attributed to these diffuse and point sources of pollution. Given these results, it is debatable whether one should encourage indirect groundwater recharge systems for rural runoff.

6.01

Driving Forces for GSI for Malta – Flood Reduction

Malta has experienced flood events over the years, and such occurrences are becoming increasingly more common and extreme.

Setting aside the impact of climate change (see Chapter **6.04**), the increase in the frequency and degree of flooding is primarily attributed to the following changes to land uses:

- The intensification of urbanisation in already built-up areas, through the loss of water-absorbing areas (e.g., gardens) to development and the widening and upgrading of roads resulting in an increase in impermeable ground;
- Urban sprawl, and the development of previously undeveloped land across the country, together with an increase in building/upgrading/widening of roads (without drainage), replacing agricultural land, with a concomitant consequential loss of adsorption capacity for rainwater; and,
- The undocumented loss of use of rainwater harvesting structures and the lack of maintenance of flood mitigation infrastructure (such as roadside soakaways and dams in valleys).

Flood events in Malta exhibit characteristics particular to a densely built Mediterranean island. The geomorphology of the islands has led to the low-lying harbour areas being identified as the most suitable for the development of urban centres. Often, these low-lying areas include dry valleys which over time have been built-up and incorporated into the main urban fabric (e.g., Valley Road, Msida). Therefore, when a storm event occurs, dry valleys revert to conveying channels for stormwater. Such flows along the watercourses are ephemeral and last for only a few hours. Therefore, although no natural permanent surface streams or rivers exist in the Maltese islands, urbanisation in areas which are naturally susceptible to the conveyance of stormwater runoff can lead to the temporary flooding of same with runoff. Within this context, flooding in Malta occurs when water is conveyed through watercourses in low-lying areas and not because of river or stream overflows.

Malta is typically prone to flash floods. These are rapid onset floods that occur after heavy rainfalls on particularly steep terrain gradients. These are characteristic of Mediterranean storm systems[8]. Due to the short lead time for advance preparation, warning, and evacuation, and due to the force of rapidly flowing waters, the losses suffered from flash floods can be substantial.

The intensity of heavy precipitation events has increased in Europe since the 1960s. A recent study has shown that the number of days with very heavy precipitation over Europe has increased on average by about 45% during the period of 1981 - 2013 compared with 1951 -

[8] https://floodlist.com/europe/malta-floods-november-2021

1980[9]. **Table 5** illustrates the monthly maximum peak rainfall depth per hour recorded in Malta over the period 2008 - 2018.

Peak rainfall [mm/h]	Gen	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	4.1	6.5	3.7	**6.7**	0.7	0.7	0	0.1	27.4	6.9	2.9	**14.1**
2009	13.9	11.1	4.3	3.5	1.1	0.9	0.1	0.2	**42.1**	3	7.6	7.5
2010	3.5	1.5	10	0.3	2.4	0.8	0.1	0	13.4	32.2	5.1	3.8
2011	8.4	8.7	**11.2**	3.7	1.9	0.1	0.1	0	3.3	12.8	8.7	5.2
2012	5.1	7.7	**11.2**	5.4	0.1	0.1	0.1	0.1	12.9	23.2	8.7	8.1
2013	6.2	3.4	2.8	2.5	0.4	0.2	0.1	**23.5**	13.1	4.3	10.7	6.6
2014	7.8	2.3	4.9	1.5	1.4	0.8	0.1	0.1	0.1	15.5	7.8	6.6
2015	3.8	6.6	5	0.7	**7.8**	0.3	**0.2**	17.8	7.2	21.3	2.7	2.9
2016	0	0	3.6	1.2	2.3	**18.7**	0.1	5.2	9.3	4.6	**11.2**	6.8
2017	**14.7**	10.3	5.1	4.1	0.2	2.5	0	2.1	19.3	**36.4**	10.5	4.7
2018	4.5	**34.6**	7.5	1.5	0.7	6.2	0.1	13.4	1.4	27.3	10.4	12.5
Average	6.5	8.4	6.3	2.8	1.7	2.8	0.1	5.7	13.6	17.0	7.8	7.2

Table 5: Monthly peak rainfall depth per hour data between 2008 - 2018 (MET Office**)**

The maximum peak rainfall depths per hour for each month during the period of 2008 - 2018 are indicated in bold and underlined, whilst the annual maximum peak rainfall depths per hour are highlighted. **Table 6** documents the flood events and their consequences during the decade 2011 - 2020.

Flood Event Date	Total rainfall [mm]	Rainfall duration [h]	Peak Rainfall [mm/h]	Source of flooding	Consequences
03 September 2012	65.8	24.0	12.9	Pluvial	traffic disruption, streets flooded, car accidents, damage to public and private property
21 August 2013	26.4	4.0	23.5	Pluvial	traffic disruption, streets flooded, low damage to infrastructures
05 October 2014	29.5	21.0	13.3	Pluvial	traffic disruption, streets flooded, flight diversions
19 November 2016	36.1	13.0	11.2	Pluvial	traffic disruption, streets flooded
05 October 2017	97.4	77.0	36.4	Pluvial	traffic disruption, streets flooded, low damage to infrastructures
10 February 2018	125.8	30.0	34.6	Pluvial	One fatality, traffic disruption, streets flooded, damage to infrastructures, car accidents, damage to public and private property, flight diversions
21 June 2018	9.1	2.0	6.4	Pluvial	traffic disruption, streets flooded
22 October 2018	39.7	4.0	27.3	Pluvial	traffic disruption, streets flooded

Table 6: Consequences of flood events during the decade 2011 - 2020 (EWA)

Flooding afflicts significant areas on an annual basis, particularly in the lower (and more densely urbanised) parts of the catchments. The social, economic, and financial impacts of floods in Malta are high because the affected areas are densely populated and encompass vital infrastructures.

[9] https://www.eea.europa.eu/data-and-maps/indicators/precipitation-extremes-in-europe-3/assessment-1

Figures 26 and **27** show how the low-lying areas in Malta are densely urbanized and built up, usually at the lower reaches of the catchments where runoff accumulates without significant attenuation.

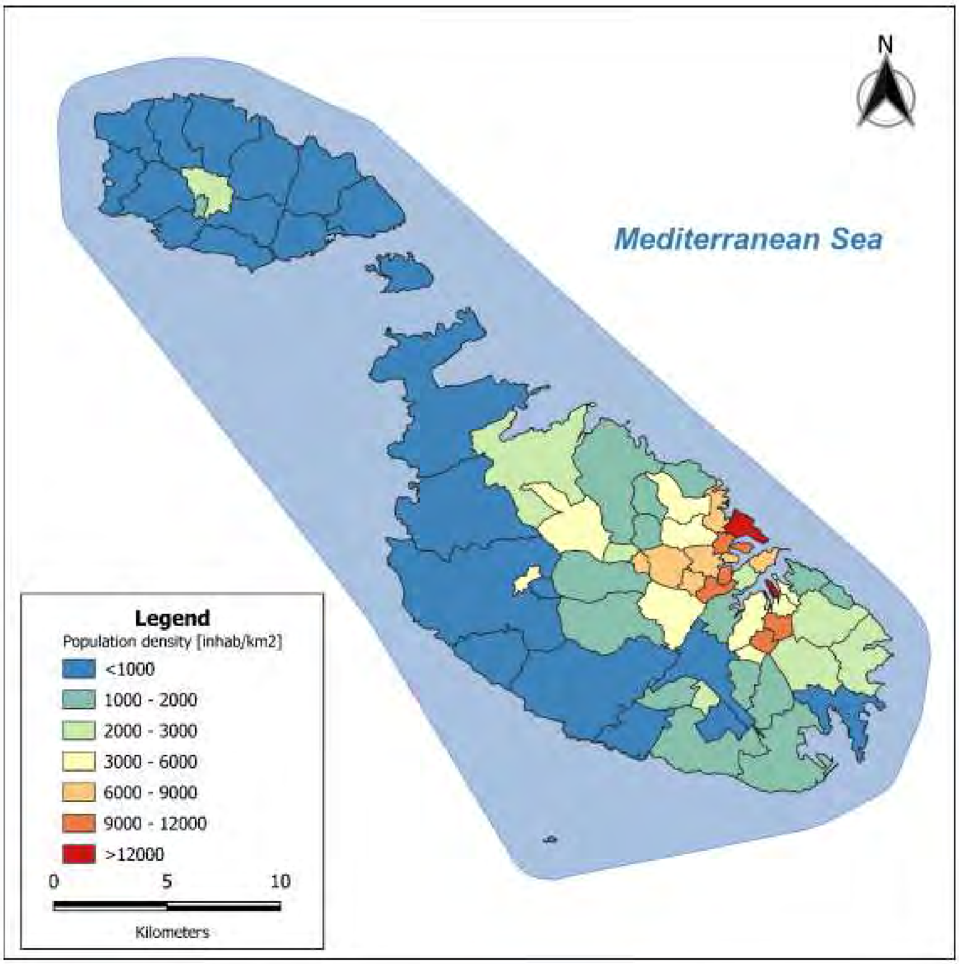


Figure 26: Population density per local council showing the propensity of the population to live in the North-East low-lying areas (NSO, 2019)

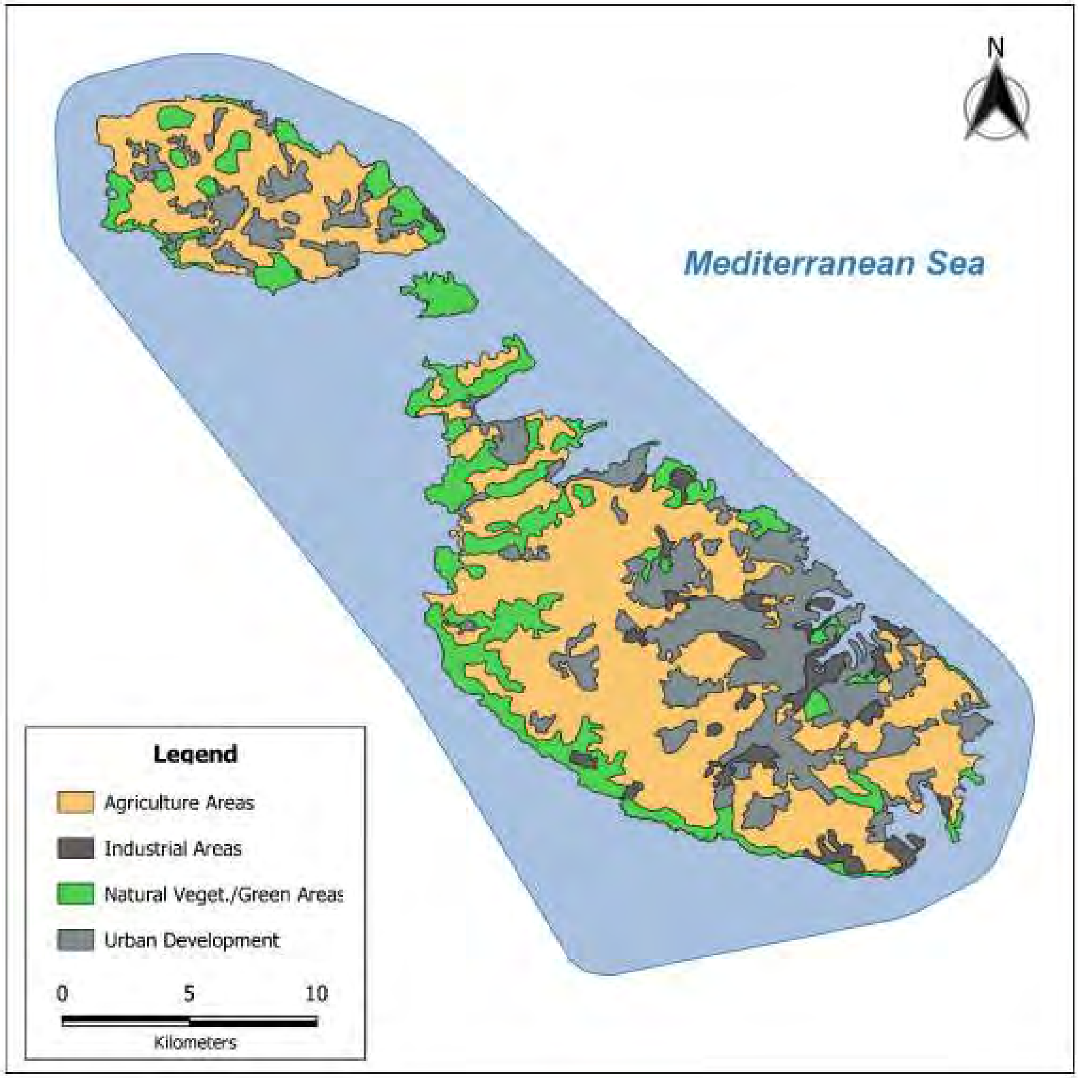


Figure 27: Map of land use showing how the low-lying areas (predominantly the harbour areas) are built up (Corine Land Cover, 2018)

Historical Flood Events

The management of the flood risks has been hampered by a lack of a national integrated approach to rainwater and valley management. Historical flood events have resulted in large economic, environmental, and public health damages.

In 2003, for instance, several rain gauges registered 24 hours rainfall depths with a return period higher than 50-year: Naxxar: 205 mm (~ 140-year); Ta' Qali: 198 mm (~ 100-year); San Ġwann: 181 mm (~ 60-year). The 2003 extreme storm event was followed by another in 2006.

The Malta Insurance Association (October 2009) considers Malta's extreme rainfall events to be in the 100 – 200 mm group for the maximum 24 hours precipitation. The 2003 storm had an intensity of 226 mm/24 hours, and generated runoff with a flow velocity of 9 km/hr (5 km/hr currents sweeps away a person). It is calculated that the rainfall depth of a 5-year return period event is 84 mm in 24 hours. High flood risk areas are in Marsa (golf course and sports areas), Burmarrad and Xlendi. **Figures 28 (1), 28 (2)** and **29** illustrate the 2003 and 2006 flash floods in two of the most affected areas (Birkirkara and Qormi). The flood events of 2003 and 2006 produced severe damages.

A Cost Benefit Analysis (CBA) was carried out in 2010 in preparation for the National Flood Relief Project (NFRP) that was subsequently implemented to alleviate flooding in four catchment areas. The CBA assessed the damages arising from the 2003 and 2006 flood events to estimate damages arising from 5/10-year return period events.

The 2003 and 2006 flood events caused physical damage of public and private assets (such as infrastructure, houses, vehicles, etc.) and intangible losses such as human life and others. The calculation of damages was conducted considering the prevailing market value of the tangible damages and the estimated value of losses, according with the following:

Social losses in terms of deaths, injuries, diseases, stress, cultural heritage loss;

Direct damages to buildings, goods, vehicles and infrastructures;

Indirect damages to operational and economic activities: traffic, retail, production;

Secondary damages on the general value of buildings, and activities in the flood prone areas, inefficient behaviour for fear of floods, etc.; and,

Environmental damages, which are not negligible especially when stormwater is often diverted to the sanitary sewer system, which is not adequate to drain the additional discharge, with the consequence that sewage is released downstream of the catchments.

Figure 28 (1): 2003 and 2006 flood scenes in Birkirkara

(CBA Study and Technical Assistance – Politecnica Feb 2010)

g) Birkirkara (2003): Il-Qasab (public perception)

h) Birkirkara (2006): Il-Qasab (downstream)

i) Birkirkara (2006): Il-Qasab (upstream)

j) Birkirkara (2006): Triq Mannarino (upstream)

k) Birkirkara (2006): Triq Mannarino (downstream)

l) Birkirkara (2006): Triq Mannarino (downstream)

m) Birkirkara (2006): Triq Mannarino (upstream)

n) Birkirkara (2006): Triq Mannarino (sewers)

Figure 28 (2): 2003 and 2006 flood scenes in Birkirkara

(CBA Study and Technical Assistance – Politecnica Feb 2010)

Figure 29: 2003 flood scenes in Qormi

(CBA Study and Technical Assistance – Politecnica Feb 2010)

The estimated damages suffered by the most highly impacted catchment areas (**Table 6**) were:

Birkirkara-Msida: 8,400 inhabitants and 350 economic activities were directly affected while 60,000 inhabitants were indirectly affected. About 63% of the catchment area was urban, including the towns of Lija, Balzan, Attard, Birkirkara and Msida. The occurrence of a 5-year return period event would cause an estimated total damage of €11 million (of which €6.7 million as direct damages to buildings and contents),

Gżira: 2,000 inhabitants and 100 economic activities were directly affected while 20,200 inhabitants were indirectly affected. The occurrence of a 5-year return period event would cause an estimated total damage of €3.6 million (of which €1.5 million as direct damages to buildings and contents);

Marsa: 4,800 inhabitants and 400 economic activities were directly affected while 41,300 inhabitants were indirectly affected. The occurrence of a 5-year return period event would cause an estimated total damage of €7.0 million (of which €3.7 million as direct damages to buildings and contents); and,

Marsascala: 2,200 inhabitants and 200 economic activities were directly affected while 25,000 inhabitants were indirectly affected. The occurrence of a 5-year return period event would cause an estimated total damage of €3.7 million (of which €1.3 million as direct damages to buildings and contents).

	Basin Area (Kmq)	Population Directly Affected	Population Indirectly Affected	Economic Activities	5-years Damages (million Euro)				
					Social	Buildings	Infra-structures	Traffic & Economy	Total Damages
Birkirkara-Msida	11	8,400	60,000	350	0.50	6.7	2.0	1.8	11.0
Gzira	2	2,000	20,200	100	0.50	1.5	0.7	0.85	3.6
Marsa	47	4,800	41,300	400	0.50	3.7	1.0	1.7	7.0
Marsascala	4	2,200	25,000	200	0.50	1.3	0.73	1.2	3.7
Total	**64**	**17,400**	**146,500**	**1,050**	**2.0**	**13.2**	**4.4**	**5.6**	**25.3**

Table 7: 5-year return period event damage estimates (CBA Study and Technical Assistance – Politecnica Feb 2010)

Flood Mitigation

The NFRP (see **Figures 30** and **31**) was completed in 2015, with an investment of € 51 million. The declared objective of the NFRP is to relief the affected areas from 5-year return period floods, keeping the water depth under 10 cm, the level over which starts causing damages. Specifically, it was designed to address the main problematic areas as regards flooding in the catchments of Birkirkara-Msida, Gżira, Marsa and Marsascala. The stormwater management infrastructure built as part of the NFRP thereby significantly reduced the adverse consequences of 5-year return period events within these catchments. This project also increased the resilience of these catchments to rainfall events with a higher return period.

The main component of the NFRP consists of a flood mitigation storm drainage system in the Birkirkara-Msida catchment (11 km in length) which includes first flush oil and grit interceptors connected to culverts draining stormwater. These culverts are in turn connected to an underground tunnel network conveying runoff from Naxxar, Mosta, Lija, Attard, Balzan, Birkirkara, Msida, Gzira and discharge it into the sea from Ta' Xbiex outfall. The bored tunnels have a diameter of between 3 m and 7 m and are at a depth of between 8 m and 52 m.

The project incorporates a pumped soakaway with a capacity of 10,000 m^3 at the mouth of Wied Għollieqa, upstream of Gżira. Runoff is pumped in this soakaway from Ta' Xbiex outfall. The overflow from the soakaway discharges into the Gzira underground tunnel that is connected to the Birkirkara - Ta' Xbiex tunnel. This soakaway has the potential to give useful data on percolation rates and water quality characteristics. It also can alter the phreatic surface of the groundwater in the area. No such data is yet available.

A separate component drains the Qormi - Marsa catchment into the Marsa harbour; this generally follows the previous open concreted channels in the valley bed which were hydraulically improved. Another component drains the Żabbar catchment into the sea just north of Żonqor Point, Marsascala.

The NFRP does not cover the whole country and is totally absent in Gozo. The catchments covered by the NFRP have experienced an increase in flood protection since its introduction, while others have not[10].

[10] https://timesofmalta.com/articles/view/cars-carried-away-by-floodwaters-as-heavy-rain-pelts-malta.917155

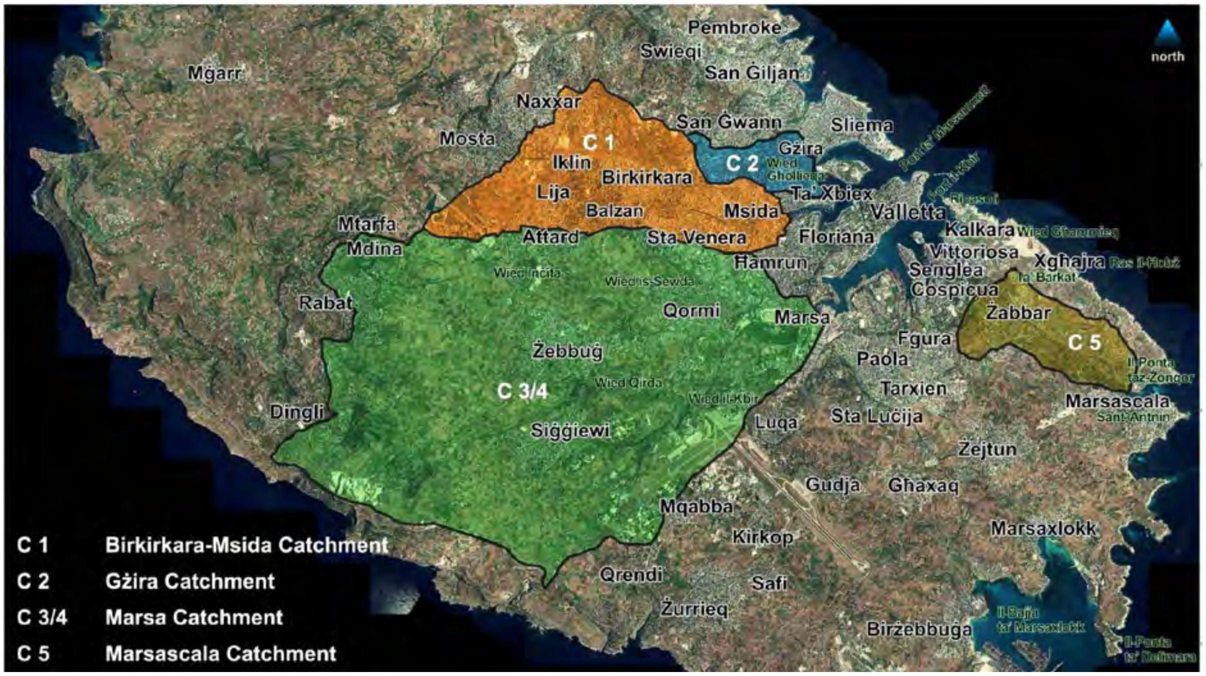


Figure 30: NFRP catchments

Figure 31: NFRP internal view of a tunnel confluence

On 25 November 2021, Malta experienced a major storm event when 75 mm of rain fell in few hours in the morning. As a result, there was flooding across the country, with dozens of vehicles submerged, swept away, an elderly man needing airlifting, and various walls collapsing. The flooding was also extreme in the areas protected by the NFRP, (see **Figures 32 (1)** and **32 (2)** for the scenes in Msida). It is evident that the NFRP does not cope with events with return period higher than 5-year.

Figures 32 (1) and **(2):** 2021 flood scenes in Msida (Times of Malta)

The risks of flooding were assessed by the Energy and Water Agency (EWA) in its Preliminary Flood Risk Assessment (PFRA) for the Malta River Basin District, 2019.

The objective of the PFRA was to identify areas where the risk of flooding is considered as significant. This PFRA considered past and possible future flooding caused by runoff. It also considered the potential adverse consequences on human health, the environment, cultural heritage and economic activity by taking into account, as far as possible, issues such as the topography, the position of watercourses and their general hydrological and geological characteristics, the effectiveness of existing anthropogenic flood defence infrastructures, the position of populated areas, economic activities and long-term developments including the impacts of climate change.

Table 8 presents the flood risk significance for the areas that were identified as being the most predisposed to flooding for storms with return periods of 5 year (T = 5), 50 year (T = 50) and 200 year (T = 200). The risk is insignificant in all areas for the storm having a 5-year return period, becomes high in Burmarrad, Qormi-Marsa, and Xlendi for the storm with a return period of 50 year, and almost all areas would experience significant or high risk for the storm with a return period of 200 year.

It is evident that, as urbanisation continues, and the extreme effects of climate change increase, the existing conventional flood protection systems would have to be upgraded.

The rehabilitation of existing GSI and the introduction of new GSI helps alleviate flood risks. The degree of mitigation depends on the extent of rehabilitation/construction of such GSI, with the biggest beneficiaries being the flood prone areas, which would otherwise suffer more flooding as further development contributes more direct runoff.

S/N	Catchments	T = 5		T = 50		T = 200	
		Risk	Total	Risk	Total	Risk	Total
1	Birkirkara-Msida	Insignificant	3	Normal	14	Significant	41
2.1	Birzebbugia 1	Insignificant	1	Normal	13	High	16
2.2	Birzebbugia 2	Insignificant	1	Low	9	Normal	12
3	Burmarrad	Insignificant	6	High	18	Significant	22
4	Gzira	Insignificant	3	Low	9	Significant	29
5	Kalkara	Insignificant	3	Normal	13	High	18
6	Marsascala 1	Insignificant	3	Normal	13	Significant	20
7.1	Qormi-Marsa 1	Insignificant	3	Normal	13	Significant	28
7.2	Qormi-Marsa 2	Insignificant	3	High	18	Significant	48
8.1	Marsalforn 1	Insignificant	4	Normal	12	Significant	29
8.2	Marsalforn 2	Insignificant	3	Insignificant	4	High	16
8.3	Marsalforn 3	Insignificant	3	Insignificant	6	High	18
9	Mgarr ix-Xini	Insignificant	4	Normal	12	Normal	15
10	Ramla	Insignificant	6	Normal	12	High	17
11.1	Xlendi 1	Insignificant	4	Low	10	Normal	13
11.2	Xlendi 2	Insignificant	4	High	17	Significant	31

Table 8: Likelihood of flood risk for 5-year, 50-year and 200-year return periods (EWA)

6.02

Driving Forces for GSI – Groundwater under Stress

Chapter 3.00 describes the type, extent, and nature of the aquifer systems of Malta.

The strategically and economically important mean sea-level aquifers are in poor quantitative status (i.e., they are in deficit) because of over-abstraction, and they are also in a poor qualitative status due to high levels of Nitrate and Chloride.

In the absence of rivers or lakes, groundwater is the only naturally occurring source of freshwater. Historically, through the harvesting of springs and, from the late 19th century onwards through mining, groundwater has sustained the population. It has enormous economic and strategic importance for the country.

Groundwater still contributes approximately 40% of Water Services Corporation (WSC) drinking water supply, the balance being made up by seawater reverse osmosis (RO) plants.

Just over 13 million m^3 per year are currently produced by WSC from underground sources, the main source being the underground galleries at Ta' Kandja. WSC has also 12 other pumping stations and 134 boreholes from where water is extracted. Peak WSC groundwater production reached almost 20 million m^3 per year from the late 1970s on to 1997 when it was decreased because of increasing salinity levels of some of the groundwater sources and the increased production and efficiency of the RO plants.

The increased local private access to borehole drilling technology in the 1970s led to the drilling of thousands of private boreholes across Malta in the last 40 – 50 years, with the water being abstracted by agricultural, commercial and industrial consumers, and households. The exact volumes that have been and are being abstracted other than WSC are not known but are estimated to be anywhere between 20 and 25 million m^3 per year.

Figure 33 shows the location of WSC freshwater production sources while **Figure 34** shows the location of registered groundwater sources (boreholes, artesian wells, and springs) in 2008.

Replenishment of the aquifers is by natural recharge (and to a much lesser extent, artificial recharge and leakage from the perched aquifers and the water supply system). Historically, runoff discharged into the sea was less because of different land morphology, good water absorption by the soil and infiltration into the ground. However, this has changed because of the increase in built up areas, loss of agricultural land and natural habitats, and disuse of existing water harvesting infrastructure.

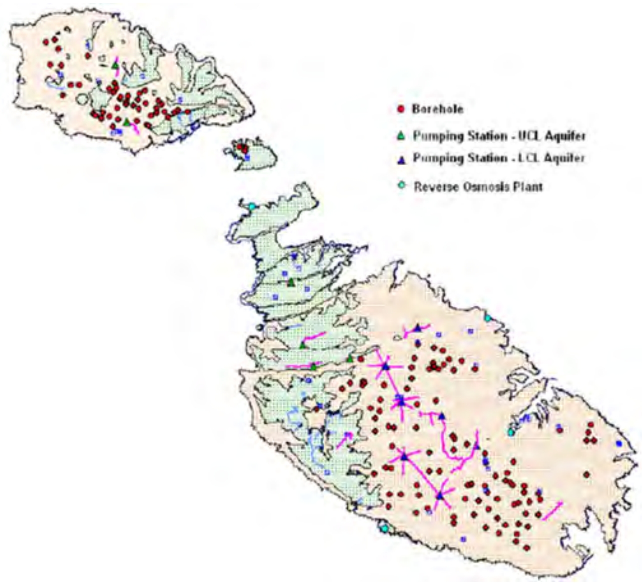


Figure 33: 2008 location of WSC freshwater production sources (MRA)

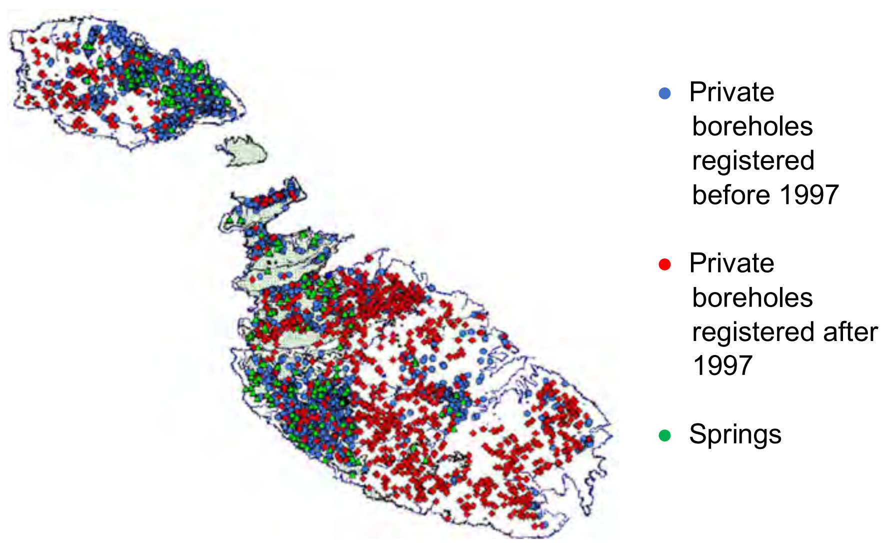


Figure 34: 2008 location of registered groundwater production sources other than WSC (MRA)

Natural recharge is estimated to be around 52 million m^3 a year (which represents around 30% of the annual precipitation).

Table 9, from the 2nd Water Catchment Management Plan, presents an annual water balance model for the aquifers. The mean-sea level aquifers yield 28.2 million m^3 per year and are in deficit by an estimated 3.5 million m^3 per year.

Aquifer System	Natural Recharge Mm^3	Leakage from Perched Aquifers Mm^3	Artificial Recharge Mm^3	WSC Abstraction Mm^3	Agriculture Abstraction Mm^3	Other Sectors Abstraction Mm^3	Natural Discharge Mm^3	INFLOW Mm^3	OUTFLOW Mm^3	BALANCE Mm^3
Malta Mean Sea Level Aquifer System	28.8	1.4	6.25	(11.2)	(7.5)	(3)	(18)	36.25	(39.7)	**(3.45)**
Malta Perched Aquifer Systems	11	(1.4)	2.7	(0.8)	(5.6)	(1)	0	13.7	(8.8)	**4.9**
Gozo Mean Sea Level Aquifer System	9.75	0.75	2.35	(2)	(3.5)	(1)	(6.4)	12.85	(12.9)	**(0.05)**
Gozo Perched Aquifer System	2.2	(0.75)	0.9	0	(2)	(0.25)	0	3.3	(3.0)	**0.3**

Table 9: Water balance model for the aquifer systems

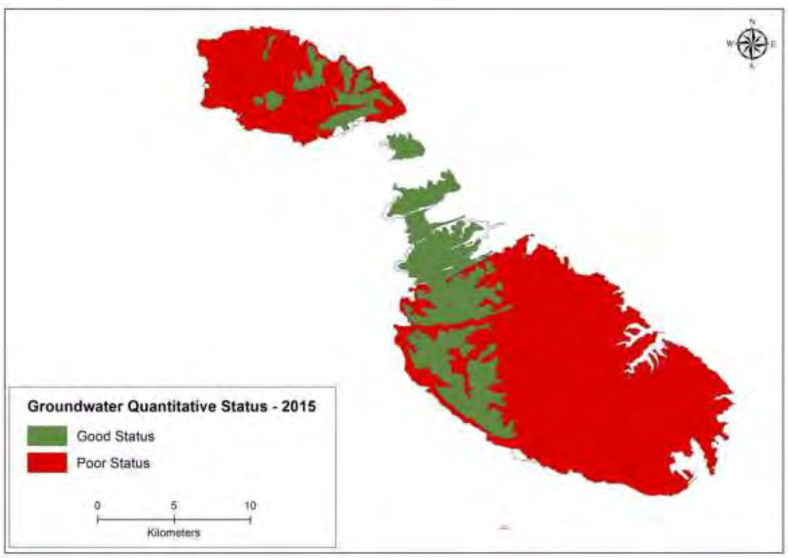


Figure 35: 2015 groundwater quantitative status

The aquifers are also under threat from a qualitative perspective (**Figure 35**). The quality of groundwater is highly variable with contamination of groundwater by Nitrate and Chloride being the main quality issues of concern.

Nitrates occur naturally in the environment and are produced from the decaying of vegetation. The natural Nitrate level in the mean-sea level aquifers is generally expected to be low. The significant Nitrate contamination in groundwater is largely attributed to anthropogenic activities, namely the application of nitrogenous fertilizers and leaching of animal waste.

Groundwater has generally high levels of Chloride concentrations because of overextraction and seawater intrusion. Generally, Chloride levels in the perched aquifers are significantly lower than in the mean sea-level aquifers, and these lower values result from the topographical nature where the perched aquifers are largely protected from seawater intrusion.

Table 10, from the 2nd Water Catchment Management Plan, shows that, except for three relatively minor aquifers, all the aquifers do not pass the qualitative status assessment and are classified as poor. These results are depicted geographically in **Figure 36**.

Groundwater Body	General Qualitative Test	Saline Intrusion Test	Associated Surface Waters Test	Drinking Water Test	Status Assessment
Malta Mean Sea Level	Fail	Pass	n/a	Pass	Fail
Rabat Dingli Perched	Fail	Pass	Pass	n/a	Fail
Mgarr-Wardija Perched	Fail	Pass	n/a	Pass	Fail
Pwales Coastal	Fail	Fail	n/a	n/a	Fail
Mizieb Mean Sea Level	Pass	Pass	n/a	Pass	Pass
Mellieha Perched	Fail	Fail	n/a	n/a	Fail
Mellieha Coastal	Pass	Pass	n/a	n/a	Pass
Marfa Coastal	Fail	Fail	n/a	n/a	Fail
Comino Mean Sea Level	Pass	Pass	n/a	n/a	Pass
Gozo Mean Sea Level	Fail	Pass	n/a	Pass	Fail
Ghajnsielem Perched	Fail	Pass	n/a	n/a	Fail
Nadur Perched	Fail	Pass	n/a	n/a	Fail
Xaghra Perched	Fail	Fail	n/a	n/a	Fail
Zebbug Perched	Fail	Pass	n/a	n/a	Fail
Victoria-Kercem Perched	Fail	Fail	Pass	n/a	Fail

Table 10: 2015 results of the qualitative status assessment tests for groundwater bodies

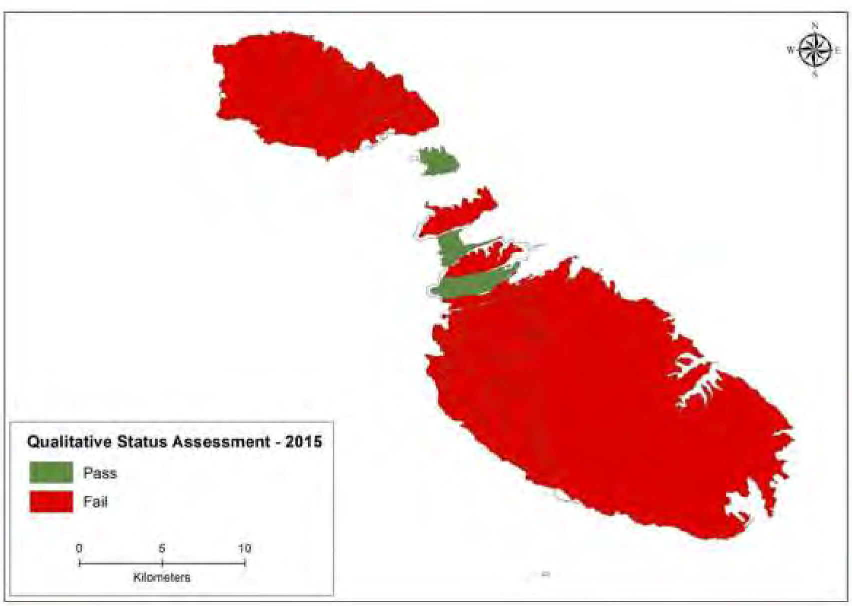


Figure 36: 2015 groundwater qualitative status

How Can GSI Alleviate Pressure from Malta's Groundwater Systems?

There are several GSI technologies which support the aquifers' rehabilitation and replenishment, and these can be generally classified as either:

- Those which use runoff (with or without treatment) as an alternative to groundwater (technologies for inhouse use); or,
- Those who channel runoff into the ground to enhance the quantity and quality of groundwater reserves through (controlled) aquifer recharge.

Technologies for Use of Runoff

Technologies falling under this category are designed to divert, capture, and store rainwater for use onsite or off-sites. They usually require infrastructure having large storage volumes, as they are designed to retain the water for some time. The most common technology within this category is traditional rainwater harvesting, whereby rainwater falling on impervious surfaces (generally roofs) is channelled to a (generally underground, rock cut) cistern, or tank, for temporary storage for use in subsequent months as second-class water. By (partially or completely) meeting the demand for second-class water within the precinct (which can be a residence, an office block, a commercial or industrial concern, a garden, agricultural land, etc.), the use of (and therefore abstraction of) groundwater is avoided, thus reducing stress on the aquifers from a quantitative perspective. The quality of groundwater is also henceforth improved through a reduction in seawater intrusion arising from pumping.

As described in **Chapter 5.02**, the quality of runoff generated on roofs in Malta is adequate for use as second-class water for flushing toilets, laundry, irrigation (landscaping or cultivation of crops) or for industrial use (as wash water).

Technologies for Infiltration of Runoff

The second group of technologies can be referred to as Indirect Aquifer Recharge Systems. These technologies are designed to temporarily harness the water (i.e., they have some storage) but 'lose' the water to the ground. The storage capacity required is only for temporary retention to generate pressure (head) for the water to seep down to the ground. Use of the stored water is possible, but the intention is usually to lose the water at a fast enough rate to have capacity to handle the runoff generated from the next rain event. These technologies are suitable in cases where there is no use for second-class water onsite or within the vicinity, or where the volumes of runoff to be managed are much larger than the volumes of water that can be harvested onsite.

Aquifer recharge systems can also be used to compliment technologies for inhouse use, such that the overflow from the latter systems can be directed into the ground for recharge.

Indirect Aquifer Recharge Systems help to reduce stress from aquifers by increasing the recharge volumes and help to reduce the deficit by introducing runoff into the ground that would otherwise have been lost to the sea. It follows that the recharge water (runoff) has to be of a quality that would not negatively affect the quality of the receiving groundwater. Indirect aquifer recharge projects should follow the "no deterioration" principle stipulated by the EU Groundwater Directive, and the quality of the recharge water should meet the Groundwater Threshold Values stipulated in the 2nd Water Catchment Management Plan.

Chapter 5.02 describes how the quality of runoff generated on roofs in Malta is of such a quality, that, except for the runoff generated by the first storms at the start of the rainy season, can be used for indirect aquifer recharge.

From preliminary tests on urban stormwater samples carried out in 2021 - 2022 (described in **Appendix 10.03**), it was inferred that the quality of urban runoff meets the groundwater threshold values for indirect aquifer recharge, following pre-treatment, if required, and the undertaking of a risk assessment.

The potential for indirect aquifer recharge systems to make a significant positive impact on the recovery and rehabilitation of Malta's groundwater systems is huge.

6.03

Driving Forces for GSI – Soil Protection, Public Health, Green Spaces

One of the impacts of flooding in Malta is the loss of topsoil and the overflowing of sanitary sewers. After heavy rainfall, it is often observed that the sea in coastal areas at the mouths of the lower reaches is dark brown with the load of eroded soil, which is washed down from fields in rural areas, and also from sewage from the surcharged manholes. The patently illegal yet commonplace disposal of rainwater to the sanitary sewers is discussed in **Chapter 1.00**.

The erosion of topsoil from fields partially stems from general lack of maintenance of the boundary rubble walls (*ħitan tas-sejjiegħ*) of terraced fields (**Figure 37**). The rubble walls effectively act as soil barriers and vertical porous filters of water and the topsoil is typically kept horizontal as they have a very low stable angle of repose. They also, by the very act of terracing, transform the topography and hence cause the water to infiltrate slowly to the ground and thus encourage percolation to the aquifers.

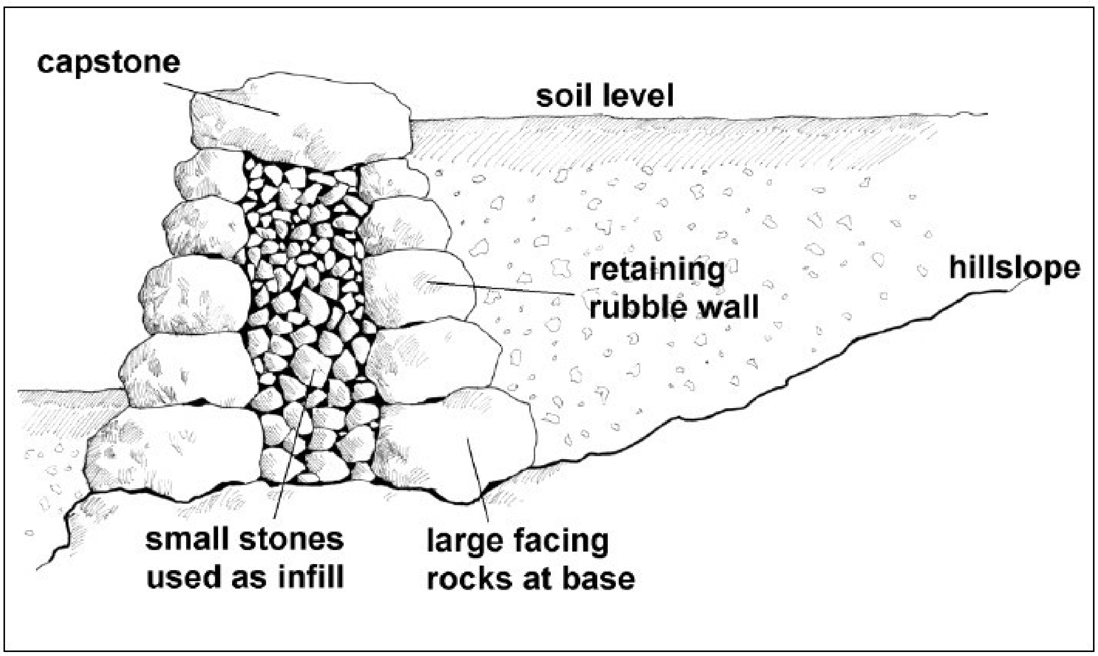


Figure 37: Rubble wall cross-section showing internal fill (Role' and Attard)

These walls successfully retain and keep the soil well drained. However, due to their drystone construction, they require labour-intensive maintenance. They are a habitat for a wide variety of fauna and fauna where the stone joints offer a surface with shade, moisture, and a growth medium[11]. Unfortunately, collapsed walls are becoming more common with the growing abandonment of agriculture (**Figure 38**). Soil is naturally carried in suspension with runoff.

Figure 38:

Collapsed rubble wall in Għargħur

(Times of Malta)

Sewage overflows are commonly experienced in rainfall events. The Sewerage Master Plan[12] (1992) identified rainfall load as far more critical than the peak dry weather flow and recommended buffering of the excessive flows in on-line tanks (retention basins) or surcharged galleries. Some recommendations were carried out in successive years. However, the current position of Water Services Corporation (WSC), which operates the sewerage system, is that there is no provision for carrying stormwater and "the wastewater infrastructure is designed to take wastewater only"[13]. Overflowing manholes in streets are a hazard to traffic and the ensuing sewage is a health hazard as it flows freely (**Figures 39** and **40** refer).

Figure 39:

Note damage and colour at flooded Xlendi Bay in 2021

(L. Cardona)

11 Our Ancestral Country Allies: The Rubble Walls: Vella & Garrido. Integrated Resources Management (IRM) Co. Ltd. Malta

12 Sewerage Master Plan for Malta and Gozo - Volume 1: COWI Consult. Ministry for the Environment (1992)

13 Unauthorised water in sewers – Stephen Zerafa WSC PRO, Times of Malta 29/1/2012 https://timesofmalta.com/articles/view/Unauthorised-water-in-sewers.404301

Figure 40:

Note colour at flooded Msida coastal road

(L. Cardona)

It is not being claimed that GSI will eliminate flooding. What is being advocated is the adoption by land managers of a wide spectrum of alternative/complimentary measures to manage runoff which would condition behaviour and approach to mitigate flooding. More intense storms brought about by climate change may mask improvements brought about by the adoption of GSI (**Chapter 6.04**). However, the realisation of wisely chosen and well-engineered GSI should augment groundwater quality and quantity and reduce flooding.

The adoption of GSI, especially in the urban context, provide positive environmental impacts of environmental services. GSI inevitability imposes some limits on the intensity of development. For an underground infrastructure for runoff percolation to the mean sea-level aquifer, the net effect is better groundwater quality by supplanting saline water intrusions.

Moreover, GSI which is on/above the ground such as soakaways, green roofs, trees, and permeable pavements involve making a space for water. Such spaces attract nature and provide barriers to development. If managed properly, these spaces have the potential to become amenities in themselves. Recent developments of this kind include the roof garden at the Valletta Design Cluster (**Figure 41**). Such retrofitting is challenging and costly, but surely beneficial.

Figure 41: Roof garden at Valletta Design Cluster

(https://www.vca.gov.mt/en/valletta-design-cluster/our-facility)

In the light of the Public Administration's policy for the creation of green spaces[14], the political will across the political spectrum and hopefully the populace, there are clear opportunities to introduce GSI as part of considered and deliberate greenspaces. It would be thoughtless to begin to plan for green spaces without provision of appropriate, properly engineered and managed water supplies, and it would be tragic if such a supply were to be dependent on abstracted groundwater or mains water, which are currently the main water sources for much of Malta's current landscaping.

[14] Article 284 PL manifesto 2022
https://robertabela.mt/wp-content/uploads/2022/03/MALTA-FLIMKIEN-MANIFEST-ELETTORALI-2022.pdf
Article 62 PN manifesto 2022
https://assets.nationbuilder.com/pn/pages/3115/attachments/original/1646670856/PN_Manifesto_22.pdf?1646670856

6.04

Driving Forces for GSI – Climate Change

Changes in the climate, and in particular, precipitation patterns with respect to volume, intensity, and frequency have a great influence on the design, efficiency, and effectiveness of any storm water infrastructure, whether it is green or grey.

The climatic situation in Malta is already challenging prior to the onset of climate change rainfall is highly seasonal, with the customary scenario of 70% of the annual precipitation occurring from October to March, and mainly in the form of storms. This is normally followed by months of little or no rain from May to August, which in turn are followed by a showery autumn. During the short winters, precipitation is usually sufficient for crop irrigation but soil water retention does not suffice for the relatively warm and dry spring seasons. The hot, dry summers are followed by warm and showery autumns, normally also with a rainfall deficit.

The facts that precipitation is:

- Unevenly distributed throughout the year,
- Low, and,
- Mostly in the form of intense showers

result in a situation where stormwater infrastructure has to be sized to manage heavy storms and would be idle for most of the year. The fact that the country is completely dry for some months of the year also results in the accumulation of wind-blown deposits of silt and debris, which are then carried away by the first rains, resulting in the blocking and reduction of the efficacy and efficiency of the stormwater infrastructure.

However, on the plus side, dry summers allow for the possibility of scheduled cleaning and maintenance of the systems before the onset of the autumn rains.

Chapter 3.00 gives an overview of the climate of Malta with emphasis on precipitation.

Rainfall records have been maintained systematically for over 100 years. Annual rainfall is highly variable. During the period 1840 to 2000, the highest annual maximum was 1031 mm (in 1859), and the lowest annual minimum was of 148.8 mm (in 1977).

The 30-year annual average precipitation was 553 mm during the period 1961 - 1990, and 543 mm during the period 1991 - 2020. There was a 10 mm decrease or 2% reduction in annual average precipitation over a 30-year period. Since 1923, there has been little change in rainfall during winter and summer, whereas there has been a decrease of 0.14 mm per year during spring and an increase of 0.8 mm per year during autumn.

During the rainy season, the number of days per year with thunderstorms has increased by 9 since 1950. The existence of convective rainfall is corroborated by the positive trend in the daily maximum rainfall between 1923 and 2000, since this type of rainfall is of short duration and often heavy. An increase in the daily maximum rainfall is observed notwithstanding the fact that, over a full year, the absolute number of days with rainfall in the range 1 – 50 mm is decreasing.

The following climatic changes are also observed:

- Increase in hours of sunshine;
- Increase in the mean ambient temperature (including warmer nights); yearly recorded maximum temperatures have gone up by about 3°C over 100 years;
- More heatwaves; summer heatwaves are becoming more frequent. During the period 1967 - 2014, annual maximum and minimum temperature increased by 0.09°C and 0.02°C per annum respectively. Observed extremes in the maximum and minimum temperatures are typical of desertification.
- Increasing aridity, from the combined effects of lower annual precipitation, precipitation being concentrated to a few heavy storms, increased evaporation arising from higher temperatures, and heatwaves.

The long-term forecasts for precipitation are less reliable than those for temperature. The scaled precipitation values give an estimated decrease of around 17% (to a best guess with 50% probability) amounting to a reduction of about 60 mm in the annual mean rainfall by 2100. The major decrease in rainfall is expected in autumn, with an increase during winter and little change during the rest of the year. The overall result is that the shift to less rain in autumn would have the greatest impact and would exacerbate dryness due to higher temperatures and the combined effect of enhanced evapotranspiration[15].

The Environment and Resources Authority (ERA) presents a similar forecast with its predictions for the 21st century showing precipitation decreases of between 5% and 15% and between 20% to more than 25% for the stabilization and high-end climate (RCP4.5 and RCP8.5) scenarios. In addition, concentration of rainfall to fewer higher intensity events is expected. These new climate patterns are expected to further compound drought and water availability issues[16].

Climate Change makes an already challenging water management situation even more challenging. The choice, sizing, and design of GSI must take these climatic changes in consideration. The increase in intensity impacts the choice of the design event storm. As described in **Chapter 6.01**, the NFRP was designed for a 5-year return period event calculated on rainfall statistics till 2010. The hourly rainfall depth was then calculated as 45 mm[17]. This rainfall depth is largely confirmed by the 2020 report by the Energy and Water Agency[18] (**Figures 42** and **43** refer).

With increasing intensities of rainfall, it is probable that higher return periods would need to be designed for, and an amalgam of green and grey stormwater infrastructure are required to address flooding issues to give resilience to the adopted solutions.

---

15 https://www.climatechangepost.com/malta/climate-change
16 https://era.org.mt/topic/drought/
17 National Flood Relief Project: Feasibility Study Report 2010 (Politecnica) - Ministry for Resources and Rural Affairs
18 Flood Hazard Maps and Flood Risk Maps for the Malta Basin District EWA 2020

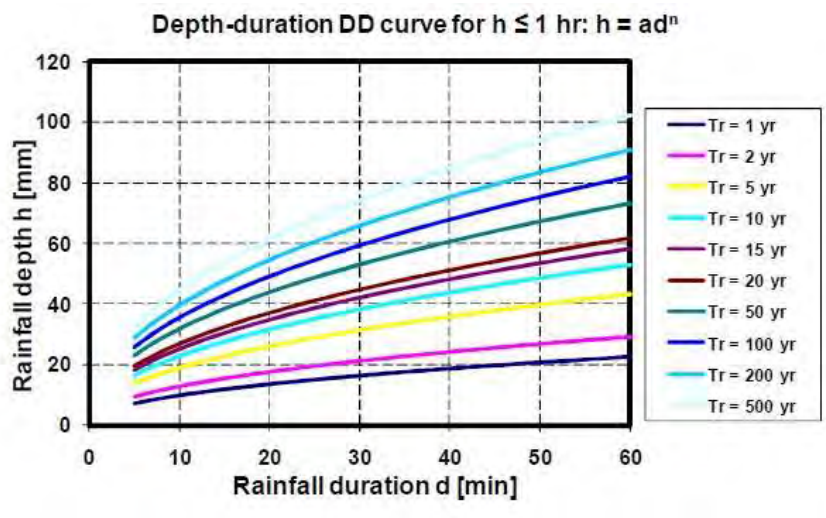


Figure 42:

Depth duration curves for 1-to-500-year return periods up to 1 hour (2010)

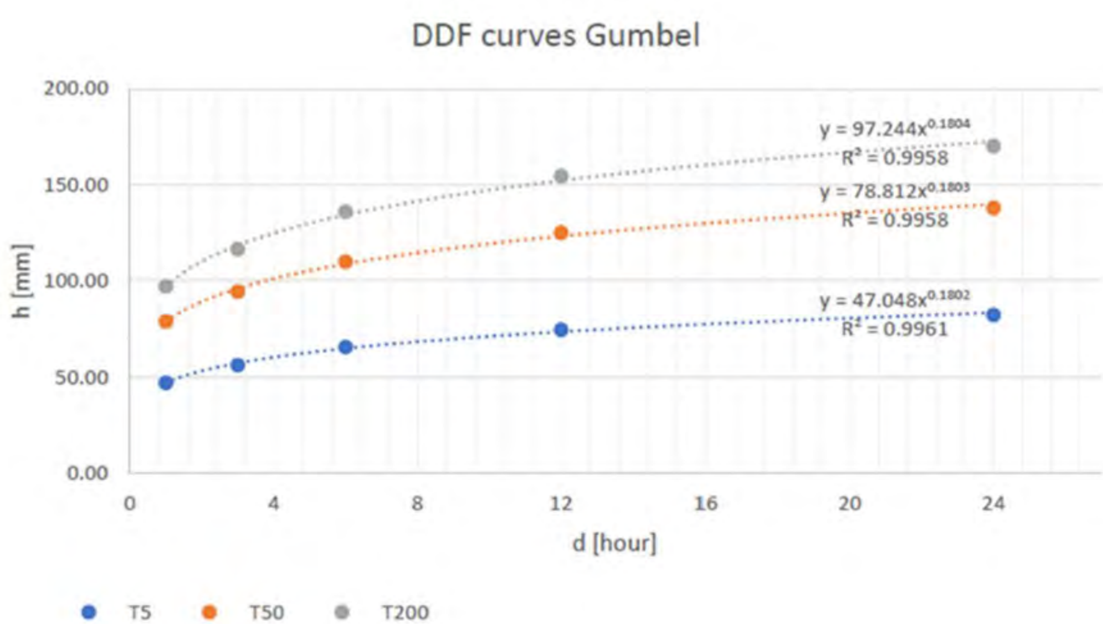


Figure 43:

Depth duration curves for 5-year, 50-year and 200-year return periods up to 24 hours (EWA, 2020)

6.05

Driving Forces for GSI – Water Policy

The water challenges faced by a small densely populated country in a semi-arid region of the world are described in **Chapter 3.00**. Throughout the centuries, the rulers of the Maltese Islands sought ways of how to manage and regulate this scarce resource. This Chapter describes the main policy measures, legislation, and targets which directly or indirectly, enforce or encourage GSI.

1. Legislation Stipulating the Construction of Rainwater Harvesting Systems in Buildings

Historically rainwater has been perceived to be a cheap and readily available source of water, which when adequately stored can provide households with an alternative to the mains water supply. Almost all buildings constructed prior to the 1940s thus incorporated private and communal cisterns to collect rainwater for private and communal use. Harvested rainwater constituted then an important resource. Public perception and behaviour however changed over time and rainwater harvesting has tended to decrease in importance. This is due to various factors including the development of a reliable mains water supply, higher living standards and greater pressures on land resources.

Nevertheless, the requirement to construct rainwater cisterns in buildings remains to this day. Until the coming into force of the Energy Performance of Buildings Regulations, 2012, article(97)(n)(viii) of part V of the Code of Police Laws required the construction of cisterns in domestic premises and regulated their size. All houses were obliged to have a cistern in a good condition of a capacity of at least 3 m^3 for every 5 m^2 of floor area of each room of the house.

The Conservation of Fuel, Energy and Natural Resources (Minimum Requirements on the Energy Performance of Buildings) Regulations, 2015 and Technical Document F Part 1: Minimum Energy Performance Requirements for buildings in Malta[19], applicable for new or renovated buildings from 1st January 2016, requires the collection of rainwater in suitable wells or cisterns. Technical Document F Part 1 specifies the technical requirements related to the construction and size of cisterns as well as rainwater drainage, and its use. The volume requirement in m^3 is the total roof area (m^2) multiplied by a factor of 0.6 m except for "shops and showrooms and places of public gathering and entertainment"[20] (**Figure 44**).

This Regulation, which is under the remit of the Building and Construction Agency (BCA), is self-regulating with the obligation being placed on the *periti* and the developers. WSC advises

---

19 Legal Notice 434 of 2015

20 Section 6, Table 10: Technical Document F Part 1: Minimum Energy Performance Requirements for Buildings in Malta Building Regulation Office Ministry for Transport and Infrastructure Malta

developers to adhere to the Regulation (amongst others) in its standard response as a statutory consultee in the vetting of development planning applications (**Figure 45**).

Table 10: Size of well or cistern

Building Type	Size of cistern (m^3)
1. Domestic dwellings (inc. Apartment blocks)	Total roof area (m^2) x 0.6m
2. Hotels, Schools, Offices, Factories, Industrial buildings and Hospitals	Total roof area (m^2) x 0.6m
3. Shops and showrooms, and places of public gathering and entertainment not integrated in 2 above	Total roof area (m^2) x 0.45m
4. External paved areas (inc. open terraces and balconies) *	Total paved area (m^2) x 0.6m

*Note:

This requirement applies only if the total open paved area is greater than 300sq.m

Figure 44:

Document F Part 1 sizing of cisterns

water services corporation

WSC Consultation to Development Permit

In accordance with the development in question, the applicant shall make sure that rain water and/or run-off collection from roofs, yards, balconies (and any other exposed areas) is being managed as such that no rainwater, including overflow pipes (by pumping or gravity system), even from water storage reservoirs and/or oil interceptors, are connected to the WSC sewage network.

Developers are obliged to check with the Manager region Office WSC for the invert level of the existing sewer and the provision of water up to the new level where water tanks shall be installed by sending an e-mail to region.consultations@wsc.com.mt, requesting this information.

For Class Orders: 3a, 3b, 4b, 4c, 4d, 5a, 5b, 5c, 6a, 6b, developers are requested to submit floor plans (1:100) of the drainage system (rainwater and wastewater) to the Discharge Permit Unit, or via e-mail at dpu.consultations@wsc.com.mt.

Developers are advised to view requirements in:

1. Sewage Discharge Control Regulations S.L. 545.08.

2. L.N 29/10 Part III (Roads in inhabited Areas) Clause 12.

3. DC 2015 Clause 4.3.3 Provision of Water Reservoirs and Second-Class Water Policy P47.

4. Building Regulations Technical Guide Document F where these apply to the proposed Development

Figure 45:

WSC standard response to development planning applications: note item 4

2. A Water Policy for the Maltese Islands – Sustainable Management of Water Resources, June 2012[21]

This document presented the Government's framework of action in the water sector and the priority areas which need to be addressed for the sustainable management of water resources. It outlined key objectives and policy statements for this sector for the period 2010 - 2015. Among others, it promoted the full utilization of non-conventional sources of water, which includes stormwater. Indeed, **Policy Area 5** was dedicated exclusively to rainwater harvesting with policies aimed at a better use of rainfall to address these issues on a local and national scale and to increase infiltration of rainfall to recharge the aquifers. It also sought opportunities for capturing and storing rainfall water in cisterns and reservoirs, and to continue and intensify efforts to promote the practice of harvesting rainwater to increase the available storage capacity. The main measures proposed in this area included:

- The need for health and safety standards and codes of practice for the safe use of harvested rainwater;
- A review of the existing legislative framework and alignment of building regulations and planning policies in order to ensure appropriate level of enforcement of legislative provisions related to the construction of rainwater harvesting facilities in new developments and use of rainwater;
- The need for the better utilization of rainwater, but with due attention to be given to the selection and building of the most cost-effectiveness technologies;
- Grants for to the construction and rehabilitation of rainwater harvesting systems on farms, in private residences and in industry; and,
- The integration, where possible, of runoff storage or artificial recharge facilities in flood-relief initiatives (with due consideration of the location of the artificial recharge sites and the quality of the inflowing water).

3. National Climate Change Adaptation Strategy, May 2012[22]

The National Climate Change Adaptation Strategy was drafted by the Climate Change Committee appointed in August 2009 and adopted in May 2012. The Strategy includes recommendations on how Malta could adapt to the impacts of Climate Change, including impacts on water. Indeed, out of the 85 recommendations, 26 (Recommendations **26** to **52**) relate to water. Among these, a significant number specifically address stormwater.

Recommendations **30**, **32** and **33** propose grant schemes directed towards the construction or rehabilitation of existing reservoirs to capture rainwater for use in agriculture, industry, commercial entities, and residences.

Recommendation **35** addresses the issue of enforcement of the legal provisions that mandate that buildings must have rainwater capture reservoirs or wells. It also recommends the introduction of a one-off Flood Fine on those properties that do not have rainwater cisterns

[21] https://www.parlament.mt/media/72581/10177.pdf

[22] https://environment.gov.mt/en/Documents/Downloads/maltaClimateChangeAdaptationStrategy/nationalAdaptationStrategy.pdf

and are therefore contributing to floods during every storm event. The revenue collected thereof would finance the upkeep of flood mitigation infrastructure such as roadside reservoirs, soakaways, and dams.

Recommendation **36** suggests that water for landscaping projects should only come from harvested rainwater, not groundwater.

The Strategy also presents targets (Recommendation **37**) for the re-use of captured rainwater (and recycled greywater) to 2 million m^3/year until 2020, going up to 3 million m^3/year in 2030.

Recommendations **42** and **43** propose measures that aim to restore the performance of dams in valleys for flood mitigation and aquifer recharge.

Recommendation **45** proposes the carrying out of a cost benefit assessment to study the impact of a 100% and 150% increase in rainwater harvesting infrastructure to be carried out between 2014 - 2021 and 2022 - 2029. It further recommends a thorough review of the status of existing stormwater reservoirs, soakaways and dams be carried out with urgency, together with the appropriate cost-benefit assessments.

With regards to the construction of roads and road landscaping projects, the Strategy recommends that the designs for said works include reservoirs to act as water catchment areas to cushion flooding as well as allow for the seepage of such water into the aquifer and should seek to progressively increase the number of existing soakaways along the road infrastructure in such a way as to divide catchments into manageable smaller sub-catchments which allow for recharge of the aquifer (Recommendation **46**).

Recommendation **51** proposes that the relevant authorities continue with the studies underway to determine whether the artificial recharge of aquifers in Malta are technically and financially feasible.

4. The 2nd Water Catchment Management Plan for the Malta Water Catchment District 2015 – 2021[23]

The2nd Water Catchment Management Plan (2nd WCMP) sets out ways how to protect, improve and restore the water environment and addresses surface waters (coastal waters and waters found in valleys, streams, and springs) and groundwaters. The 2nd WCMP updates Malta's 1st WCMP issued in 2010 and continues to develop the programme of measures required to achieve the environmental objectives set under the 1st WCMP. The driving force is the consolidated EU Water Framework Directive (2000/60/EC) (WFD) which seeks to achieve good status for all water bodies The WFD is transposed into national legislation by the Water Policy Framework Regulations.

The 2nd WCMP has legal value and a political aim to give directions and objectives to be achieved in the field of water management by administrative bodies, the local authorities, and the general public.

[23] https://era.org.mt/wp-content/uploads/2019/05/2nd_Water_Catchment_Management_Plan-Malta_Water_in_Maltese_Islands.pdf

Section 9 of the 2nd WCMP (Measures required to improve and protect our waters) lists and describes measures (actions/projects/studies) that were envisaged at various dates starting from 2015.

With respect to stormwater management, the following measures are of particular interest:

RWH1 – Survey on the status of existing rainwater harvesting infrastructure, identification of potential users of rainwater harvested in these infrastructures, undertaking of rehabilitation works and development of a management framework to ensure the effective use of harvested rainwater. The implementation of this measure was envisaged to start in 2017.

RWH2 – Development of the administrative capacity required to ensure the effective implementation of current legislative requirements in relation to the development of rainwater harvesting facilities and associated secondary water conveyance systems. This calls for the effective implementation of the regulatory requirements outlined under Technical Document F Part 1: Minimum Energy Performance Requirements for buildings in Malta, following a technical review of existing legislation that would be undertaken to optimise the storage requirements for rainwater harvesting cisterns in view of existing constant-use scenarios as opposed to the needs for a carrying over capacity from the wet to dry season. It is envisaged that this review could result in lower storage requirements, and thus lower the economic impact to users related to the development of these facilities.

RWH4 – Support schemes for the development of rainwater runoff harvesting facilities in the agricultural and commercial sectors. The agricultural sector is highly dependent on groundwater, which is the main source for irrigation water, followed by harvested rainwater and treated sewage effluent. Promoting alternative sources for irrigation water is key to reduce groundwater abstraction for irrigation, whilst maintaining the operational capacity of the sector. There is still good potential for rainwater harvesting especially from rural roads and tracks to provide an irrigation alternative to groundwater.

RWH6 – Rehabilitation of existing rainwater harvesting dam structures in valleys. Valleys provide the lowest terrain of a water catchment and as such are very important for natural recharge. The restoration of dams is therefore conducive towards this aim as it would augment infiltration of harvested rainwater. This measure would seek the development of a valley management master plan which would regulate the long-term rehabilitation of rainwater runoff storage areas behind valley dam structures whilst ensuring the necessary level of protection to the valley ecosystem.

With regards to flooding, the following measures of the 2nd WCMP are of particular interest:

FLD1 – Modelling the impact of the National Flood Relief Project on flood hazard and risk in identified catchments.

FLD2 – Flood Hazard and Risk Assessment in catchments not included in the National Flood Relief Project.

FLD3 recognises that the diversification of the tools available to manage rainwater runoff is an important aspect of any integrated flood management strategy. This measure involves the carrying out of a comprehensive assessment for the inclusion of Sustainable Urban Drainage Systems (SuDS) and Natural Water Retention Measures to mitigate flood hazard and risk. This measure seeks the development of a master plan identifying the potential inclusion of Sustainable Urban Drainage Systems and National Water Retention Measures as environmentally friendly flood mitigation measures. The master plan would identify key measures and projects where the introduction of such measures can be undertaken on a national level. Furthermore, the development of a guidance document to better guide the adoption of these measures would be developed.

FLD5 - Implementation of Sustainable Urban Drainage Systems and Natural Water Retention Measures complements **FLD3**. The implementation of the plans developed under measure **FLD3** is important to ensure that the full potential of these alternative rainwater runoff management systems is harnessed. The implementation of this measure would be coordinated with Local Councils to increase the appreciation of these sustainable water management systems in the local context. Project implementation would be prioritised according to the project mitigation potential, both from a quantitative perspective (reduction in rainwater runoff generation) and the impact on the population and economic activities in the catchment.

From the aspect of good water governance, measure **GVN3** addresses the lack of knowledge on water efficiency and water conservation and therefore advocates the development of guidance documents to assist operators in achieving best practice in water management practices. The guidance documents would aim to develop a knowledgeable operation supported by proper documentation (manuals) to enable proper use and avert wastage. The current GSI Manual is one of these guidance documents.

The responsibility for the implementation of these measures falls under more than one Body Corporate/Department/Authority/Agency etc. **Appendix 10.04** lists the Body Corporates/Departments/Authorities/Agencies etc. that are to a higher or lesser degree involved in stormwater management and describes their responsibilities.

7.00

How to Calculate Runoff

To properly manage the stormwater generated by a catchment area, it is necessary to have an estimate of:

- The ***volume*** of runoff over a period of time (e.g., a year) and
- The ***rate*** of precipitation.

1. Calculating Runoff Volumes

The volume is important if the rainwater is to be collected and used as a resource. It is advantageous to design drainage systems that capture and use surface water because this helps to reduce runoff volumes from the site and allows this valuable resource (water) to be put to good use. Rainfall is likely to become an even more valuable resource in the future, as freshwater becomes more scarce, due to climate change and population growth. The volume of runoff that would be generated on a cover type can be calculated using the following formula:

Runoff Volume (cubic metres) =

[Runoff Coefficient] x [precipitation, in metres] x [catchment area in metres squared]

This formula has three components:

A. Runoff Coefficient

The Runoff Coefficients for different cover types in Malta are shown in **Figure 46**. The values range between 0.1 for terraced fields (which are flat, absorb and retain water and soil) to 0.9 for flat impervious roofs with a slope to quickly drain the water away.

Runoff Coefficients for Different Cover Types	
Roof	0.9
Asphaltic and concrete road	0.85
Pervious pavement (concrete blocks)	0.4
Gravel Road	0.7
Paved areas	0.9
Flat grass	0.15
Grass on medium slope	0.2
Grass on steep slope	0.25
Garigue	0.15
Green roofs, intensive	0.35
Green roofs, extensive	0.65
Terraced fields	0.1
Urban soils	0.2
Unused bare land	0.25

Figure 46:

Runoff Coefficients for different surfaces in Malta

B. Precipitation (Annual, Monthly, etc.)

The mean annual precipitation in Malta over the period 1961 – 1990 was 553 mm. **Figure 47** shows the mean monthly precipitation, maximum and occurrence during the period 1922 – 2010.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly precipitation (mm)	87.75	60.53	42.73	22.10	9.92	3.12	0.49	7.31	42.94	86.28	87.73	102.48
Highest monthly precipitation (mm)	248.20	187.90	178.00	118.40	49.10	76.20	18.00	155.50	266.90	476.50	420.30	302.60
Year of highest monthly precipitation (mm)	2009	1965	1925	1994	1976	2007	1959	1964	1997	1951	1999	1970

Data collected by the Malta Airport MetOffice

Figure 47: Mean monthly precipitation, maximum and occurrence during the period 1922 - 2010 (The Climate of Malta: statistics, trends and analysis 1951 - 2010, NSO)

C. Catchment Area

The catchment area is the planimetric surface area in m^2.

Calculation Example:

The volume of water that can be collected from a flat roof measuring 100 m^2 over a year is:

$$\text{Volume of runoff} = [0.9] \times [0.553] \times [100]\ m^3$$

$$\text{Volume of runoff} = 49.77\ m^3$$

To put this figure in perspective, a typical citizen uses 33 m^3 of water per year, for showering, flushing toilets, dish washing, washing clothes etc.

More complex projects may require separate computations for runoff volumes to arrive at a total volume of water that can be harvested. For example, for a public garden with a footprint of 6000 m^2, of which 4000 m^2 are landscaped, and the remaining 2000 m^2 made up of pavements and hard surfaces, the estimate for the total annual volume of runoff generated is:

$$= [0.2] \times [0.553] \times [4000]\ m^3 + [0.9] \times [0.553] \times [2000]\ m^3$$

$$= 995.40\ m^3$$

2. Calculating Runoff Flow Rates

There are several methods to determine the runoff flow rate especially for large catchments.

A basic widely used method is the Modified Rational Method[24]. For the great majority of cases encountered locally for individual sites, the simplified version of the Modified Rational Method formula can be used, namely:

$$\mathbf{Q = [\ C\ ] \times [\ i\ ] \times [\ A\ ] / 3600}$$

where:

- Q is the flow in litres per second,
- C is the dimensionless runoff coefficient,
- i is the intensity of rainfall in mm per hour, and

[24] https://learn.hydrologystudio.com/hydrology-studio/knowledge-base/modified-rational-method-step-by-step/

- A is the area collecting rainfall in square metres (m^2).

For calculations for a one-hour storm with a 5-year return period, one could adopt the respective intensity which is **45 mm/hr** (see **Figure 42** in **Chapter 6.04**). Higher values can be adopted for more intense storm events.

This formula is particularly useful to calculate the volume of runoff at a collecting point e.g., at the inlet to a collecting grating. It is conservative since it does not attenuate the rainfall involving a time of concentration i.e., it assumes all the rainfall arrives instantaneously at the point of outlet.

Runoff Flow Rate from a typical 100 m^2 roof in Malta

For the one-hour storm with a 5-year return period, the design flow rate Q would be:

$$Q = [0.9] \times [45] \times [100] / 3600 \text{ litres/second}$$

$$Q = 1.125 \quad \text{litres per second}$$

This will provide a rough preliminary estimate on the flow rates to be expected and therefore on the sizing of the drainage system and the GSI to be selected and installed.

Other methods, entailing the use of computer programs and models, have a number of assumptions or simplifications of the situation on the ground to approximate reality.

Modelling of catchments implies some form of verification of the results, which is done by calibration; the input rainfall event is measured (in practice, a simplified synthetic rain pattern is used), and the stream flow at defined points in the catchment collected and compared with the model results. Assumptions on the catchment characteristics may need to be adjusted and a number of observations taken in order to attain a good model reflecting the behaviour of a large catchment. The situation becomes more complex when looking at the catchment response in time, and not just modelling the peak inflow and outflow. Moreover, the estimations of ground absorbance (run-off coefficients) need to be examined in detail.

These modelling methods include:

- the **SCS-CN** method (The US Soil Conservation Service (US) Curve Number (CN) Method), which involves the determination of CN Curve Number (CN) which takes into account the soil-vegetation-land use complex of the catchment and the antecedent soil moisture condition in the catchment just prior to the commencement of the rainfall event; and,

- the **Synthetic Triangular Hydrograph** method, which is derived from theory and experience, and its purpose is to simulate basin diffusion by estimating the basin lag based on a certain formula or procedure.

There are many computer programs such as **HEC-HMS**, **SWMM, MIKE+, OpenFlows Flood, InfoWorks,** etc. which all can model catchments behaviour under various flow scenarios to give simulations of reality.

Such approaches are valid in large catchments say over 2,000 m^2, and not adopting such methods for large catchments can lead to gross over estimations of results.

8.01

GSI Techniques – Rainwater Harvesting (RWH) Systems

Rainwater harvesting (RWH) is the collection of rainwater runoff for use. Runoff can be collected from roofs and other impervious areas, stored, treated (where required) and then used as a supply of water.

RWH systems have several key benefits such as:

- They can meet some of the building's total water demand, by meeting part/all of the building's requirement for second-class (non-potable) water;
- They can help reduce the disposal of runoff from a site, and reduce flooding; and,
- They can provide an emergency source of water in times of drought or extreme water scarcity, or for firefighting.

The collected water can generally be used for a range of non-potable purposes, such as flushing toilets, laundry, external uses such as car washing and irrigation, and for the filling and topping-up of pools. In a typical Maltese household, the demand for second-class water may account for as much as half the total water demand; more in the case of properties having a garden and/or a pool.

Figure 48 shows a schematic diagram of a typical RWH system, where rain falling on roofs (and external paved areas of buildings) is channeled by gravity to a below-ground cistern, where it is stored and then pumped for use as non-potable water within the same building.

Debris carried over from the roofs settles at the bottom of the cistern and accumulates over time, requiring removal. Provided that the roofs are not accessible by pets, used for the storage of potentially hazardous material, and there is no ingress of sewage into the cistern, the collected water can be safely used as second-class water without treatment.

The pump can be a surface or submersible one and can deliver water at pressure to the user points (e.g., toilets) or used to fill a tank which then feeds the user points by gravity. In the latter case, the water level in the tank is maintained by a mechanical or an electrical control system which switches on the pump when the water level in the tank falls below a preset level.

Guidelines for the Use of Harvested Rainwater

The Regulator for Energy and Water Services (REWS) provides guidelines[25] on the use (and limitation on use) of rainwater. These include:

[25] Guidelines for the use of domestic well water – Regulator for Energy and Water Services (REWS) https://www.rews.org.mt/#/en/rewsfa/74

- Untreated rainwater is not recommended for drinking due to the presence of microbiological contaminants. In general, it is recommended that it is not used where there is the possibility of direct contact with the skin, i.e., personal hygiene and consumption etc.

- Certain secondary uses such as flushing toilets, laundry, washing of floors or irrigation can be carried out without any significant health hazard subject to a number of plumbing safeguards and prevention of contamination.

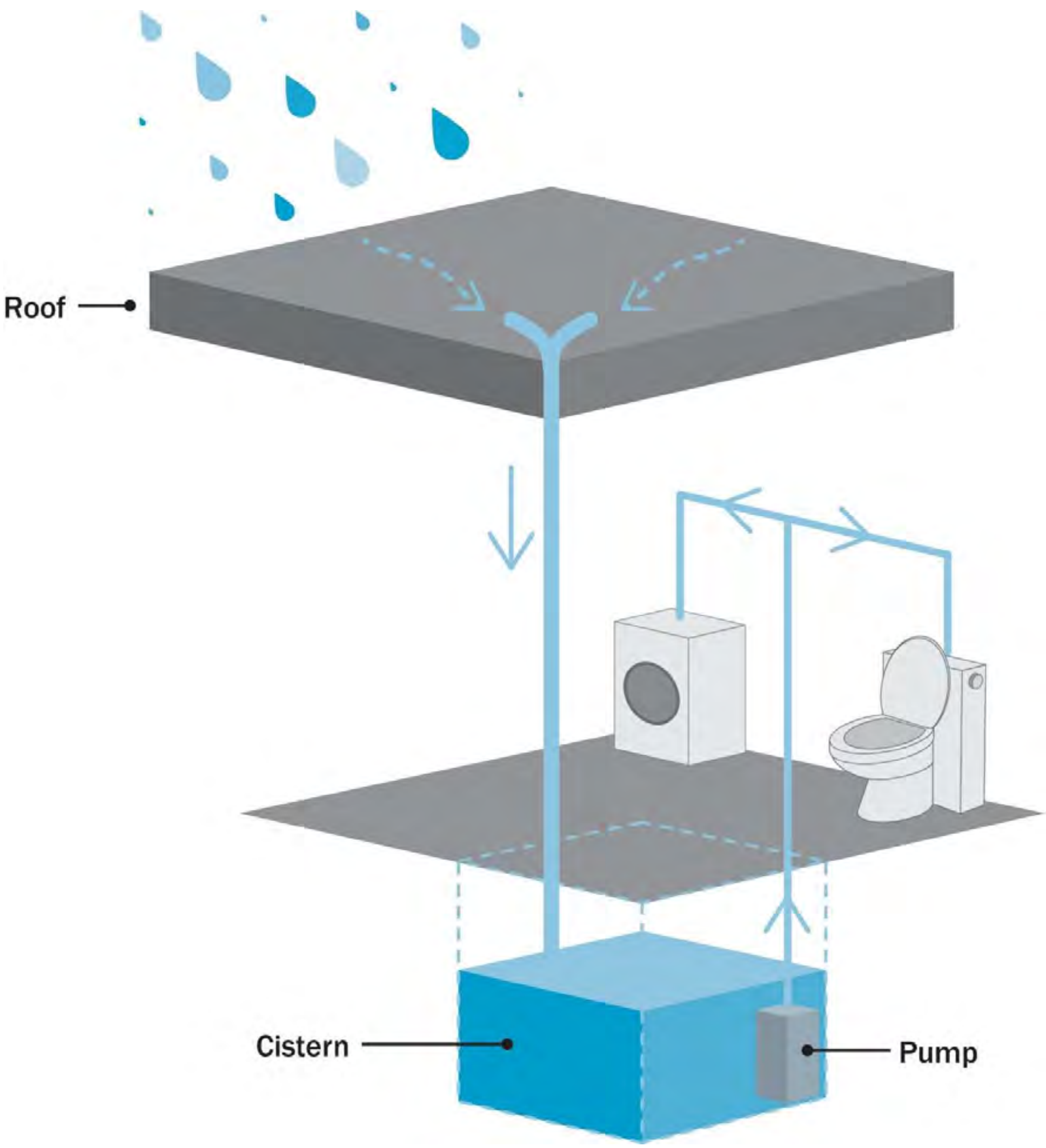


Figure 48: A typical rainwater harvesting system schematic

Nevertheless, even when used for secondary purposes, REWS warns that specific problems include:

- Presence of foreign matter including small animals, plant residues etc. which may enter cisterns due to defective screens or covers and can be a source of taste, odour and colour problems;
- Unacceptable bacteriological counts due to the presence of bird and animal excreta;
- Elevated concentrations of iron and lead due to corrosion of tanks or from paints with high lead content used for rainwater collection. Paints and lime linings which have not been allowed to dry and harden properly have been found to produce highly alkaline water which can result in skin irritations; and,
- Stagnated water. Stored water tends to be more stagnated particularly if not in continual use.

Optimization of the Sizing of Cisterns in Buildings

In Malta, RWH systems are installed in buildings because:

- The building's owners recognise the requirement of second-class water, which can be adequately met through the collection of rainwater. (In the recent past, when security of mains water supply was an issue, RWH provided an emergency supply of water until the mains water supply was restored), and/or

- Of the mandatory requirement.

Much of the costs of a RWH system are related to the provision of the water storage component i.e., the cistern. The costs of the pump, power controls and pipework are relatively low in comparison to the water storage component. The cost of the cistern, in turn, depends on its size.

The sizing of a cistern is a function of:

- The area contributing runoff to the cistern;
- The local seasonal rainfall characteristics;
- The usage of it;
- The rates of usage.

Another parameter is the runoff coefficient.

The minimum sizing of cisterns in buildings are prescribed by Document F Part 1: Minimum Energy Performance Requirements for buildings in Malta, which calculation is based on the roof area and factors of 0.6 and 0.45) (**Figure 49**).

Document F – Conservation of Fuel, Energy and Natural Resources
(Minimum requirements on the Energy Performance of Buildings Regulations, 2006)

Size of well or cistern **Table F.10**

Building Type	Size of cistern (m^3)
1. Domestic dwellings (inc. Apartment blocks)	Total roof area (m^2) x 0.6m
2. Hotels, Schools, Offices, Factories, Industrial buildings and Hospitals	Total roof area (m^2) x 0.6m
3. Shops and showrooms, and places of public gathering and entertainment not integrated in 2 above	Total roof area (m^2) x 0.45m
4. External paved areas (inc. open terraces and balconies) *	Total paved area (m^2) x 0.6m

***Note:**

This requirement applies only if the total open paved area is greater than 300sq.m

Figure 49: Document F Part 1 sizing of cisterns

While this method is easy to design a RWH systems in buildings, the ensuing calculations result in oversized storage capacities, entailing the construction of large (and expensive) storage volumes with the consequence that RWH systems are being disregarded among building developers, owners and users. Unfortunately, in the lack of enforcement of the RWH regulations, this has resulted in fewer RWH systems being constructed in the last years (refer to **Appendix 10.05** for details).

It has been recognised among stakeholders that optimization of the sizing of RWH in buildings was required.

Measure **RWH2** in the 2nd WCMP stipulates the need for "a technical review of existing legislation …. be undertaken to optimise the storage requirements for rainwater harvesting cisterns in view of existing constant-use scenarios as opposed to the needs for a carrying over capacity from the wet to dry season. It is envisaged that this review could result in lower storage requirements, and thus lower the economic impact to users related to the development of these facilities".

Internationally, there exist a variety of models for calculating the optimum size of a RWH system, varying from the Simple Model (which uses average annual rainfall, building occupancy rate, estimated consumption figures for non-potable water (which vary for residential and commercial buildings) to more accurate calculations that require the pattern of demand to be modelled, together with a continuous rainfall time series and runoff model. The latter enables temporal patterns of supply, storage, and demand to be predicted, together with frequencies of overflow operation and supply shortfall. However, these approaches do not work for Malta because:

- The Simple Model assumes almost-constant monthly precipitation, which is certainly not the case in Malta, with wet autumns/winters and very dry late-springs/summers; and,
- The more sophisticated calculations are beyond the scope of this Manual and require the input of an expert.

For this reason, an optimised spreadsheet is developed to calculate the optimum cistern size for buildings in Malta based on:

- Default values for mean monthly precipitation (see **Figure 50**), runoff coefficients, toilet water consumption per capita per day (estimated at 21 litres in a household or office); and,
- User inputs relating to size of household (in the case of a single residential building), number and occupancy of apartments (in the case of a block of apartments), number of employees (in the case of an office, commercial or industrial building), and number and occupancy of beds (in the case of a hotel)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly precipitation (mm)	87.75	60.53	42.73	22.10	9.92	3.12	0.49	7.31	42.94	86.28	87.73	102.48
Highest monthly precipitation (mm)	248.20	187.90	178.00	118.40	49.10	76.20	18.00	155.50	266.90	476.50	420.30	302.60
Year of highest monthly precipitation (mm)	2009	1965	1925	1994	1976	2007	1959	1964	1997	1951	1999	1970

Data collected by the Malta Airport MetOffice

Figure 50: Mean monthly precipitation, maximum and occurrence during the period 1922 - 2010 (The Climate of Malta: statistics, trends and analysis 1951 - 2010, NSO)

The spreadsheet calculates the monthly demand for second-class water starting from the start of the rainy season (1st September). It also calculates the monthly collected runoff, offsetting one against the other to establish whether there is a water deficit or surplus every month, and at the end of the year.

In situations where the volume of runoff collected over a year exceeds the annual demand (for second-class water), the optimum capacity of the cistern is the cumulative monthly deficit of second-class water in the summer months. Such size of cistern would suffice for the demand. The surplus runoff would have to managed additionally.

However, in situations where the annual demand for second-class water exceeds the volume of runoff collected over a year, then the optimum capacity of the cistern is calculated on the basis of the cumulative monthly surplus during the winter months. Such size of cistern would ensure that all surplus water in winter is collected and made full use of during the summer months.

The optimum sizing of a cistern for a number of case studies are presented in **Appendix 10.02** and are summarised below:

Case Study 1A: 4-person occupied Townhouse without a garden, 140 m^2 roof area, rainwater used for flushing toilets and laundry

Supply > demand, Optimum cistern capacity = 15.1 m^3 (equivalent to 'Doc F factor' of 0.11 based on cumulative summer deficit), 70% utilisation of collected runoff, 30% surplus runoff.

Case Study 1B: 4-person occupied Townhouse with 70 m^2 garden, 140 m^2 roof area, rainwater used for flushing toilets, laundry and irrigation

Demand > supply, Optimum cistern capacity = 23.5 m^3 (equivalent to a 'Doc F factor' of 0.17 based on cumulative surplus), Full utilisation of collected runoff.

Case Study 2: Block of 15 apartments, 2-person per apartment, 270 m^2 roof area, 70% occupancy, rainwater used for flushing toilets

Demand > supply, Optimum cistern capacity = 36.6 m^3 (equivalent to a Doc F factor of 0.14 based on cumulative surplus), Full utilisation of collected runoff.

Case Study 3: Office Block, 1200 m^2 roof area, 120 employees, 80% occupancy, rainwater used for flushing toilets, floor washing, fire-fighting drills

Supply > demand, Optimum cistern capacity = 206.9 m^3 (equivalent to a 'Doc F factor' of 0.17 based on cumulative summer deficit), 97% utilisation of collected runoff, 3% surplus runoff.

Case Study 4A: Manufacturing facility/warehouse 2500 m^2 roof area, 30 employees, rainwater used for flushing toilets

Supply > demand, Optimum cistern capacity = 19.3 m^3 (equivalent to a 'Doc F factor' of 0.01 based on cumulative summer deficit), 13% utilisation of collected runoff, 87% surplus runoff.

Case Study 4B: Manufacturing facility/warehouse 2500 m^2 roof area, 30 employees, rainwater used for flushing toilets and processing

Demand > supply, Optimum cistern capacity = 348.5 m^3 (equivalent to a 'Doc F factor' of 0.14 based on cumulative surplus), full utilisation of collected runoff.

Case Study 5: Public Garden with 6200 m^2 of soft landscaped area and 2300 m^2 hard-surfaced area, rainwater used for irrigation

Demand > supply, Optimum cistern capacity = 396.1 m^3 (equivalent to a 'Doc F factor' of 0.06 based on cumulative surplus), full utilisation of collected runoff.

Case Study 6: Hotel of 800 beds, seasonal occupancy, rainwater used for flushing toilets

Supply > demand, Optimum cistern capacity = 957.5 m^3 (equivalent to a 'Doc F factor' of 0.05 (based on cumulative summer deficit), 59% utilisation of collected runoff, 41% surplus runoff.

If the same hotel utilises second-class water for irrigation or filling pools, demand > supply, Optimum cistern capacity = 5,040.8 m^3 (equivalent to a 'Doc F factor' of 0.25 based on cumulative surplus), full utilisation of collected runoff.

As can be seen from these case studies, the calculated 'Doc F factors' tend to converge towards 0.15 - 0.20 in all cases, except for extreme situations where:

- There is limited demand for second-class water when compared to the supply (e.g., case study 4A manufacturing facility with no demand for rainwater as process water) where the calculated 'Doc F factor' is only 0.01;
- When the second-class water demand is huge when compared to the supply (e.g., case study 5 public garden) where the calculated 'Doc F factor' is 0.06); and
- When the second-class water demand is huge in summer and large volumes of runoff are collected (e.g., case study 6 hotel without need for irrigation or filling pools) where the calculated 'Doc F factor' is 0.25.

The reduction in cistern capacity from the current regulatory requirement is substantial, by as much as 66% to 75%.

Passive and Active RWH systems

It should be mentioned that the optimised calculations are based on passive systems. The term "passive" refers to the fact that the space available in the cistern/reservoir to store runoff at any particular time is entirely dependent on the balance between the demand and supply, and the water level is not managed actively. Active systems are alerted when a heavy event is approaching (days or hours ahead) and pump out the stored water down to a set level whenever a threshold is exceeded.

RWH systems for runoff management are designed to capture a specific depth of rainfall. They therefore only contribute to extreme event flow management during the initial stages of extended extreme events and during high intensity, short duration rainfall when site drainage systems are overwhelmed while the RWH tanks are still capturing and storing runoff.

Treatment of Collected runoff for Use

RWH systems collecting runoff from roofs should deliver a water quality that is suitable for applications such as flushing toilets, laundry and irrigation. Runoff that contains a high pollutant loading (e.g., a high degree of sediments, heavy metals or animal faeces) may only be appropriate for use after treatment. The treatment of harvested runoff may be required where the usage-specific risk assessment indicates the need for a specific water quality.

Treatment measures include pre-treatment, settling, filtration, biological treatment, and disinfection. The water should be kept cool, which is the case with underground cisterns.

Special care should be taken of water from tanks exposed to elevated temperatures due to bacterial growth. Rainwater does not contain salts, hardness (unlike groundwater) or chlorine (unlike mains water) and is ideal for irrigation.

Construction Considerations

Rainwater Drainage

- The capacity of the system should be adequate to carry the anticipated flows at each part of the system.
- The system should be of appropriate materials to conduct water from roofs or other areas to a cistern without contributing to dampness in any part of the building or adjoining building.
- Roof falls should be sufficient to prevent the build-up of water on roofs and should direct the water to sufficient channels and outlets as appropriate. Falls of between 1:80 and 1:100 are recommended.
- Rainwater pipes may discharge onto another gutter or surface provided that the latter is also drained and has the capacity to deal with the combined runoff.
- Rainwater pipes and their fittings should be appropriate for their purpose and should be fixed to the external face of the walls of buildings.
- Where it is necessary to introduce rainwater pipes within buildings, they should be completely accessible and should not be embedded within walls or passed through inaccessible wall cavities.

Cisterns/Storage Tanks

- Storage tanks or cisterns should be placed/installed in a safe, secure location, either underground, indoors, on roofs, or adjacent to buildings with easy accessibility for maintenance. Underground installations are preferred as they tend to have improved performance with respect to the control of water temperature, reducing bacterial growth in summer. Where the tank has to be installed close to a building, structural considerations, such as the depth of the foundations and the watertightness and its overflow provision, are particularly important. The presence of underground utilities may also constrain the location of the tank.

- The watertightness of the underground cistern should be tested to ensure that rainwater does not flow out and potentially contaminated water (e.g., sewage) does not seep into the cistern.

Interception traps

Rainwater should be led into the cistern through an interception trap consisting of one or more chambers designed to settle out pollutants from the rainwater prior to its being stored within the cistern.

Access

Safe access for inspection and cleaning the cistern is to be provided by means of suitable non-ferrous step irons, ladders or steps incorporated into the structure.

Application summary

- Collection of runoff from roofs of buildings (small or large);
- Ideal when there is a need for second-class water (and preferably all year-round use as this results in a reduced storage component);
- Ideal for irrigation because of the low salinity of runoff when compared to groundwater;
- Preferably where the building/site is supervised;
- Mostly new build (retrofitting is possible but limited);
- Collection of runoff from impervious surfaces (small or large), but pre-treatment (sedimentation pit or oil-water separator) may be required (to be determined on a case-by-case basis).

8.02

GSI Techniques – Green Roofs

Green roofs have been found to be eminently effective even in the local climate. Roof gardens made up of potted plants which are becoming increasingly common locally are not considered as Green Roofs, however even they can offer elements of the GSI of Green Roofs, such as incident water absorption and ambient cooling. Green Roofs are intended primarily for interception storage within the vegetation and also the substrate. Diagrammatically the set-up is as per **Figure 51**.

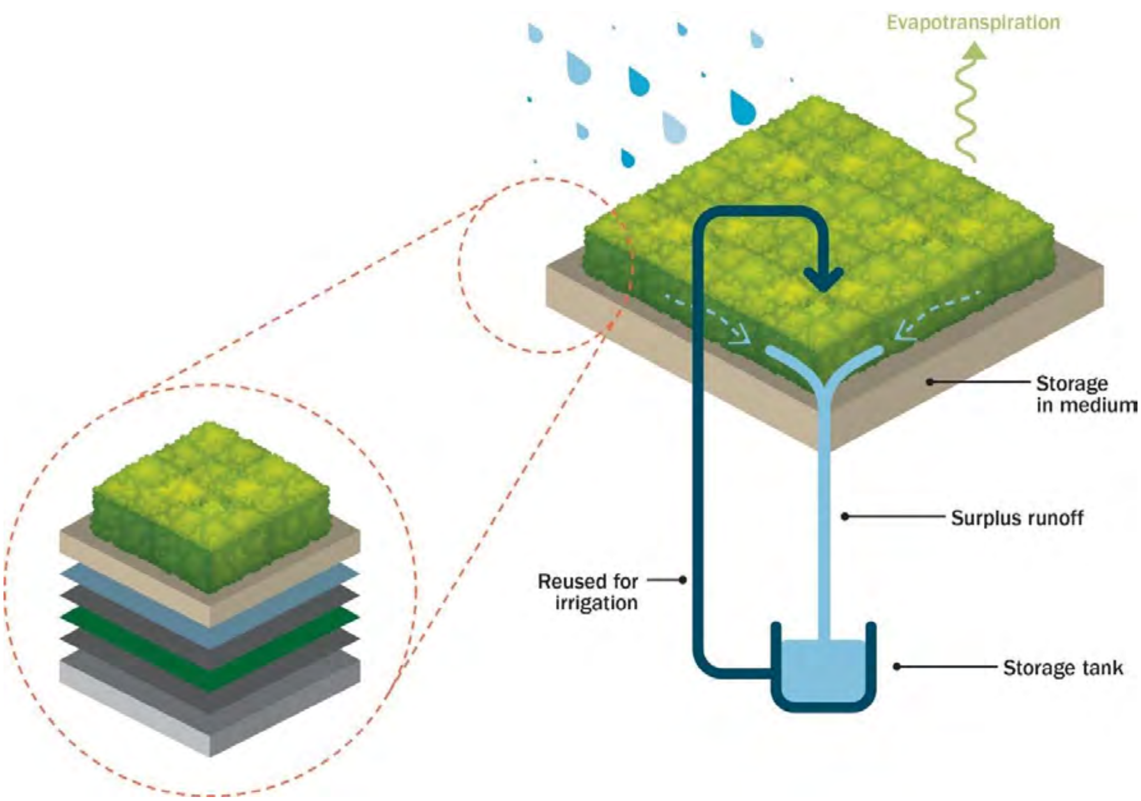


Figure 51: Diagram of green roof performance and operation

Sufficient local research has been carried out, especially at the University of Malta, to establish a local Malta standard which is to be followed in any implementation[26].The following points are useful guidance:

- Optimum roof pitch of 1 in 50;

---

[26] SM 3700:2017 Green Roofs - Criteria for the planning, construction, control and maintenance of Green Roofs MCCAA

- Multiple outlets with inspection boxes to reduce risk from blockages;
- Lightweight engineered substrate and appropriate vegetation;
- There are two types: extensive and intensive;
- Extensive green roofs are not usually accessible. Locally they are 100 – 150 mm thick, lightweight, cheap, suitable for retrofits;
- The use of species such as the native *Sedium sediforme*[27] will require little or no need for irrigation at a minimum100mm depth of substrate;
- Intensive green roofs are usually accessible as public spaces/gardens. They have deeper substrates, higher maintenance requirements, and have good water retention capacity.
- Falls for the green roofs must be consistently graded without deflections or depressions.
- A high quality, robust waterproofing layer is required and is vital. The layer should be certified for use on green roofs to resist root penetration, etc.

The surplus runoff (i.e., rainwater that is not retained by the green roof) can be collected after settling out of suspended particles and re-used in the same green roof. Various layouts can be used to accommodate a green roof for installation of photo-voltaic (PV) modules to harness solar energy. The main constraint is Policy P48 which requires PV modules on roofs not to rise more than the height of 1 metre set by a boundary screen wall at roof level[28] (**Figure 52**). Although some plants on green roofs grow under elevated PV modules, maintenance logic strongly suggests that separate spaces for each of these uses be thought out and planned accordingly.

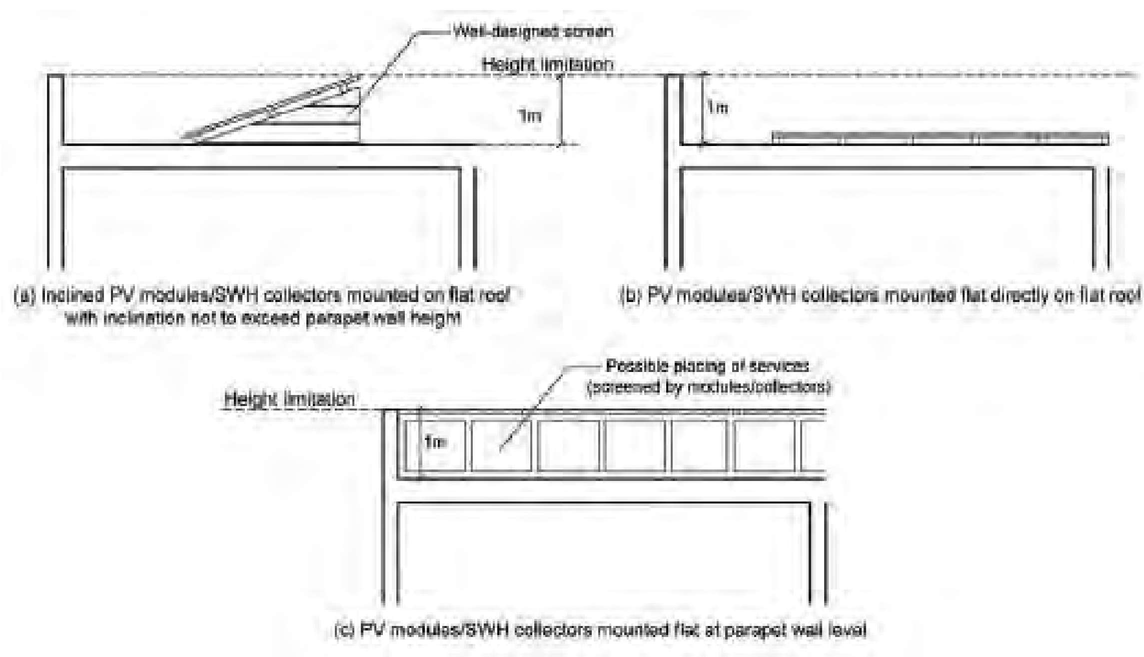


Figure 52: DC 15 Policy P38 options for PV modules on roofs (MEPA)

27 http://www.llifle.com/Encyclopedia/SUCCULENTS/Family/Crassulaceae/33770/Sedum_sediforme
28 Development Control Design Policy, Guidance and Standards – MEPA 2015

Some successful recent local green roof developments are shown in **Figures 53**, **54**, **55** and **56**.

Figure 53:

Green roof at University of Malta

Figure 54:

Green roof at Ħas-Saptan Enemed fuel depot facility

(VIVACITY Ltd.)

Figure 55:

Close up of planting at green roof at Ħas-Saptan Enemed fuel depot facility

(VIVACITY Ltd.)

Figure 56:

Maintenance at Pollinator Garden, Palazzo Falson, Mdina

(VIVACITY Ltd.)

Application summary

- Roofs of residential and office buildings which are currently not largely used for other purposes (e.g., air drying of clothes, capture of renewable energy sources, heating, ventilation, and air conditioning equipment, etc.);
- Preferably where the roof is supervised;
- Gives value to aesthetics and sustainability;
- There is a requirement for insulation (for energy-saving);
- New build and retrofitting (especially if the existing roof lack adequate waterproofing and insulation but can take additional loads);
- Where space at ground/below-ground level is at a premium.

8.03

GSI Techniques – Infiltration Systems and Soakaways

This chapter provides guidance on systems that are specifically designed to promote infiltration of surface water into the ground.

There are many different types of infiltration systems. These include soakaways, infiltration trenches, infiltration blankets, infiltration basins and Compact Infiltration Systems (CIS) systems (the latter are described separately in **Chapter 8.12**). Bioretention systems and pervious pavements can also be designed to allow infiltration (see **Chapter 8.07** and **Chapter 8.09** respectively).

Infiltration systems deliver the dual benefits of reducing runoff rates and volumes while enhancing groundwater recharge. The rate at which water can be infiltrated depends on the infiltration capacity (permeability) of the surrounding soils/rock. The presence of joints or fissures in the rock greatly enhances the water-dissipating performance of the system.

The most common infiltration system in use in Malta is the soakaway. Soakaways are excavations that allow temporary storage of water before it soaks into the ground. As described in **Chapter 4.00**, several were constructed in the 1970s and 1980s adjacent to arterial roads to receive runoff water flowing along these roads and reduce flooding.

Figure 57 shows the operating principle of soakaways. Runoff flowing along arterial roads is directed towards the soakaway constructed in close proximity to the road. The soakaway has a design storage capacity to contain the volume of runoff generated during a specific design storm. The soakaway is designed to lose water through the floor and the sides. A catchpit may be installed before the runoff reaches the soakaway to settle out settleable solids. Sediments settle at the bottom and have to be occasionally desludged as the sludge reduces the effective volume and reduces the rate at which water seeps out of the soakaways.

Apart from soakaways, there are:

- **Infiltration trenches**, which are simply linear soakaways. The advantage of trenches over soakaways is that they can often be kept shallower and can help increase the infiltration area. However, the storage volume is generally smaller.
- **Infiltration basins**, which are flat-bottomed, shallow landscape depressions that store runoff (allowing pollutants to settle and filter out) before infiltration into the subsurface soils.
- **Infiltration blankets**, which are large shallow systems that are typically constructed using permeable aggregate or geocellular units that act as extensive soakaway systems. Examples include car parks where the storage layer is part of the car park pavement construction, recreational playgrounds or sports pitches.

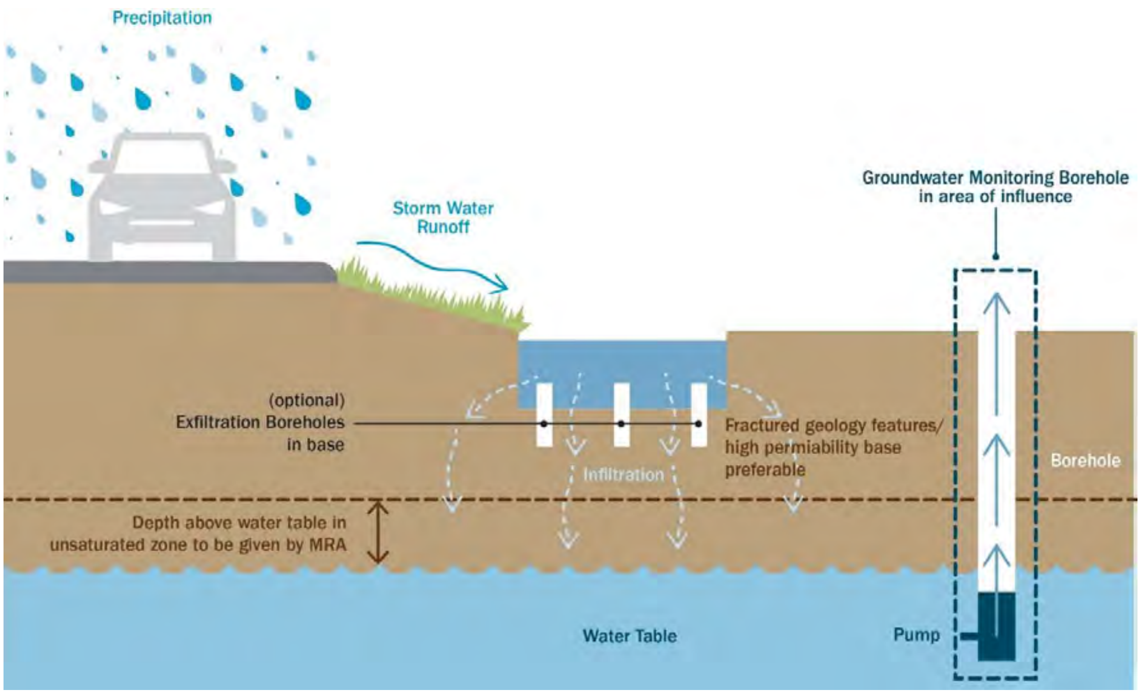


Figure 57: Diagram of soakaway

General Design Considerations

Water Quality

Infiltration systems facilitate the discharge of surface water runoff into the ground and ultimately the aquifers. It is therefore crucial that any runoff is suitable to infiltrate into the ground so that the groundwater is not put at risk of contamination. Analytical tests of runoff in a major urban catchment (Birkirkara-Msida) do not manifest levels of pollution that prohibit infiltration. ***Indirect aquifer recharge systems*** do not inject water into the saturated zone of the aquifer.

There are no legal prohibitions of the construction and operation of indirect aquifer recharge systems in Malta *per se*, and these can:

- Be built outside and within the groundwater safeguard zones and
- Be designed to handle runoff from roads, public spaces, etc. if the runoff collected thereof is not severely contaminated or can adequately be treated through the use of technologies (e.g., silt traps, oil-water separators etc.).

Nevertheless, when planning an infiltration system, a risk assessment should be carried out to:

- Determine potential contamination sources in the upstream catchment area to the stormwater management point. The risk assessment should also be carried out for small scale projects, which might lose the benefit of dilution from runoff coming from a larger catchment area.

- Confirm that the pollution load of the stormwater to be managed is low (and/or manageable with pre-treatment if necessary), and that the quality of the water recharging the aquifer meets the quality standards and threshold values listed under the EU Groundwater Directive (GWD).

Performance Considerations

The performance of an infiltration system is dependent on the infiltration capacity of the surrounding soils and bedrock, and the depth to groundwater. The depth to groundwater is usually well below the ground in most situations except for coastal areas). Effective upstream pre-treatment is required to remove sediment and silt loads to prevent long-term clogging and subsequent failure of the system.

Performance is very much dependent on the geology which, in Malta, is very heterogeneous and varies spatially and in depth. The water dissipating performance may be severely compromised in clayey/impervious environments or when there the depth to the saturated zone to the aquifer is limited. Hydrogeological should be carried out to determine the permeability of the bedrock and whether the geology is fractured, which greatly enhance the performance. In some cases, boreholes may be drilled in the bottom of the soakaway to increase the water dissipation rate.

The design process for infiltration systems should also assess the risk of dissipated water reaching and damaging below ground level buildings and foundations in the vicinity or downstream.

Soakaways constructed in low-permeability bedrock may retain water for long periods of time, with the water becoming stagnant and septic. It is recommended that soakaways in urban areas be roofed to prevent them from becoming breeding grounds for mosquitos and nuisances to the neighbourhoods. Moreover, roofed areas provide space for recreational areas, car parks, etc. Adequate access for maintenance should be provided.

Hydraulic Design

In theory, infiltration systems designed for flood prevention should be designed to manage specific storms with a 10- or 30-year return period for example. However, land, especially in urban areas, may be a limiting factor and the sizing depends on the space available rather than the desired drainage.

The infiltration component should discharge from full to half-full within a reasonable time so that the risk of it not being able to manage a subsequent rainfall event is minimised. Where components are designed to manage storms with a 10- or 30-year return period, it is usual to specify that emptying occurs within 24 hours. If the emptying is envisaged to take longer, it may be necessary to increase the storage component and weigh this cost against the risk of flooding in situations of consecutive rainfall events. In any case, an infiltration system should have an overflow above the design water storage level conveying runoff downstream.

Water should be used as second-class water as much as possible to provide the dual benefits of increasing the effective storage volume while providing a sustainable source of water.

Infiltration can play an important role in providing interception, capture and retention of the first 5 minutes of any rainfall event, even on sites with low infiltration rates.

An Example of a Functioning Soakaway in Malta – Mater Dei Hospital (MDH), **Msida**

Infiltration systems are considered to be more 'space-efficient' and more cost-efficient when compared with RWH systems. This means that, for the same footprint of construction or the same excavated volume, they are able to manage and recover significantly more stormwater.

A strategically located functioning soakaway on the side of a major thoroughfare recover multiple times the volume of water that can be harvested by a RWH system of the same volume. The method of water recovery is of course different. While the user of a RWH system derives direct benefit from the harvested rainwater, in the case of a soakaway, this benefit is transferred to the Government in the form of replenished groundwater aquifers.

The soakaway at Mater Dei Hospital (MDH), Msida is a fine functioning example. This soakaway is designed to channel all the stormwater generated onsite into the ground. The justification for this soakaway is that there is not significant demand for stormwater onsite. Irrigation water in the precincts is provided by an onsite greywater recycling system. The soakaway is excavated in Lower Globigerina Limestone. It has a large number of fissures, enabling a high infiltration capacity.

According to MDH, the water dissipation capability of the soakaway is very high, with overflow into the adjacent Wied Għollieqa only being recorded on a handful of occasions between 2002 - 2021. One such incident happened on the 25th November 2021, when 97 mm of rain was gauged in 24 hours, with most of the rain in the span of a few hours in the morning. It was reported that the soakaway drained completely within 24 hours even though it overflowed. This means that the runoff being generated from a built-up area of 140,275 m^2 is effectively drained by means of a dedicated drainage structure occupying a space of 400 m^2 equivalent to 0.28% of the total catchment area (see **Figures 58** and **59**).

Figure 58: Aerial photo of Mater Dei Hospital (MDH) with a footprint of 140,275 m^2

Figure 59: Aerial photo of the soakaway with a footprint of 400 m^2 at Mater Dei Hospital (MDH)

This GSI is practically maintenance-free, nuisance-free, has zero carbon emissions, and contributes almost 70,000 m^3 of freshwater to the aquifer every year equivalent to 175 m^3 per m^2 area.

The alternative to the MDH soakaway would have been a RWH system with a reservoir volume of 84,200 m^3 (using the 0.6 factor stipulated in Document F), equivalent to a space measuring 100 m x 100 m x 9 m deep (10,000 m^2 of area). The soakaway is 25 times more space-efficient than an equivalent RWH system when managing runoff. Nevertheless, all the collected water in a RWH system would have ended as runoff since there is no demand for it.

The MDH soakaway was tested when it was under construction in June 2002 as part of the Malta Resources Authority's (MRA) procedures then in place for the authorisation of indirect discharge to groundwater (as per Legal Notice 203/2002). Several water tankers were brought in to discharge to an empty pit which had a number of protruding well casings from the boreholes drilled in the bottom of the soakaway to aid the drainage. As can be seen from the photos (**Figures 60** and **61**), not much response was developed before a vortex developed in a location where a borehole had not been drilled (**Figure 62**) and drained 3 water tankers in a short while. The development of head is key to the efficacy of the soakaway.

Figure 60:

MDH soakaway under test

Figure 61:

Borehole wells at MDH soakaway under test

Figure 62:

Vortex development in MDH soakaway under test (in line with boreholes)

Figure 63:

2021 general view of MDH soakaway showing shrubbery in base

MDH soakaway features elements such as:

- A perimeter safety fence;
- Natural vegetation;
- A galvanised steel staircase;
- Protruding (about 300 mm) borehole casings above ground to prevent sediments from clogging the boreholes;
- An overflow to the adjacent watercourse.

The performance of the soakaway would be better monitored by the authorities with a nearby borehole/s to assess the behaviour of the water table elevation and water column quality in response to the filling and discharging cycles of the soakaway.

The soakaway at Mater Dei Hospital is clearly a success story and demonstrates the suitability of infiltration systems for relatively large buildings/sites, e.g., building/sites having a catchment area in excess of 10,000 m^2. Infiltration systems can be constructed anywhere subject to site-specific hydrogeological investigations, risk assessment and risk management.

Application summary

- Runoff generated on (relatively large > 10,000 m^2) hard-surfaced areas, which could be roofs, roads, parking areas, etc. (but can also be used to drain runoff in rural areas, in which case it will take the form of a vegetated depression);
- Where flooding is an issue (soakaways can be designed to handle large volumes of runoff from successive storms);
- Areas where the bedrock has high permeability;
- Where there is no use for the runoff within the building/site or vicinity;
- Where excavation/building of large RHS systems are difficult/expensive;
- Mostly new build (retrofitting is possible but limited);
- Management of local/regional runoff;
- Where there is no risk that infiltration water can seep into/damage neighbouring structures or structures lying downstream of the infiltration system (though this may be mitigated by proper design);
- Where there is a sufficient depth to the water table;
- Preferably new build (retrofitting may be difficult because of space/construction constraints);
- Management of runoff that is not heavily silted (if silt is an issue, pre-treatment is required);
- Where aquifers are depleting and groundwater is high in Nitrate and Chloride.

8.04

GSI Techniques – Proprietary Treatment Systems (PTS)

Proprietary treatment systems (PTS) are pre-manufactured products which remove specified pollutants from surface water runoff. They are especially useful where the site limits the use of other methods or where they offer specific benefits in contributing to a GSI design criteria. They are often (but not always) subsurface structures and can often be complementary to landscaped features, reducing pollutant levels in the runoff and protecting the amenity and/or biodiversity functionality of downstream components. They can be useful in reducing the maintenance requirements of downstream GSI or in avoiding the risk of disturbance of those areas during routine silt removal operations. Historically, they have only been considered as pre-treatment devices but they can provide a valuable function in removing pollutants from runoff and may therefore be considered as an integral part of a holistic system. PTS delivering reductions in a wide range of contaminants are available, and increasingly sophisticated proprietary systems are being developed.

Their treatment performance may also be more dependent on routine inspection or maintenance than other types or GSI. Maintenance regimes need to be robust where there is no indication when maintenance is required (such as an alarm or visibility). Where large volumes of sediment may accumulate in the system, suction equipment is usually needed to remove it and appropriate access will have to be provided.

Interception and attenuation are usually delivered separately using either surface or subsurface storage. Means of delivering amenity and biodiversity criteria may also need to be considered. The main treatment processes in the most commonly available proprietary systems are:

- Biological filtration;
- Filtration;
- Filtration and adsorption;
- Physical removal of sediment;
- Physical removal of floatables;
- Wetting and drying to promote degradation.

Figure 64 shows the various types of PTS, their descriptions, and respective treatment processes.

Proprietary systems	Description	Treatment process
Proprietary bioretention systems in structures	Filtration devices that use soils (or other filter media) and which support plants or bacterial biofilms	Filtration, adsorption, bioremediation
Treatment channels	Channels that are designed to collect and treat water rather than convey it along the channel; can include proprietary filter media within the channel; can include weir and baffles at intervals to trap oils and floatables	Physical removal of sediment, oils and floatables; wetting and drying to promote degradation
Hydrodynamic or vortex systems	Structures that use gravity and centrifugal force to separate out and collect medium-sized (50 to 250 μm) sediments and other litter or debris; smaller particles may be able to be removed by varying the flow rate into the system.	Physical removal of sediment by gravity
Proprietary filtration systems	Devices that filter water by passing it through various filter media; they are constructed in chambers and do not support vegetation.	Filtration and adsorption
Oil Separators	Structures designed to separate gross amounts of oil and large size (>250μm) suspended solids from water by allowing light non-aqueous phase liquids to float and large sediment particles to sink; many also have baffles, coalescers and oils skimmers to speed-up or enhance the performance.	Physical removal of floatables, physical removal of sediment by gravity
Multi-process	Systems that include multiple treatment process in series	Various

Figure 64: Description of types of PTS

The most common PTS used locally GSI are the oil separators used to treat runoff from roads and forecourts, and grit separators, used widely in the National Flood Relief Project (NFRP). Points to consider in the installation of PTS are:

- They must be accompanied by their simple index approach mitigation indices[29].
- The choice is dependent on space, access, types of pollutants removed, and the range of flow events for which contaminant removal is desired;
- Can be considered as pre-treatment devices before certain features;

[29] https://www.deeproot.com/blog/blog-entries/using-the-simple-index-approach-and-deeproot-silva-cell-for-suds/

- Must be considered after above ground and biodiversity friendly methods are ruled out;
- They may require more frequent and routine maintenance than other methods to ensure that they work as planned

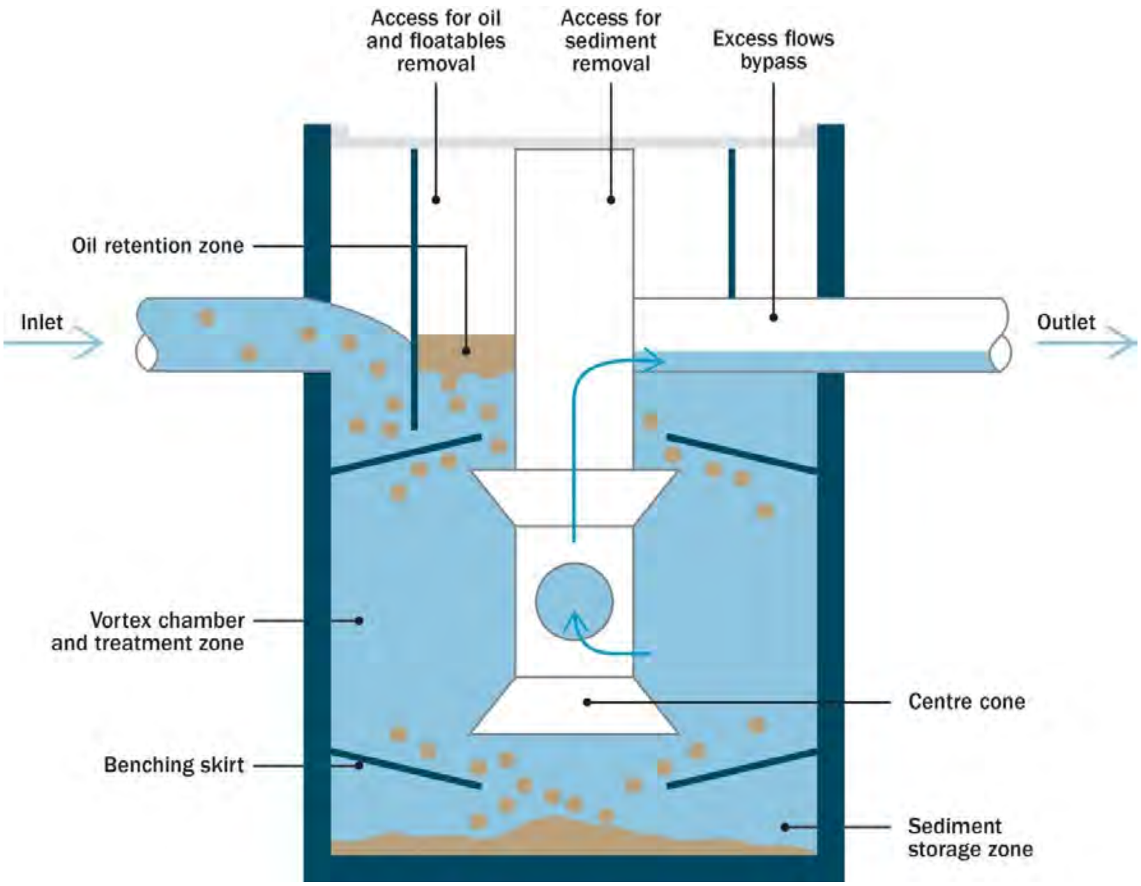


Figure 65: Schematic of separator type of PTS

Application summary

- Runoff generated on Forecourts, roads, etc.;
- Different treatment processes for different pollutants;
- Mostly new build (retrofitting is possible but limited);
- Routine inspection or maintenance.

8.05

GSI Techniques – Filter Drains and Filter Strips

Filter Drains

Filter drains are often called French drains but are essentially shallow trenches filled with stone or gravel that create temporary subsurface store of the reduction, direction, and filtration of surface water runoff. They are often in a trench lined with a geotextile layer or may be unlined to allow infiltration to the ground depending on the suitability of the underlying soils and the groundwater protection. Filter drains can alternately be laid with geocellular products; these versions are designed principally for conveyance, and not treatment. Filter drains have been used locally as dewatering measures under pools or basements or on shoreline quays, primarily for conveyance (**Figure 66**).

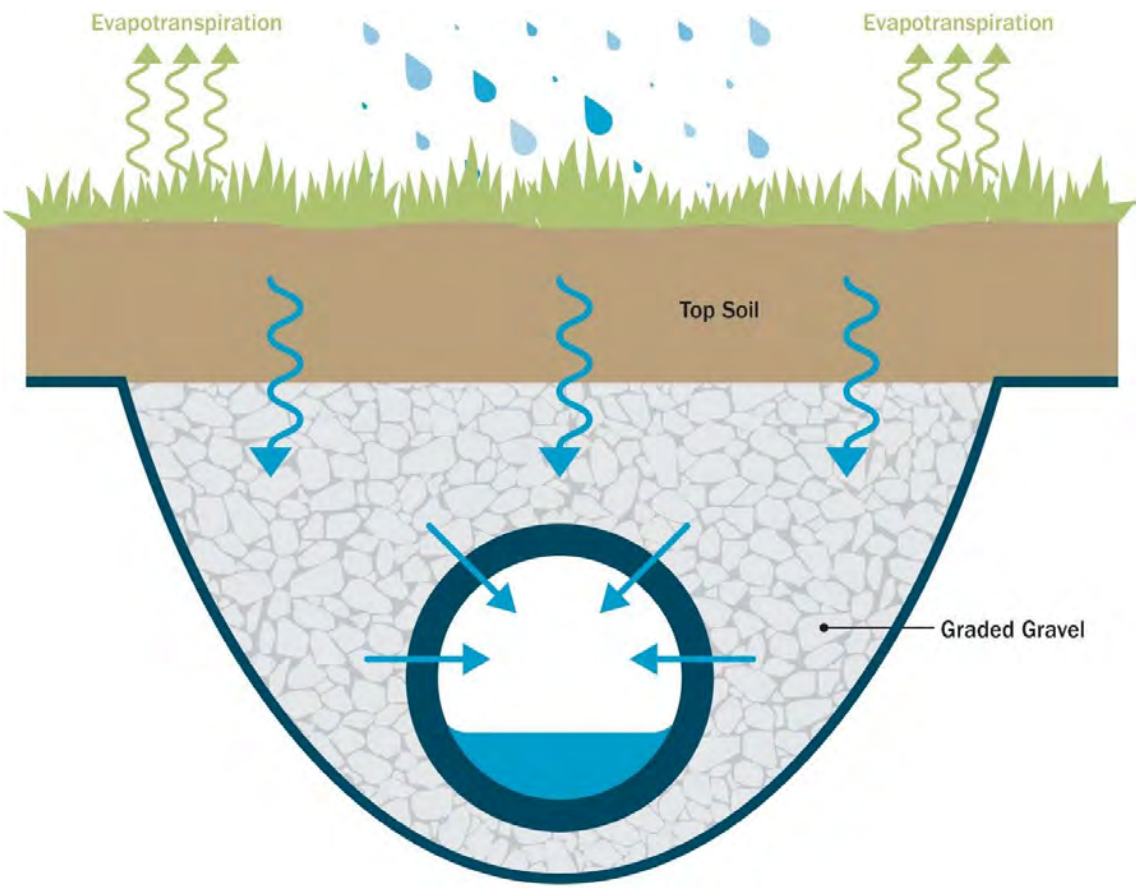


Figure 66:

Diagram of a filter drain cross section

Filter drains can be used to receive lateral inflow from an adjacent impervious surface following some pre-treatment, say by a filter strip, to remove sediments which can otherwise cause failure. In the absence of such pre-treatment, a regularly serviced geotextile layer fitted at a shallow depth below the filter drain can suffice.

Filter drains can reduce pollutant loads in runoff by removing fine sediments, metals, and hydrocarbons. The gravel in the filter drain can provide a surface area for the encouragement of adsorption and biodegradation.

Filter drain trenches are often laid in the main line of flow, and thus have to take events with high return periods. A perforated pipe is to be provided near the base of the filter drain to collect and convey the water downstream. As such, these drains can replace normal pipework and gullies stormwater collectors.

Filter drain depths should be between 1 – 2 m. The depth of filter medium beneath the inflow pipework should be at least 0.5 m to be effective. The drain widths are determined by the diameter of the pipe and the surround e.g., a 150 mm diameter pipe would require a 150 mm surround giving a total width of 450 mm. The voids ratio and the permeability of the fills should be high enough to allow percolation and avoid blockage. The loading for superimposed traffic is essential to be resistant by the build-up over the drain, to avoid crushing of the granular fill. Where possible, vehicular traffic should be directed away from filter drains.

Filter drains are generally appropriate for catchments with small impermeable areas and can be incorporated into landscaped areas from the outset (**Figure 67(1)** and **67(2)**). The longitudinal slope should not exceed 2% as low velocities are needed for stable water conveyance and for the pollutant removal to operate properly. They are designed for intermittent flow and need to drain between events. They can be useful where other vegetated systems of GSI are impractical as they can be built under impervious surfaces Overflow pipes should by-pass the filter medium to avoid scour and damage.

Filter Strips

These are strips of vegetation intended to treat runoff from generating surfaces by promoting sedimentation, and filtration in the root zone, and infiltration beyond the root zone. The runoff is set to run in sheet flow across the strip at low velocities such that the treatment process can take place. Such strips are often used as pre-treatment systems in sequence with other systems such as swales and bio-retention systems by either filtering out the sediment or providing treatment.

At low to moderate influent velocities, filter strips can take out sediments, organics, and heavy metals from the runoff. However, in intense storms where the soil permeability is saturated, the loss of water taken up is reduced and only low levels of infiltration would occur.

The slopes to the strip need to be shallow between 1 and 5%, and the strip needs to extend the full width of the drained area. They are thus indicated widely for road, car park and runway verges. Clogging at the interface between the draining surface and the vegetation, or in appropriate slopes across the strip affect the performance. Design consideration should be given to restricting vehicular access onto the filter strip.

Filter strips could be used in areas of high vulnerability of the groundwater if an impermeable geomembrane liner is laid. A maximum flow velocity of 1.5 m/s is indicated to prevent erosion during design flows, however much lower flows are better for treatment take up.

The topsoils should be suitably permeable, and the underlying soils should also have some capacity to store and infiltrate runoff. In low return period events, the flow rate across the strip should be controlled with a piped outlet. Filter strips do not tend to provide significant infiltration during large storm events. Typically, the flow depth should be approximately 100 mm, the peak flow velocity should be 0.3m/s, and the time of runoff across the strip should be at least 9 minutes. A flow spreading medium such as gravel tilled trenches say 150 mm wide, 50 - 100 mm deep should be introduced upstream of the full length of the strip and this also serve to trap sediment.

The strip itself can be planted with dry-area grasses or plants, with shallow roots. Trees and dense shrubs should be avoided unless the flow path length is sufficiently large; the reason is that the base vegetation cannot be maintained properly, say on a monthly basis, with a thick overlying growth. The major maintenance requirement of filter strips is in fact mowing, generally to a length of 75 – 150 mm length. Sediment removal can be done by uprooting the planted zone every say 10 years and replanting appropriately.

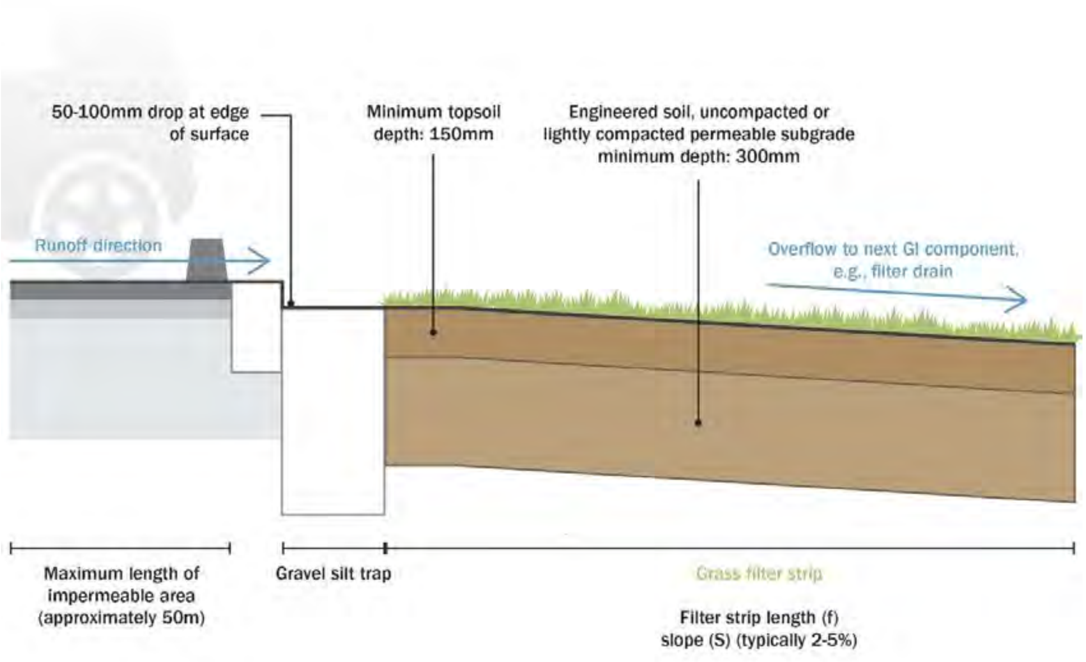


Figure 67 (1):

Diagram of a filter strip edge detail at parking cross section

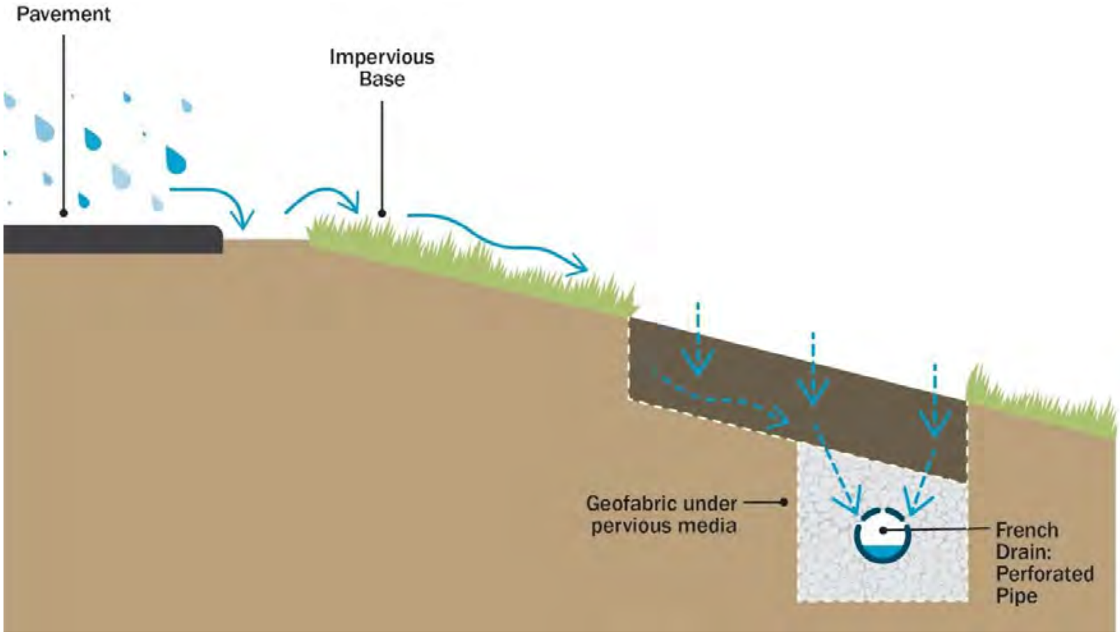


Figure 67 (2):

Filter strip with collector filter drain

Application summary

- Managing runoff from long surfaces such as roads, car parks or runways;
- New build and retrofitting (e.g., where green spaces are being created);
- Where surrounding ground has a high permeability.

8.06

GSI Techniques – Swales

Swales are limited in local situations due to their required resultant sizes since land is scarce, and the relative impermeability of the soils. However, there may be limited particular applications where swales are the most appropriate solution. Swales are low-cost linear vegetated features in which surface water can be stored or conveyed, and can be designed to allow infiltration where appropriate (**Figure 68**).

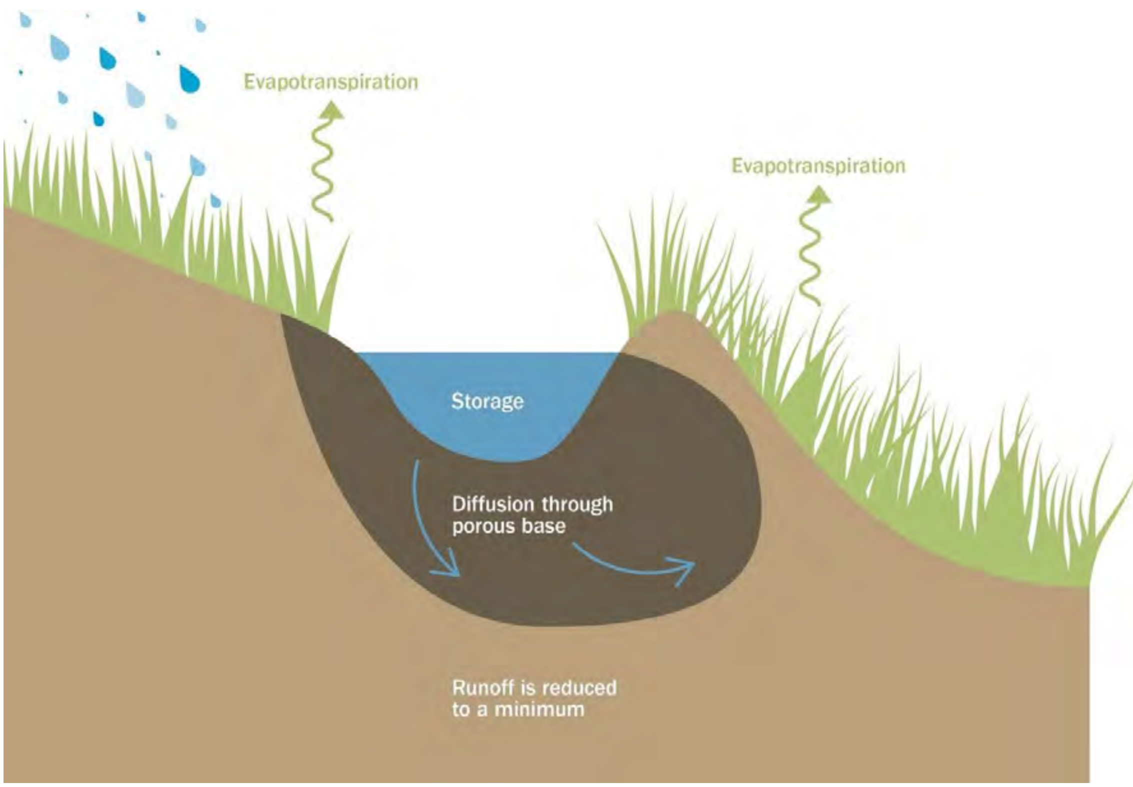


Figure 68: Diagram of cross section through a swale configuration

The following design features are to be considered:

- Maximum side slopes of 1 in 3, 1 in 4 preferred;
- Base width of 0.5 - 2.0 m;
- Must be designed for shallow flows and adequate water quality treatment whilst preventing flows from concentrating and creating erosion channels;
- Peak flow velocity should be limited to 0.3 m/s to ensure adequate runoff

filtration.

- The time of travel of runoff along the swale should be at least 9 minutes.
- Check dams and appropriate pre-treatment systems can be used to improve both hydraulic and water quality performance by reducing velocities, increasing resistance time and increasing infiltration/storage.
- Flow velocities for extreme events should be kept below 2 m/s to prevent erosion.
- Water should be preferably directed laterally into a swale rather than entering the swale as a single point inflow to minimise erosion and to disperse pollution widely.

A sustainable intervention using swales in Malta is found in a 1.4 hectares site in Baħrija (**Figure 69**), where a permaculture farm was set up. The farm involves a combination of RWH systems and swales for infiltration.

Figure 69: View of a swale at Baħrija Oasis

Application summary

- Managing runoff in rural areas;
- Areas where there is an incline;
- Where there is a thick soil layer;
- Where the soil and bedrock have high permeability and good infiltration properties.

8.07

GSI Techniques – Bioretention Systems

Bioretention systems are shallow landscaped depressions or constructed units which rely on engineered soil and vegetation to remove pollution. They require:

- Sufficient area to temporarily store the water quality treatment volume;
- The water quality treatment event must half drain within 24 hours to provide adequate capacity for multi-event scenarios.
- Minimum depth to groundwater of 1 m, if unlined;
- Overflow/bypass facilities for extreme events;
- Maximum recommended area that can drain to a bioretention system is 0.8 hectare.
- Typically, the surface area of the bioretention system should be 2 - 4% of the overall site area to be drained to prevent rapid clogging of the bioretention surface.

A diagrammatic representation of a bioretention system is in **Figure 70**.

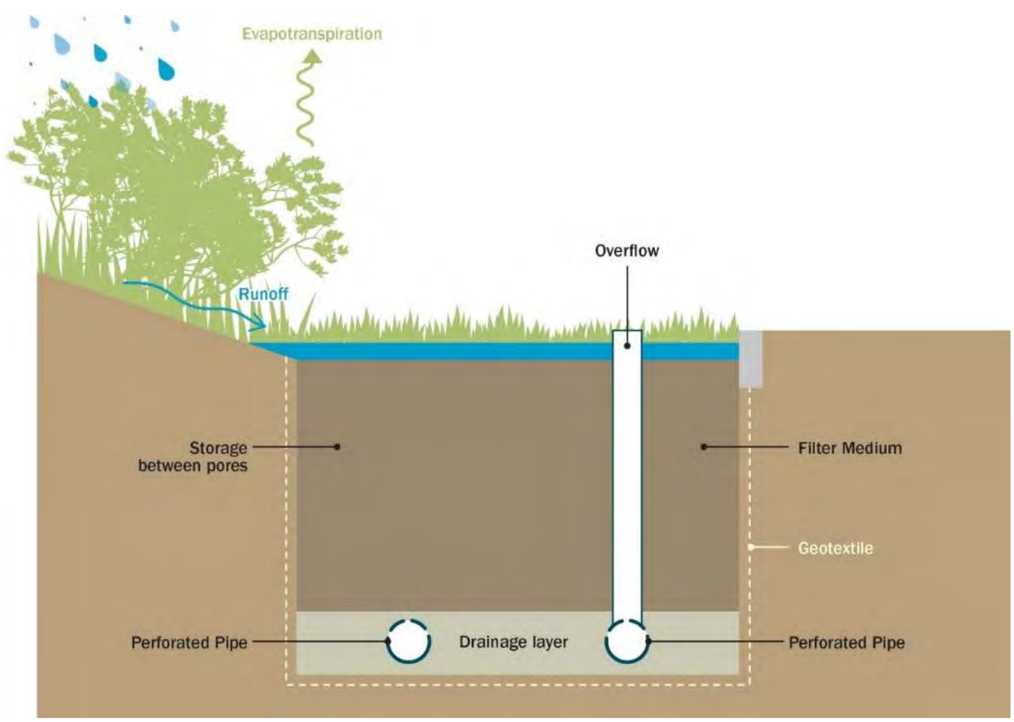


Figure 70:

Diagram of a bioretention system

Biological treatment for runoff has not been locally widely applied with success, as the lack of rainfall throughout most of the year effectively kills off the biomedia in the reactor, making it unavailable for the onset of the rainy season. There are parallels with the design of filter beds for primary treatment in sewage treatment, but in the latter, there is clearly the potential for a much more regular influent and source of supply to keep the reactor working. Locally even bioretention systems for sewage treatment has not been markedly successful, with the one at the Cottonera Waterfront being effectively abandoned (**Figures 71** and **72**).

Figure 71:

Bioretention tank at Cottonera Waterfront (the final stage in a sewage treatment process)

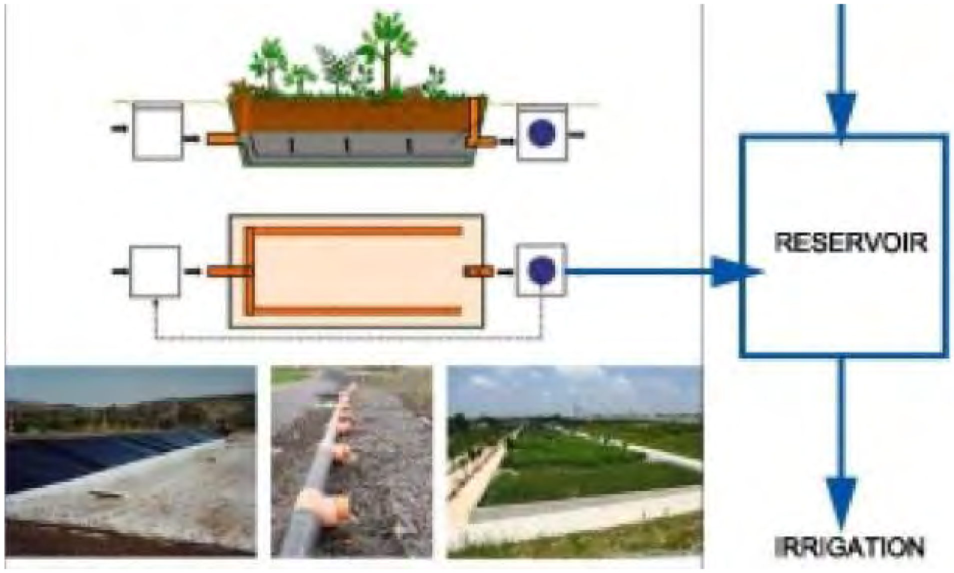


Figure 72:
Process diagram of bioretention system at Cottonera Waterfront (part of final stage in sewage treatment)

The Cottonera Waterfront system was part of research on the performance of different aquatic macrophytic species in shallow basins to achieve the reduction of solids including Nitrate, Phosphate and Potassium (NPK) loads, Sodium Chloride and heavy metal pollutants found in treated water by natural processes. Research was to determine which species are most suited for phytoremediation purposes in Malta. No publication of this research could be traced. The system was to reduce the microbial content to ensure suitability of treated water for irrigation.

Application summary

- Best suited for draining runoff from open urban areas (public or private);
- Value is given to aesthetic quality of vegetation irrigated by the treated water and the ensuing improvement in air quality in urban areas;
- A sustainable source of water for irrigation.

8.08

GSI Techniques – Trees

Trees have a large number of beneficial contributions to the urban environment, besides contributing to effective surface water management strategies. They also:

- Add beauty and character to the urban landscape, which in turn helps improve the health and well-being of local communities, raising the value of residential and commercial areas;
- Reduce annual building energy consumption by moderating the local climate, keeping it cooler in summer and warmer in winter;
- Filter harmful pollutants from the air, including carbon sequestration;
- Mask and reduce unwanted noise;
- Create vital wildlife habitats enabling more species to thrive in the urban environment.

In surface water management they have the following contributions:

Transpiration – the evaporation of water drawn up through roots to the leaves draws large amounts of water from the soil.

Interception – leaves, branches and trunks both intercept (thereby allowing for evaporation) and absorb rainfall, reducing the amount of water reaching the ground.

Increased infiltration – root growth increases soil infiltration capacity and rate.

Phytoremediation – the water drawn up in the tree takes up also trace amounts of harmful chemicals including metals, organic compounds, fuels and solvents which are present in the soil, often from urban deposition. These chemicals are used in tree elements or are transformed into less harmful substances and used by the tree itself.

Trees can be planted within a range of infiltration GSI components such as soakaways and swales to improve their performance, or they can be used as standalone features within pits or planters. They should be intended to manage runoff from a local area as would a single road gulley, and not to manage large volumes of water collected by several gulleys and channels. A diagrammatic illustration is in **Figure 73**.

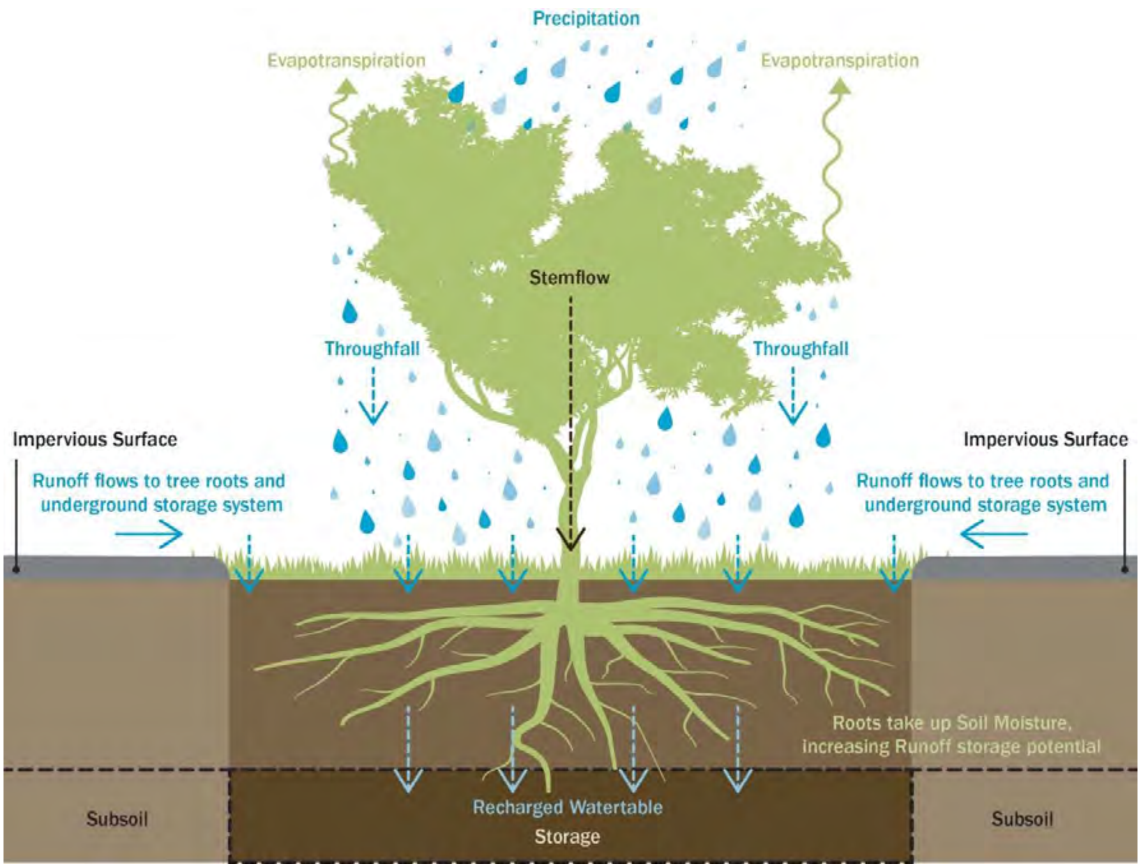


Figure 73: Tree planting diagram

Trees require sufficient space, appropriate soil, sufficient gas exchange, adequate drainage, and a supply of water. Soil properties and soil volume are vital for growing trees in urban landscapes and using them successfully as a means of managing runoff. The key is to consider rooting volume early in the design process so that it can be cost effectively provided.

Any tree pit or planter should provide adequate rootable soil volume and appropriate levels of water and air availability to the roots so as not to inhibit tree growth. These factors are influenced by the soil's porosity (amount of available pore space), permeability (how interconnected pore spaces are), and infiltration rate (how quickly the water moves through the soil). Roots also require sufficient organic material and nutrients within the soil, and require suitable drainage so that they do not become waterlogged.

There is a balancing act between providing enough water for the trees' needs and preventing the soils becoming saturated. This is achieved by ensuring that water storage is below the rootable soil volume for the majority of the time (occasional inundation of roots may be acceptable – seek the advice of an arboriculturist) and allowing water to flow freely below the whole area of rootable soil.

The availability of a sufficient water supply to the tree is crucial. It is important to ensure that the runoff area draining to the tree provides sufficient water for when it is fully grown. This needs to take into account the likely rainfall during the growing season, the storage capacity within the soil rooting volume, the rate of evaporation from the soil and the risk of dry years.

Designing the tree planting zone to accommodate the largest size tree possible will increase its capacity to manage runoff. Mature, large species trees with their large, dense canopies manage surface water runoff most, and should be considered where the location is appropriate. Big trees require large volumes of suitable soil and above-ground space to grow. If too little soil is available, the tree will not reach full stature, regardless of what species of tree is planted. Poorly designed sites - those lacking adequate soil and space - generally require continuous, costly plant healthcare and often continual replacement of trees.

Trees for GSI will tend to be located in an urban environment, and street trees in particular can be subject to conditions that make it difficult for them to thrive. The main risks are soil compaction and limited access to air and water for the roots.

There are various engineering structures that can be used to improve growing conditions for urban trees by expanding the rooting environment as much as possible beneath paved surfaces using load-bearing systems to avoid soil compaction around the roots.

Structural growing media

Structural growing media refers to a group of soil-and-gravel mixes that are designed to support tree growth and serve as a sub-base for pavements. Structural growing media are highly porous, engineered aggregate mixes designed to be used under asphalt and concrete pavements as the load-bearing and levelling layer.

The three main types of structural growing media are:

<u>Sand-based substrate (also known as tree soil)</u>

This predominantly comprises of medium to coarse sand (0.2 - 2 mm) which is usually blended with a fine-grade green compost (providing an organic matter content of 2 - 4%) and 2 - 4% clay to add suitable water and nutrient retention properties. More recently, variations have been developed that include a higher proportion of coarser sands to provide more air voids after compaction.

<u>Medium-sized aggregate substrate</u>

This substrate uses a mix of angular aggregate that can be compacted to 95% of maximum dry density while still retaining void space between the angular particles. The void space is filled with soil. The coarse aggregate particles form a matrix that supports and distributes the loads from vehicles. This prevents compaction of the finer tree soil in which tree roots can grow and prevents heaving of the pavement around the tree. There are many variations of the aggregate/soil mix but typically the aggregate will be of 25 - 100 mm diameter and the proportion of soil is around 20 - 35%. Because the load-bearing capacity of the aggregate depends on the strength and durability of the particles, it is recommended that, where it is used below trafficked areas, it meets the durability and particle shape requirements for sub-base used below pervious surfaces. The soil element can be various mixes of clay, sand and compost. This type of substrate can be used below lightly trafficked areas such as car parks.

Stone skeleton substrate

Also known as the Stockholm system, this is similar to the medium-sized aggregate substrate but uses larger aggregate particles in a base layer of 100 - 150 mm diameter. The base layer is covered by a layer of 63 - 90 mm aggregate. The aggregates are compacted, and soil flushed into the spaces between the larger particles. The system is provided with inlets that allow surface water and air to freely enter the substrate. The system can support heavier traffic loads than the above systems, e.g., heavy goods vehicles and buses.

Trees are sensitive to pH (acidity or alkalinity) and pH can significantly affect the life and health of a tree and its ability to absorb nutrients. When using any structural growing media, the pH of the soil and water will be influenced by the type of aggregate used in the mix, and tree species should be used that are compatible with the pH of the growing environment and the structural growing medium.

Modular structures

Modular structures, also referred to as "crate systems", are cuboid plastic, concrete, plastic/steel or plastic/concrete structures that provide a load-bearing structure into which the substrate is placed. The structure supports the loads from the overlying pavement and prevents compaction of the substrate. They can be used to support car parks and roads and to prevent compaction of the tree soil in a similar manner to the coarse aggregate in a structural growing medium. The structures can provide a guaranteed volume of soil for the tree roots, an extra volume for surface water runoff attenuation and structural support to prevent the soil becoming compacted at the surface. They are usually covered with grilles and extend below the adjacent hard surfacing.

The load-bearing capacity of the structures and the design requirements depend on the material from which they are made. Many of the considerations for geocellular structures will also apply to plastic systems. The structural element comprises a small proportion of the overall volume compared to the aggregate based systems, so there is a greater rootable volume available (see **Figure 74**).

Figure 74:

Modular structure: cross section showing tree planting and utilities in pedestrianized urban setting (GreenBlue Urban)

Raft systems

Raft systems provide a planar structural layer that is constructed over the rooting environment. The raft distributes the concentrated wheel and other loads across a wider area, to prevent damage to the soil structure and help absorb loads resulting from any required compaction of overlying layers. Also, the raft allows free movement of oxygen and water to root systems.

Different types of raft system are:

Cellular confinement systems

These are also referred to as geocells which are different from large-scale geocells constructed using geogrids below embankments or anti-compaction mats. These are a series of HPPE strips that are opened up and pinned to provide a series of honeycomb-shaped cells that are filled with coarse aggregate (typically 4 - 40 mm or 20 - 40 mm) to promote free air and water exchange with the soils below.

Geocellular sub-base replacement systems

These are geocellular units that have joints that provide a structural connection so that the system acts as a raft to distribute load. The units can be filled with soil to provide a rooting environment.

Either of these systems can be designed to support traffic loads from any road-going vehicles The main concern with either of these systems is access to buried utilities, and accidental excavation. They should be used in appropriate situations with due regard to the presence of services.

Tree planters

Tree planters are essentially bioretention systems (**Chapter 7.07**) with trees in them, to enhance their capacity and performance, and/or to deliver amenity and biodiversity benefits. They have similar functionality and design requirements to standard tree pits but have an open surface and generally a larger surface area, so their overall appearance is different. Where the sensitivity and/or vulnerability of groundwater lying beneath a tree means that infiltration from contaminated surface runoff should be prevented, tree pits/planters etc. should be designed with an impermeable geomembrane liner and positive drainage system to prevent waterlogging.

The inclusion or retention of trees in central strips or on footways sometimes gives rise to safety concerns, and consideration should always be given to ensuring that sight lines are not put at risk by tree planting proposals. Any protective surface grilles or other protection overlying tree pits should be designed to minimize the risk of damage by potential transient loadings – which could cause trip hazards for pedestrians.

Selection and siting of trees

To achieve optimum delivery of hydraulic, water quality, amenity, and biodiversity objectives, suitable trees should be chosen on a site-by-site basis, based on the constraints and opportunities afforded by a particular location such as:

- The likely runoff characteristics (flow rates, volumes and likely contaminants);
- The nature of the soil into which they are to be planted;
- The location and characteristics of the planting site (e.g., narrow canopy trees may be required for street locations).

The following characteristics tend to increase the effectiveness of trees in reducing surface water runoff and filtering pollutants (note that not all are complementary):

- Wide spreading and dense canopies;
- Long life expectancies;
- Fast growing rates;
- High tolerance to summer drought tolerance of saturated soils;
- Resistance to air and water pollutants common in urban environments extensive root systems;
- Rough bark;
- Tomentose or dull foliage surface;
- Vertical branching structures.

It is important to locate tree pits at a reasonable distance from buried utility services such as electric cables and water pipes. Trenching works to repair services can cut tree roots, and equally tree roots can damage utility infrastructure. There is no specific minimum distance, and it depends on the utility infrastructure, its resistance to movement and damage caused by trees, and the consequence of any damage. However, the risk of damage can be minimized by installing root barriers around the rootable volume of soil (note that these can often be as simple as using standard manhole rings or geotextile fabrics specifically designed as root barriers). Underground utilities can be placed around and even through tree pits, geocellular crate systems and suspended pavement systems. However, all underground utilities should be protected from water and root penetration.

Interception design

Interception provided by the tree canopy will vary with tree type and will increase over the life of a tree as it grows. The interception may be negligible for the first few years. It is therefore best to ignore this aspect in the hydraulic design of GSI, while recognizing that it will have a long-term benefit and will reduce volumetric runoff loads to the surface water system in the future.

Where water is directed towards a tree pit, and the tree pit is designed to facilitate even limited infiltration, then a check should be made to determine whether the tree is able to dispose of 5 mm rainfall depth over the contributing catchment area. Tree pits can help reduce flow rates from a site by facilitating infiltration and/or by providing attenuation storage. The available storage volume is provided by the void space in the soils in the pit:

Available attenuation storage in the tree pit = Volume of tree pit x void ratio in the soil/aggregate/geocellular layer designed to be the storage volume.

The level of stored water in the tree pit should be such that it will not adversely affect the health of the tree. Attenuation storage for peak flow control should normally be designed to drain down within 48 hours. This requirement should also ensure healthy root development. If tree roots are likely to be inundated for longer than this on a regular basis, then flood tolerant species should be specified. An exceedance flow route will be required with rainfall events that exceed the design capacity of the tree pits or planters. This can be achieved by installing an overflow pipe above the design water storage level or by overland flow routing.

Treatment design

Tree pits filter out pollutants from runoff and, by reducing the volume of runoff, also help to reduce pollutant loadings to receiving waters. Good pollutant removal performance is required for all runoff events up to and including events which occur, on average, about once a year. The duration of this event should be the relevant critical duration for the runoff to the tree pit. The tree soils can be designed using the same principles as bioretention systems described in **Chapter 7.07.**

Many trees are able to remove a wide variety of pollutants from soil including metals, pesticides and organic compounds. Excess Nitrogen and Phosphorus in soils are quickly taken up by trees with oxygen-rich rhizospheres because osmosis can happen freely. Robust resilient trees can also metabolize contaminants (heavy metals, inorganic and organic compounds) into their carbon-rich heartwoods, removing them from the runoff.

Hydrocarbons tend to be trapped and degraded in the upper few centimetres of soil. Therefore, their removal will be more efficient where runoff Is directed onto the surface of the soils and where this surface is well exposed to sunlight. A depth of engineered soil suitable for tree growth has been demonstrated to remove 70 - 85% of heavy metal loadings,

The acceptability of allowing infiltration from the tree pit depends on the extent of the likely runoff contamination and the capability of the filtering soils to remove pollution.

Figure 75:

Example of well-established tree lined road

Triq Burmarrad, Burmarrad

Figure 76:

Local malpractice of an urban tree planter with cement sealing around trunk and no inlet water from surrounds

Application summary

- Urban and rural areas;
- A sustainable source of water for irrigation;
- Embellishment and aesthetics;
- Improvement in air quality, shading, and noise mitigation.

8.09

GSI techniques – Pervious Pavements

Pervious pavements provide a surface suitable for use by foot or vehicular traffic, while allowing rainwater to infiltrate into the underlying structural layers. The water may take different managed paths after initial infiltration – to the ground, storage underground, or controlled discharge downstream. Treatment processes of filtration, adsorption, biodegradation, and sedimentation occur within the surface and subsurface structures. A typical cross section through various types is in **Figure 77**.

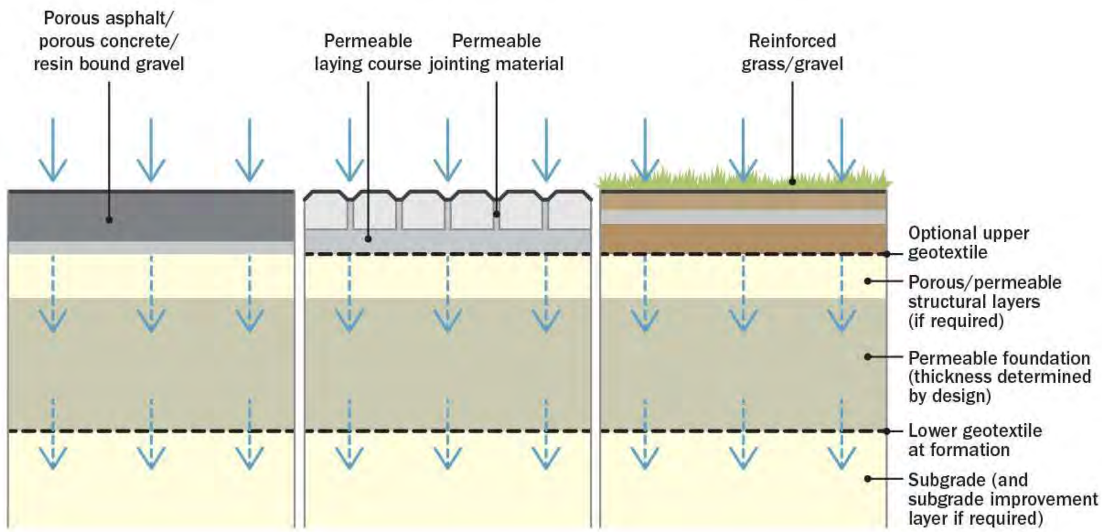


Figure 77: Pervious pavement cross section showing various types

Pervious pavements are classified either as permeable pavements or porous pavements. **Permeable pavements** are made up of the material that is impervious, but the void spaces between the blocks of the surface allow the infiltration of water. **Porous pavements** infiltrate water across the entire surface material, e.g., bound gravel, porous asphalt or porous concrete.

A common use of permeable pavements with blockwork and voids filed with grit is in roads, car parks or pedestrian areas. Often in car parks non-porous asphalt is used in through lanes, while permeable pavements are used in the car parking spaces proper, as the asphalt is more resistant to turning forces. The larger the void, the better the drainage potential. Another type involves the use of plastic or concrete grids infilled with grass or gravel; this is indicated for lightly trafficked areas where grass can be allowed to grow. This grassed system has been used locally so far with mixed to poor results, as the surface often needs irrigation to maintain growth. They can be used as a landscaping element to actually slow down traffic due to their surface roughness. It is considered that a properly engineered non-grassed pavement has considerable potential as a GSI in Malta, and thus detail as to its build up is being shared.

Figure 78:

Permeable pavement at Mosta

Figure 79:

Permeable pavement in an irrigated landscape at Attard

Figure 80:

Permeable pavement at Għarb, Gozo

Porous pavements with porous asphalts or porous concretes are used in parking areas and can be preferred if a stronger base is required, e.g., where trucks are expected, but also to reduce traffic noise. Resin bound gravel, which can be coloured, can also be used for lightly trafficked areas. Turf or artificial surfaces laid over aggregate sub-bases or plastic subbases can be suited to provide surfaces for sports, while also providing water storage for the surface.

The collected runoff that infiltrates through the surface of a pervious pavement can be allowed to percolate or collected depending on the ground conditions and the site purpose. A geocellular system under a pervious pavement could be used to provide storage for re-use purposes (**Figure 81**). Fundamentally, the build-up of the supporting ground must not be allowed to be undermined by unmanaged infiltration pathways.

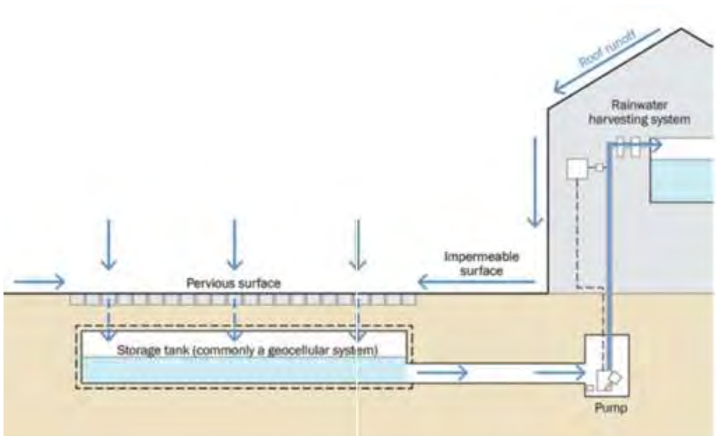


Figure 81:

Example of pervious pavement installation with geocellular water storage

A useful soil classification and their range of coefficient of permeability guide is from the UK firm Interpave (**Figure 82**).

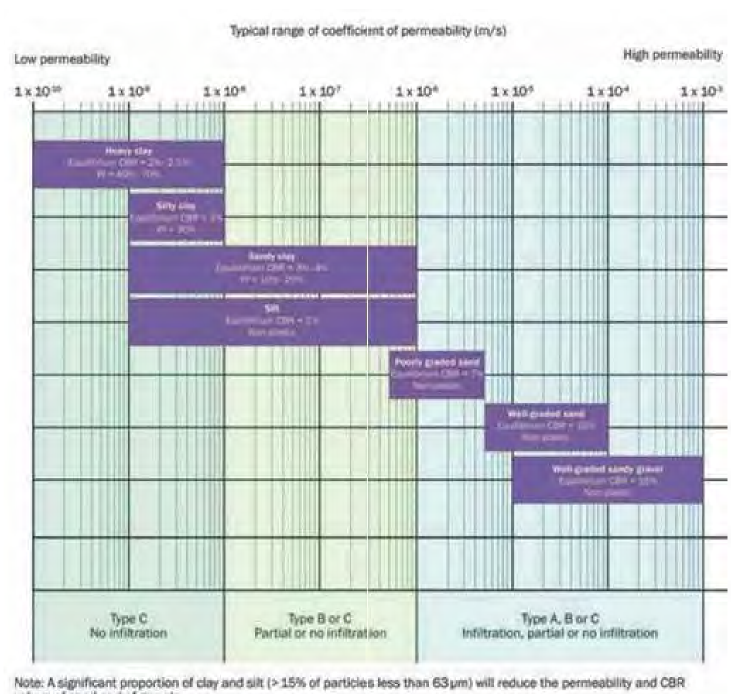


Figure 82:

Soils and their range of coefficient of permeability

Hydraulic design

The following design features are to be considered:

- Confirm the adequacy of the rate of infiltration of the rainwater through the pavement. The infiltration rate has to be significantly higher than the design rainfall intensity; a rate of 25 mm/hr is considered reasonable. A factor of 10 is applied to the surface infiltration rate to allow for clogging, so that the long-term surface infiltration rate will be a minimum of 250 mm/hr. Clogged systems can be rehabilitated using sweepers, herbicides and re-gritting the joints.

- Estimate the storage volume required for storm event management. The available storage is determined by the physical volume available and the usable voids. The available storage will be less on a sloping site and one could consider underground terracing into compartments to maximize the volume.

- Estimate the outfall capacity for the pavement (unless infiltration to the ground is the only mechanism of discharge). Outflow from the sub-base should be by a system of perforation pipes providing a large surface area for the water to flow into and these should extend 1 metre minimum into the subbase.

- Design for the exceedance of the design event. This is done by measures such as setting catchpits above the pavement surface level thereby using the surface for storage and also setting a maximum depth of ponding.

Treatment design

Pervious pavements trap silt within the top 30 mm of the blocks, offer biodegradation to organic pollutants within the pavement build-up, adsorb pollutants on the inner surface of the particles of the structure, and encourage the settlement and detention of solids. Heavy weight geotextiles have been found to be particularly effective for high oil absorption.

However, if geocellular storage is used instead of aggregate in the sub-base, such benefits are greatly reduced. A horizontal geotextile will be needed to re-offer an environment for treatment. Porous concrete appears to affect metal adsorption, and leachate of contaminants from the concrete may occur (Phosphate).

Structural design

The structural pavement design is beyond the scope of this Manual. However, the guidance is that traffic loadings as per **Figure 83** are followed:

Traffic category (BS7533)	Standard axles per day	Lifetime traffic (msa)	NRSWA road type	Maximum anticipated axle load (kg)	Example number of commercial vehicles per day	Typical application
10	≤4000	≤60	0			Arterial roads and roads in and commercial/industrial developments used by a high number of commercial vehicles Port and airport landside Bus stops and bus lanes
9	≤2000	≤30	1			
8	≤700	<10	2	8000	Approx. 420	
7	≤275	<2.5	3	8000	Approx. 170	
6	≤60	0.5	4	8000	Approx. 35	Arterial roads used by a moderate number of commercial vehicles Pedestrian areas subjection to regular over-run by commercial vehicles Industrial premises Petrol station forecourts
5	≤5	<0.05	n/a	8000	Approx. 3	Pedestrian areas subjected to occasional over-run by commercial vehicles and maintenance machines Car parks with occasional commercial traffic
4	1	n/a	n/a	2000	Mainly car or pedestrian traffic with emergency HGV vehicles only	Urban footways with no planned vehicular over-run Pedestrian areas or car parks used by light commercial vehicles
3	0	n/a	n/a	1000	No HGV	Small car parks subject to car, light van and motorcycle access
2	0	n/a	n/a	1000	No HGV	Pedestrian and cycle areas Domestic driveways
1	0	n/a	n/a	1000	No HGV	Pedestrian only areas, including domestic applications
0	0	n/a	n/a	0	No vehicular traffic	No requirement (decoration)

Figure 83: Traffic loading as per UK regulations

The indicated material qualities of the pavement (**Figure 84**) are:

Material	Stiffness
Porous asphalt	2 GPa
Porous concrete	3.2 - 7.1 GPa
Permeable sub-base for use below all types of surfacing	93 - 138 MPa
Concrete block permeable pavers	1000 - 4500 MPa depending on type of block

Figure 84:

Pavement material stiffnesses

The manufacturer's recommendations are to be followed, typically as per **Figure 85**, for sub-bases coarse graded aggregate (CGA) of 5% California bearing ratio (CBR) or greater for grass or resin bound pavement.

Traffic category (BS 7533)	Grid	Bedding Layer	Sub-base CGA (coarse graded aggregate)
4	Varies	50 mm	300 mm
3			225 mm
2			150 mm
1			100 mm
0			Sufficient to provide a suitable construction base

Figure 85:

Typical construction thickness of sub-base of 5% CBR or greater for grass or resin bound pavement

Similarly, the construction thicknesses of porous asphalt, sub-base and base hydraulically bound base (**Figure 86**) are:

<table>
<tr><th>Traffic Category (BS 7533)</th><th>Porous asphalt</th><th>Base hydraulically bound CGA (course graded aggregate)</th><th>Sub-base CGA mm</th></tr>
<tr><td>10</td><td rowspan="4">Asphalt requires specialist consideration and specification</td><td rowspan="2">Site specific using Interpave® guide for heavy duty pavements</td><td rowspan="6">150</td></tr>
<tr><td>9</td></tr>
<tr><td>8</td><td>300mm</td></tr>
<tr><td>7</td><td>200mm</td></tr>
<tr><td>6</td><td>80 mm</td><td>125 mm</td></tr>
<tr><td>5</td><td>80 mm</td><td>100 mm</td></tr>
<tr><td>4</td><td>150 mm</td><td rowspan="5"></td><td>300</td></tr>
<tr><td>3</td><td>120 mm</td><td>225</td></tr>
<tr><td>2</td><td rowspan="3">70 mm assuming hand laying</td><td>150</td></tr>
<tr><td>1</td><td>100</td></tr>
<tr><td>0</td><td>Sufficient to provide a suitable construction base</td></tr>
</table>

Figure 86:

Typical construction thicknesses of porous asphalt, base and hydraulically bound base of 5% CBR or greater

The construction thicknesses of porous concrete and sub-base (**Figure 87**) are:

<table>
<tr><th>Traffic Category (BS 7533)</th><th>Porous concrete (plain slab) thickness mm</th><th>Sub-base CGA mm</th></tr>
<tr><td>10</td><td rowspan="5">Site specific design</td><td rowspan="5">150</td></tr>
<tr><td>9</td></tr>
<tr><td>8</td></tr>
<tr><td>7</td></tr>
<tr><td>6</td></tr>
<tr><td>5</td><td>150</td><td rowspan="2">300</td></tr>
<tr><td>4</td><td>135</td></tr>
<tr><td>3</td><td rowspan="2">125</td><td>225</td></tr>
<tr><td>2</td><td>150</td></tr>
<tr><td>1</td><td rowspan="2">100</td><td>100</td></tr>
<tr><td>0</td><td>Sufficient to provide a suitable construction base</td></tr>
</table>

Figure 87:

Typical construction thicknesses of porous concrete and sub-base of 5% CBR or greater

The construction thicknesses of concrete paving blocks manufactured in accordance with EN 1338, sub-base and hydraulically bound base (**Figure 88**) are:

Traffic Category (BS 7533)	Type of surface – minimum thickness mm		Bedding layer nominal thickness	Base HBCGA	Sub-base CGA
	Concrete /clay blocks	Natural stone slabs / Concrete flag / Setts	mm	mm	mm
10					
9			Site specific design for heavy duty pavements		
8				300	
7				200	
6	80			125	150
5				100	
4		Seek advice from supplier			300
3			50		225
2					150
1					100
0	60				Sufficient to provide a suitable construction base

Figure 88:

Typical construction thickness for modular concrete paving blocks manufactured in accordance with EN 1338 over sub-base and base of 5% CBR or greater

Detailing and connections

The surface water to be taken up by the pavement should be directed as far as possible over a width of the surface and not at discrete points. Runoff connections can however be linked directly below the surface into the sub-bases through a diffuser and a silt trap (**Figure 89**).

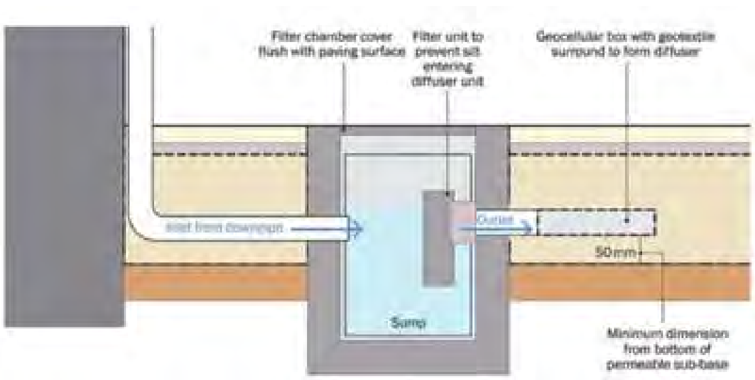


Figure 89:

Flow diffuser to connect runoff to permeable sub-base

Jointing specification

The key to the perviousness of such pavement is the joint performance, and indications are given in **Figure 90**.

BS sieve size (mm)	Percentage passing
14.0	100
10.0	90-100
6.3	80-99
2.0	0-20
1.0	0-5

Figure 90:

Bedding and jointing layer specification to BS 7533-13:2009

Application summary

- Urban and rural areas;
- Ground allows sufficient infiltration;
- Can be retrofitted.

8.10

GSI Techniques – Dams

Dams are usually classified as grey infrastructure in literature as they hold water back.

In the local context this interpretation is different, as the dams that have been built are not large concrete structures with deep water impoundment but are normally low masonry or earth dams (**see Chapter 4.00**). Their function is not hydropower or direct water supply, but primarily groundwater recharge and the encouragement of infiltration. Such activities are legally covered and promoted by the Strategic Plan for Environment and Development (SPED) under "*Protection of important groundwater recharges areas such as outcropping in layers of the Lower Coralline Limestone formation.*".[30]

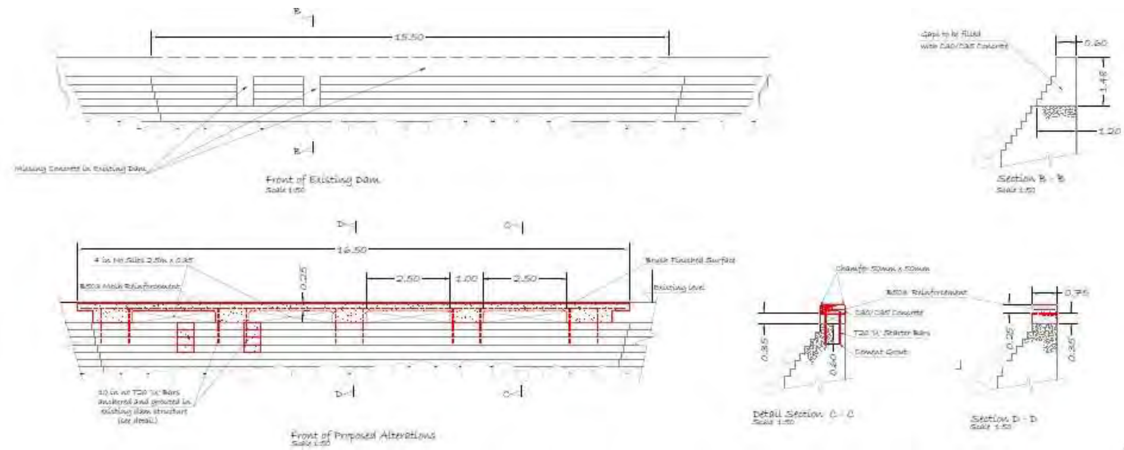
Many such dams have been built in the Maltese rural environment, and their siltation and upkeep are a perennial activity. Some of these dams have been silted up to such an extent that the habitat living in the silted material may be worth protecting in itself, and this does create a dialogue between the entities who manage valleys and who regulate activities therein (currently Parks Malta and the Environment and Resources Authority respectively). Procedures have been developed to regulate activities in valleys to avoid the elimination of harmful practices, especially the use of heavy machinery. Elements of a typical example of such protocol are:[31]

- Particulars and contact details of the supervisors responsible for the execution and supervision of works;
- Areas of maintenance works;
- Site plan indicating the specific area for proposed works;
- Area-specific methodology of procedures including machinery to be used;
- Indication of time frame for proposed works;
- Location where the debris will be carted away when it is removed;
- Inclusion of access routes;
- Requirements for monitoring.
- Measures to prevent, mitigate and offset any impacts;
- Other authorization conditions.

The construction of new dams has been carried out by the Government as recently as 2022 in Wied il-Għasel valley near Mosta, where approximately 1640 m length of valley floor were cleaned, and a series of approximately 2 metres high water storage dams were built to break the rapid flow of flood waters as well as to maximize the water retention capacity of the valley. Parts of the engineering drawings of this project are shown in **Figures 91** and **92**.

30 Thematic Objective 8: Strategic Plan for Environment and Planning (SPED), 2015

31 Method Statement: Maintenance Cleaning works of Water Retaining Facilities at Wied il-Għasri limits of Għasri village: Ministry for Gozo Eco-Gozo Regional Development Directorate, 2012



Figures 91:

Masonry dam elevation and cross-section showing 2022 interventions to raise the dam height

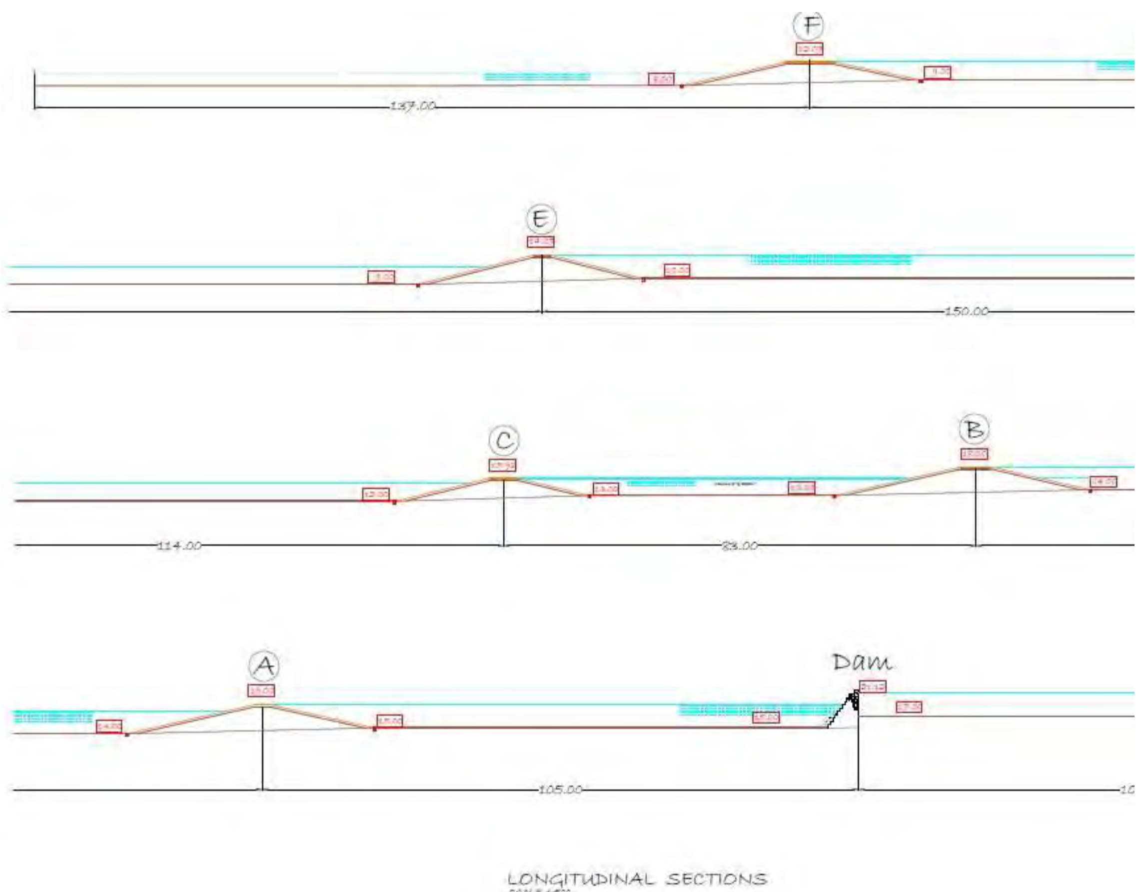


Figure 92:

Longitudinal sections through the valley bed showing the existing dam and new dams A, B, C, D, E and F

Initiatives for dam construction are limited to areas where the geology indicates the recharge potential. The construction of infiltration dams also relates to the quality issues of runoff discussed in **Chapter 5.00.** The encouragement of the percolation of runoff though such measures is a definitive indicator that the deliberate use of runoff for aquifer recharge is deemed to be a benefit in terms of water resources augmentation.

Application summary

- Valleys, where the impounded water can percolate quickly;
- Ponded water can be used as second-class water (e.g., irrigation);
- Where contours facilitate damming;
- Where existing upstream natural habitats and cultural heritage are safeguarded.

8.11

GSI Techniques – Ponds and Wetlands

Ponds and wetlands in Malta are listed comprehensively through Nature Trust as part of the Conservation of the Mediterranean Island Wetlands Project (*MedIsWet*) [32]. The database calculates the surface area covered in the 3 major sites at 31 hectares, and 52 hectares in the remaining 88 sites. Of these 91 sites, 88 are man-made. The sites included in that database include all locations which in the local context would also be classified as reservoirs, soakaways and dams. Two of the largest local sites are shown in **Figures 93** and **94**.

Figures 93 and **94:**

Wetland at Għadira, Mellieħa

[32] https://www.maltawetlands.org/general/search.php?lang=en

Figures 95 and **96:**

Il-Magħluq tal-Baħar ta' Marsaskala

In the local context, such sites are mainly rural, yet, as in the case of il-Magħluq tal-Baħar ta' Marsaskala (**Figures 95** and **96**), urban development can encroach them. Not all the sites in the *MedIsWet* database are appreciable in size, yet nonetheless the extent and documented examples show that this is a valid, though perhaps unexpected, technique for consideration in the local context.

Permanent pools support aquatic vegetation and retention time promotes sediment removal. The following design criteria apply to the creation of ponds and wetlands where applicable for stormwater management, attenuation and treatment:

- Permanent pool/marsh for water quality treatment and temporary storage volume for flow attenuation;
- Sediment forebay to maintain capacity;
- Aquatic benches to support planting, acting as a biological filter and providing ecology, amenity and safety benefits;
- Maximum side slopes of 1:3;
- Shallow, temporary storage for attenuation.

Application Summary

- Situations as natural depressions or collecting sites;
- Where land is available for periodic/permanent flooding;
- Where limited flood mitigation is required (must be strategically located);
- Embellish urban areas (in the case of ponds);
- Providing an aquatic environment for freshwater aquatic species and birds;
- Where aquifers are depleted and groundwater is high in Nitrate and Chloride.

8.12

GSI Techniques – Compact Infiltration systems (CIS)

Compact Infiltration Systems (CIS) is the name given to a locally developed infiltration systems that are compact, low-cost, and low maintenance. CIS are the result of a live research project named GEO-INF that was carried out in 2012 - 13 by *Ing.* Marco Cremona in various schools around Malta. The research project was funded by the Malta Council for Science and Technology (MCST) and had the Department of Building and Civil Engineering within the Faculty of the Built Environment of the University of Malta, the Malta Resources Authority (MRA), Solid Base Laboratory Ltd. and St. Theresa College as partners.

Research was carried out on:

1. The determination of the pollution loads in runoff from roofs;
2. Analysing rainfall patterns leading to the design and building of the GEO-INF CIS;
3. Monitoring the performance of the GEO-INF CIS;
4. Determination of runoff coefficients for roofs for different storm events;
5. In-situ permeability testing of the bedrock;
6. Developing a design tool for sizing CIS.

The research and testing were carried out on runoff generated on the roofs of 15 schools in Malta, with roof areas that varied between 100 - 250 m^2 and using shallow boreholes, (maximum depth 50 m), in the unsaturated zone of the underlying aquifer. A diagrammatic representation of a CIS is in **Figure 97**. Rainwater falling on roofs is collected in standard drainpipes that channel the water to a plastic (or fibreglass) tank placed at ground level. The water flowing into the tank immediately runs out of the tank and down a borehole via a gravel filter.

The gravel filter stops any large particles and debris from reaching the borehole, that would otherwise plug it and reduce the water dissipation rate.

The borehole is drilled to a depth that does not exceed 50% of the depth to the aquifer. This is the maximum depth suggested by the Energy and Water Agency (EWA), which remaining depth to the aquifer allows for a buffer for the filtration of any contaminants by the rock strata.

The borehole is cased to a depth of 5 metres to:

1. Provide stability for the borehole and prevent the ingress of debris into the borehole, and
2. Prevent the exfiltration of water from the upper sections of the borehole, to prevent damage to neighbouring areas.

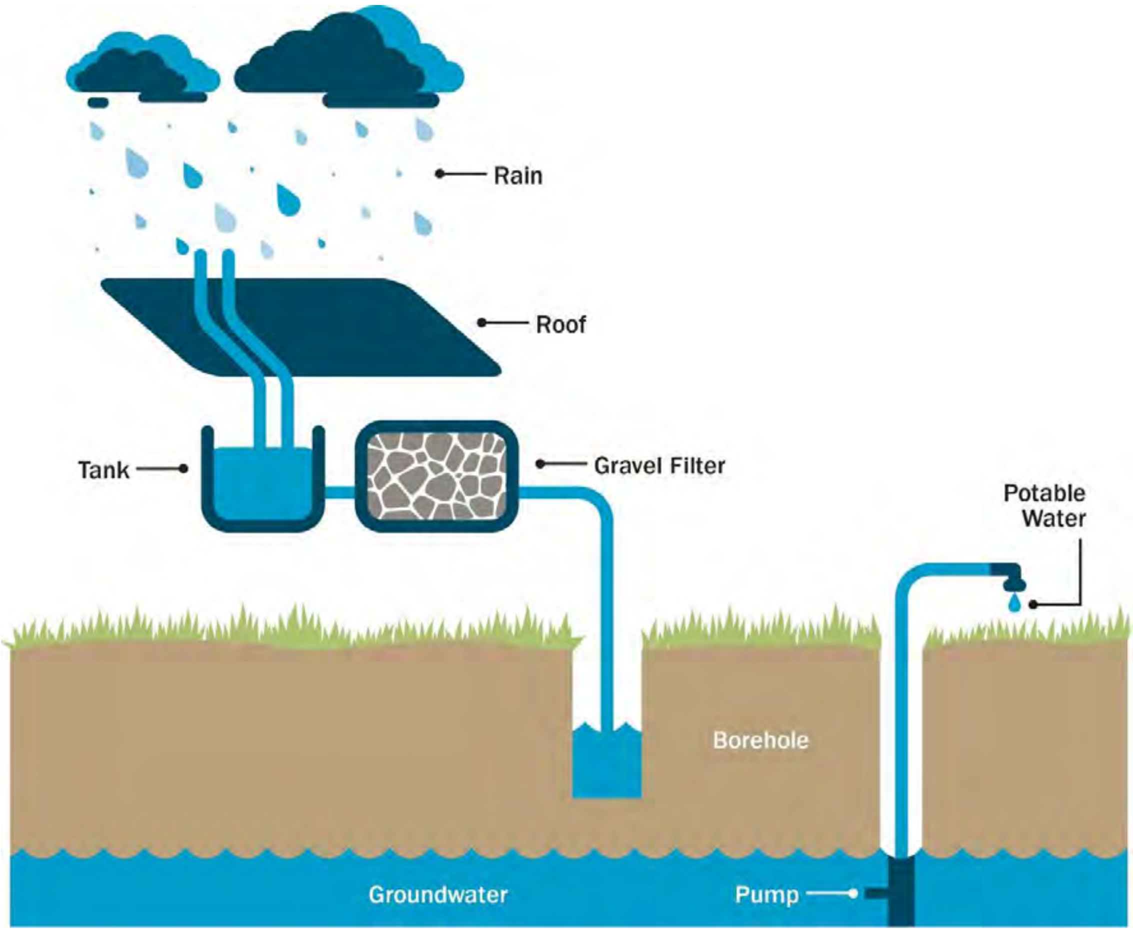


Figure 97: Schematic drawing of a Compact Infiltration System (CIS)

Once the water enters the borehole, it starts to dissipate into the rock through the sides of the borehole. If the flow rate of the runoff being injected into the borehole is more than the water dissipation rate at that water level, the water level in the borehole increases. Depending on the relative flow rates, the water level increases or decreases. When the rain subsides, the borehole empties over a period of time, which may be hours or days. The time required for emptying depends entirely on the permeability of the rock layers.

The dissipation rate depends on:

1. The (primary) permeability of the bedrock, which may not be homogeneous throughout the depth of the borehole;
2. The degree of fissuring of the bedrock (secondary permeability). The dissipation rate is significantly increased if the borehole intercepts a fissure;
3. The depth of the borehole. A deep borehole provides a larger wetted area for dissipation, as well as a larger water head; and,
4. The diameter of the borehole, as this increases the wetted area.

During a heavy storm, the water level in the borehole may continue to rise to reach the borehole wellhead. However, the system does not allow the water to overflow and spill over onto the well head because the well head, the gravel filter and the pipework connecting the well head to the gravel filter and the gravel filter to the tank are all water-tight. So, with nowhere to go, the water remains in the tank and the water level in the tank starts to rise. The function of the tank is to temporarily store the volume of water that cannot be immediately dissipated by the borehole.

Once the storm subsides, the water level in the tank drops as the water contained therein is dissipated by the borehole.

Water Quality

CIS are designed to discharge surface water runoff to the ground and ultimately into groundwater. It is therefore crucial that any runoff is suitably clean before entering the infiltration component so that the groundwater is not put at risk of contamination. Extensive analytical tests were carried out on the pollution loading of runoff collected from roofs in Malta (refer to **Appendix 10.03**), and it was found of sufficiently good quality for indirect recharge without treatment.

To avoid contamination of the receiving groundwater:

1. The application of CIS is limited to managing runoff from roofs (not terraces, yards, roads, or surfaces at ground level where the pollution load would be higher);
2. The borehole is drilled to a depth that does not exceed 50% of the depth to the aquifer, so as to provide a depth of bedrock that may filter/adsorb any residual pollutants;
3. Roofs must not be accessible to pets or for storing of materials that may leach contaminants;
4. A risk assessment would be required to identify pollution risks and ensure that quality of the water recharging the aquifer meets the quality standards and threshold values listed under the EU Groundwater Directive (GWD).

Performance of a GEO-INF CIS

The performance of a GEO-INF CIS is dependent on the infiltration capacity of the borehole. From various falling-head tests carried out on 15 boreholes drilled in the Lower Globigerina Limestone formation at different locations around Malta, it was found that the water dissipation rate of a borehole drilled in a particular location can be multiple times higher than the dissipation rate of a similar one (same depth, same diameter) drilled in another location. Large differences in permeability were also identified within the same borehole along its depth.

Figure 98 presents the results of the infiltration rate tests carried out on a number of boreholes in different locations of Malta at different depths, obtained through falling-head tests and through data-logging of water levels during actual rain events. As can be seen from the graph, there is a very large variation in the infiltration rates (from 0.01 to almost 10 litres per minute per m^2 of borehole wetted area). For the same borehole, there is an exponential increase in infiltration rate with depth because:

1. The head (driving force) increases with depth and

2. The wetted area increases with depth.

For example, the infiltration rate of the Fleur-de-Lys BH increased five-fold from 0.2 litres/m^2/min to 1 litres/m^2/min for an increase in water level in the borehole from 6.5 m to 9.5 m.

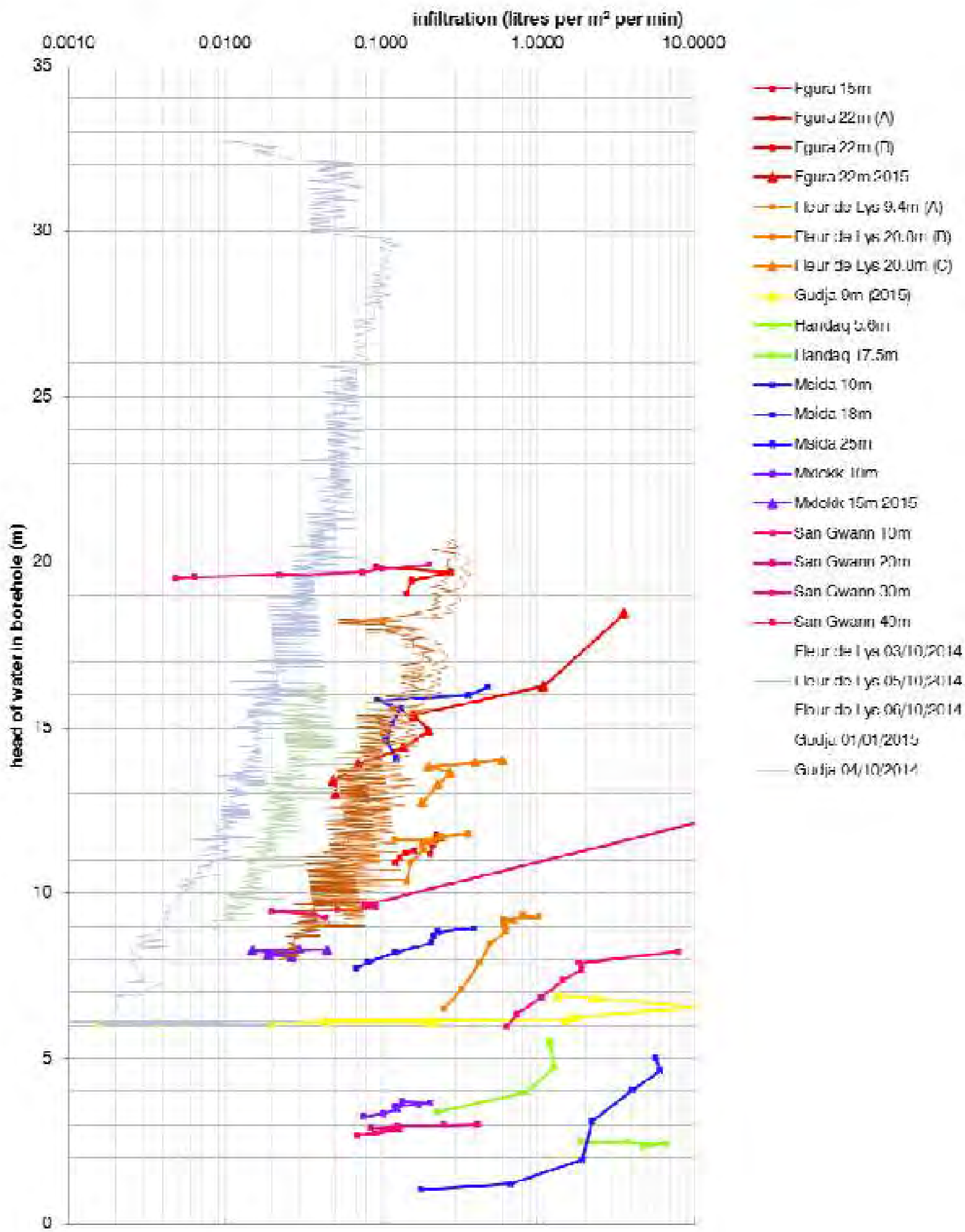


Figure 98: Infiltration rates observed in boreholes drilled entirely in the Lower Globigerina Limestone formation as part of the GEO-INF research project (2012 - 2013)

However, notwithstanding these variations, it can be estimated that a borehole drilled in the Lower Globigerina Limestone formation can provide an average infiltration rate of 0.3 litres per m^2 per minute in Globigerina Limestone. For a 0.1 m diameter borehole, this equates to 1,350 litres per m^2 per day.

Moreover, if more permeable lower coralline limestone formation and/or a fissure are intercepted by the borehole, a higher dissipation rate can be achieved. A very wide borehole (0.9 m diameter) will dissipate 9 times the flow of a 0.1 m diameter borehole.

Hydraulic Design

The objective of CIS is to infiltrate as much runoff into the ground, with the least cost and space.

An investigation of rainfall patterns (frequency and intensity) in Malta for the 10-year period spanning from 1st January 2004 to 31st December 2013 from data obtained from the Met Office, showed that most of the annual precipitation is from events of between 10 to 50 mm. (**Table 11**).

Rainfall Event	% of annual rainfall
less than 0.1 mm i.e., 0.0 mm	0%
between 0.1 mm and 1.0 mm	2%
between 1.0 mm and 5 mm	13%
between 5.0 mm and 10 mm	14%
between 10 mm and 50 mm	63%
greater than 50 mm	8%

Table 11: Rain event depth distribution between 2004 - 2013

It would be ideal to infiltrate all the runoff into the ground (no overflow). However, there are limitations on the depth and diameter of the borehole; a larger diameter borehole requires a specialised drilling rig and gives rise to issues of accessibility in retrofitting installations.

The other parameter that determines the infiltration efficiency is the size of the storage tank. The larger the volume of the tank, the more the water that can be temporarily stored to be released over time into the borehole.

Table 12 shows how the recharge efficiency increases with tank volume, for different storms. For example, a GEO-INF system with a 1000 litre tank will be able to infiltrate 79% of the runoff from a roof measuring 200 m^2 (based on an annual mean precipitation of 553 mm). It would be able to completely handle the runoff by storms delivering up to 10.6 mm of precipitation, 82% of the runoff during storms delivering up to 28.8 mm of precipitation and 53% of the runoff during heavier storms.

Scenario : 200 m² roof area, 553 mm annual rainfall, 0.9 runoff coefficient									
Storm event depth (mm)	10.6			28.8			49		
Buffer tank capacity (litres)	Collected runoff	Volume to recharge (litres)	Volume of overflow	Collected runoff	Volume to recharge (litres)	Volume of overflow	Collected runoff	Volume to recharge (litres)	Volume of overflow
500	1908	1908	0	5184	3744	1440	8820	4214	4606
		100%	0%		72%	28%		48%	52%
1000	1908	1908	0	5184	4262	922	8820	4704	4116
		100%	0%		82%	18%		53%	47%
2000	1908	1908	0	5184	5184	0	8820	5684	3136
		100%	0%		100%	0%		64%	36%

Table 12: Infiltration efficiency and tank volume for different rain events for a 200 m² roof

Installing a CIS system

In practice, the suggested procedure for the installation of a CIS system (for up to roof areas of 250 m²) is as follows:

1. Drilling of a borehole of 0.1 m diameter to the maximum permissible depth allowed (half the depth to the aquifer) and observation of the infiltration rate by means of a falling head test. This will give an indication of whether the system will deliver a satisfactory recharge efficiency.
2. The infiltration efficiency may then be improved by increasing the size of the tank.

For large catchment areas, and where operational space for a larger drilling rig is available, the borehole should be drilled to a larger diameter. Again, falling head tests should be carried out to establish whether the target dissipation rate has been achieved.

In either case, and to complete the installation, the borehole should be cased to a depth of 5m.

In situations, with large roof areas, it may be required to install more than one CIS. In this case, it is advisable that the boreholes be drilled as far away from each other as possible so that the infiltration water issued from one borehole would not affect the others.

A CIS system would require notification to the Environment and Resources Authority (ERA), which would request details of the installation described in **Appendix 10.06**.

A typical CIS system requires a space of approximately 2.5 m².

The only maintenance required is the periodic cleaning of the gravel filter. The gravel should be removed, cleaned (by power-washer) and placed back in the retaining box. The gravel, usually hard-wearing dolomite, does not erode easily and should last a number of years.

Over time, the dissipation performance of the borehole may decrease because of silting of the borehole walls, the ingress of soil from fractures in the rock intercepted by the borehole, and possible collapse of sections of the borehole itself. If the situation becomes severe, the borehole may have to be re-cored.

Figures 99, **100**, **101**, and **102:**

Views of GEO-INF CIS installations

8.13

Hybrid Solutions

Chapters 8.01 to **8.12** describes proven GSI technologies considered to be most suitable for Malta. Although the technologies have been presented as stand-alone systems (which they usually are), there may be situations where a combination of two (or more) technologies may provide an even better solution.

Chapter 8.01 describes RWH systems which have dual benefits of resource recovery and flood mitigation. However, RWH systems are only effective in mitigating flooding if there is actual take-up of the runoff being collected in the tanks. Once the storage component of a RWH system is full - as may very well happen in the course (but especially towards the end) of the wet season - the system becomes ineffective as a flood mitigation tool as any runoff entering the tank exits the system immediately as overflow.

In order to ensure that RWH systems retain some flood-mitigation capability throughout the year, these systems have to be active, whereby water is pumped out of the tank if/once the water level exceeds a certain threshold.

A hybrid solution that would work equally well would be combining a RWH system with an infiltration system, with the infiltration system installed with the overflow of the RWH system to channel the surplus stormwater into the ground. This would ensure full recovery of the water, while also providing flood mitigation and attenuation capability all year round without the costs, risks, and malfunctions of an active (pumping) system.

Other examples of hybrid systems are a PTS treating the runoff of a road which is then infiltrated, and a green roof discharging its excess to a RWH system or tree plantations on the pavement in front of the building.

9.00

Applicability of GSI Techniques

This Chapter contains information to assist the user of this Manual to make the choices that best fit the needs of the situation under consideration.

The GSI Techniques Selection Grid presented in **Table 13** directs the user to zone in on the technologies that work best for the user's particular project based on the ***type/nature*** of the project eliminating those technologies which do not work. The user is then encouraged to refer to the respective chapters in this Guidance Manual for more information about the short-listed technologies. Some situations are marked as 'Possible' because the selection also depends on the scale and location of the project, and the particular hydrogeological, physical and morphological circumstances.

Chapter reference	8.01	8.02	8.03	8.04	8.05	8.06	8.07	8.08	8.09	8.10	8.11	8.12
Legend: Y: Yes N: No P: Possible GSI technique	Rainwater harvesting	Green roofs	Infiltration systems/soakaways	Proprietory treatment systems	Filter Drains and Filter Strips	Swales	Bioretention Systems	Trees	Pervious pavements	Dams	Ponds and wetlands	Compact Infiltration Systems
Development type												
Single residence (townhouse, villa)	Y	Y	N	N	N	N	N	P	P	N	N	Y
Block of apartments	Y	P	N	N	N	N	N	P	P	N	N	Y
Commercial Centre	Y	Y	P	N	N	N	N	P	P	N	N	Y
Supermarket	Y	Y	P	N	N	N	N	P	P	N	N	Y
Outdoor sports complex (e.g. football ground) with turf	Y	N	P	N	Y	N	N	N	N	N	N	P
Outdoor sports complex (e.g. football ground) with artificial turf	P	N	P	N	Y	N	N	N	N	N	N	P
Public garden	Y	N	P	N	Y	N	Y	Y	Y	N	P	N
Open space in urban area	Y	N	P	P	Y	N	P	Y	Y	N	N	N
A number of fields in a flat area	Y	N	N	N	N	Y	P	Y	N	N	P	N
A number of fields on a slope	Y	N	N	N	N	Y	P	Y	N	N	P	N
A manufacturing facility needing process water	Y	Y	N	P	N	N	N	P	P	N	N	P
A manufacturing facility not needing 2nd class water	N	Y	Y	P	P	N	N	P	P	N	N	Y
Airport	P	P	Y	Y	Y	N	N	N	Y	N	N	N
Industrial Estate	Y	P	Y	Y	Y	N	N	Y	Y	N	N	P
Arterial roads	P	N	Y	Y	Y	N	N	Y	Y	N	N	N
Local roads with pavements	N	N	P	N	P	N	N	Y	Y	N	N	N
Roundabouts at junctions	Y	N	Y	Y	P	N	P	Y	P	N	N	N
Natural park	P	N	N	N	N	Y	Y	Y	p	P	P	N
Valley	P	N	P	N	N	Y	P	P	N	Y	P	N
Animal farm	Y	P	P	Y	P	N	N	P	P	N	N	Y
Cemetery (with landscaping)	Y	N	P	N	Y	N	N	Y	Y	N	N	N
Hotel in urban area (no landscaping)	Y	P	P	P	P	N	N	Y	Y	N	N	Y
Hotel with extensive landscaping	Y	P	P	P	P	N	P	Y	Y	N	P	P

Table 13: GSI techniques selection grid

Table 14 provides a list of pros and cons for each GIS technique, to further assist the selection.

			All systems can help reduce downstream flooding	***All systems require maintenance***
			Systems can be combined	***All systems need an overflow***
Chapter Reference	**Name**	**Description**	**Pro**	**Con**
8.01	***Rainwater Harvesting***	Direct storage and re-use	Minimum loss of water	Weight and Volume - Expense; normal location below ground (excavation issues)
			Traditional & legal Doc F requirement	Ownership & management issues of both catchment & water in multi-owner sites
			Minimal treatment at catchment; first flush management	
			Helps with peak flow lopping	
8.02	***Green Roofs***	Vegetation on top of structure	Water absorption 60% - 90% of low flow events	Weight – minimum 15 cm engineering medium & waterproofing of supporting structure
			High potential amenity value & thermal absorption	Reduction of trafficable (paved) space
			Malta Standard available SM 3700:2017	Occasional maintenance depending on planting
			Runoff can be re-used in irrigation	Runoff needs treatment
				Irrigation needed depending on planting
8.03	***Infiltration Systems /Soakaways***	Promotes direct ground infiltration - Soakaways	Efficiency depends on ground porosity/presence of fissures	Catchment treatment for pollutants especially in groundwater protection zones
			Large catchments upstream of site	Inefficient near water table/mean sea level
			Open water type may have amenity /scenic use	Filtration needed upstream to avoid clogging
			Can recover volumes of runoff that are multiple times	Open water type may be water hazard/insect breeding ground

			its built volume i.e., very space efficient	Needs depth and area
				Collects sediments with concentrated pollutants
8.04	***Proprietary Treatment Systems***	Hydraulic treatment - e.g., vortex separators, oil separators	Specific to situation: e.g., fuel stations, roads	Separated streams need removal of waste
				No reduction in downstream flow
8.05	***Filter Drains***	Trenches with gravel; "French drains", perforated pipes	Removes some pollutants on media	Filtration needed upstream to avoid clogging
			Efficient at low flows	
	Filter Strips	Grass vegetation sheet-flow interception	Removes pollutants	High land uptake
			Possible local water source	Needs sustained vegetation
8.06	**Swales**	Shallow vegetated linear channels	Infiltration through slowed water course	Takes up space
			Efficient at low flows	Needs sustained vegetation
				Requires area
				Local area low flow catchments only
				Large soil volumes
				Need good drainage
8.07	**Bioretention systems**	Shallow depressed landscaped areas - "rain gardens"	Pond creates habitat and amenity	Requires area
			Caters for frequent rainfalls	Filtration needed upstream to avoid erosion
			Removes some pollutants through vegetation & media	Needs regular maintenance and water
8.08	***Trees***	Plantations of wooded vegetation	Absorption of water on surfaces and through roots	Requires space and air, and depth of root medium

			Treatment of pollutants in tree.	Limited take up of water per tree
8.09	***Pervious pavements***	Floor surface to take pedestrian/ vehicular traffic	Infiltration through designed joints/spaces	Subsurface to absorb & dissipate incoming flow
				Overall pavement foundation can be undermined unless designed properly
8.10	***Dams***	Impoundment of watercourse	Infiltration through base increased by stored depth	Evaporation water loss
				Contrary to nature
8.11	***Ponds & Wetlands***	Filling of natural depressions	Infiltration through base proportional to depth	Subject to drying out and natural drainage
			Amenity and wildlife benefit	Evaporation
8.12	**Compact Infiltration Systems**	Use of boreholes for indirect groundwater recharge by water collected from roofs	Compact, relatively low cost, low maintenance, tested locally Good alternative to RWH where there is no demand for second-class water Good retrofitting solution Can supplement a RWH system	No treatment of the water, so the water must be clean

Table 14: GSI techniques comparative assessment table

10.01

List of Consultees

A list of stakeholders was drawn up and invitations to meet (virtually or physically) were sent out to several Departments/Authorities/Agencies//professionals. The meetings were held in 2021.

Consultees, included, among others:

- Energy and Water Agency
- Environment and Resources Authority
- VIVACITY Ltd.
- Malta Water Interest Group
- Mr. Antoine Gatt, Landscape architect
- Faculty for the Built Environment, University of Malta
- Local Councils Association
- *Kamra tal-Periti*
- Parks Malta
- Building and Construction Agency
- Building Industry Consultative Council
- Planning Authority

10.02

Rainwater Harvesting (RWH) Cistern Sizing

Case Study 1A : 4-person Townhouse without a garden														
	unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
Precipitation	mm	87.75	60.53	42.73	22.10	9.92	3.12	0.49	7.31	42.94	86.28	87.73	102.48	
Roof Area	m^2	140	140	140	140	140	140	140	140	140	140	140	140	
Runoff Coefficient		0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
Runoff Collected	m^3	11.1	7.6	5.4	2.8	1.2	0.4	0.1	0.9	5.4	10.9	11.1	12.9	69.7
Days in month		31	28	31	30	31	30	31	31	30	31	30	31	
Toilet water demand														
Flush volume	l	7	7	7	7	7	7	7	7	7	7	7	7	
3 Flushes per day, 4 persons, assuming residence is occupied all year long														
Toilet demand/month	m^3	2.6	2.4	2.6	2.5	2.6	2.5	2.6	2.6	2.5	2.6	2.5	2.6	
Washing Machine demand (assuming washing machine uses 50 litres per load)														
Loads per day		1	1	1	1	1	1	1	1	1	1	1	1	
Laundry demand/month	m^3	1.6	1.4	1.6	1.5	1.6	1.5	1.6	1.6	1.5	1.6	1.5	1.6	
Total domestic 2nd class water demand	m^3	4.2	3.8	4.2	4.0	4.2	4.0	4.2	4.2	4.0	4.2	4.0	4.2	48.9
Annual supply>annual demand, so design to meet maximum water demand in summer														
Surplus/deficit	m^3	6.9	3.9	1.2	-1.2	-2.9	-3.6	-4.1	-3.2	1.4	6.7	7.0	8.8	
Cumulative	m^3				-1.2	-4.1	-7.8	-11.9	-15.1					
required cistern capacity							**15.1 m^3**					Overflow		20.8 m^3
for a Doc F factor of							**0.11**					or		30%

Table 15: Case Study 1A: Townhouse without a garden

	unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
Case Study 1B : 4-person Townhouse with a garden														
Precipitation (mm)	mm	87.75	60.53	42.73	22.10	9.92	3.12	0.49	7.31	42.94	86.28	87.73	102.48	
Roof Area	m^2	140	140	140	140	140	140	140	140	140	140	140	140	
Runoff Coefficent		0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
Runoff Collected	m^3	11.1	7.6	5.4	2.8	1.2	0.4	0.1	0.9	5.4	10.9	11.1	12.9	69.7
Days in month		31	28	31	30	31	30	31	31	30	31	30	31	
Toilet water demand														
Flush volume	l	7	7	7	7	7	7	7	7	7	7	7	7	
3 Flushes per day, 4 persons, assuming residence is occupied all year long														
Toilet demand/month	m^3	2.6	2.4	2.6	2.5	2.6	2.5	2.6	2.6	2.5	2.6	2.5	2.6	
Washing Machine demand (assuming washing machine uses 50 litres per load)														
Loads per day		1	1	1	1	1	1	1	1	1	1	1	1	
Laundry demand/month	m^3	1.6	1.4	1.6	1.5	1.6	1.5	1.6	1.6	1.5	1.6	1.5	1.6	
Total domestic 2nd class water demand	m^3	4.2	3.8	4.2	4.0	4.2	4.0	4.2	4.2	4.0	4.2	4.0	4.2	48.9
Garden irrigation water demand														
			Garden area		Irrigation demand									
using 12,000 m^3/year/hectare			70	m^2	84	m^3/year								
Irrigation distribution		0%	15%	30%	50%	65%	80%	100%	100%	70%	40%	10%	0%	
Irrigation demand (m3)		0	2.25	4.5	7.5	9.75	12	15	15	10.5	6	1.5	0	84
Total demand		4.2	6.0	8.7	11.5	13.9	16.0	19.2	19.2	14.5	10.2	5.5	4.2	132.9
Now that annual demand>annual supply, design for total utilisation of rain water														
Surplus/deficit	m^3	6.9	1.6	-3.3	-8.7	-12.7	-15.6	-19.1	-18.2	-9.1	0.7	5.5	8.8	
Cumulative	m^3	21.9	23.5								0.7	6.3	15.0	
required cistern capacity							**23.5**	m^3						
for a Doc F factor of							**0.17**							

Table 16: Case Study 1B: Townhouse with a garden

Case Study 2 - Block of Apartments														
	units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
Precipitation	mm	87.75	60.53	42.73	22.1	9.92	3.12	0.49	7.31	42.94	86.28	87.73	102.48	
Roof Area	m^2	270	270	270	270	270	270	270	270	270	270	270	270	
Runoff Coeff		0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
Runoff Collected	m^3	21.3	14.7	10.4	5.4	2.4	0.8	0.1	1.8	10.4	21.0	21.3	24.9	134.5
Days in month		31	28	31	30	31	30	31	31	30	31	30	31	
Building occupancy	%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	
Toilet water demand														
Flush volume	l	7	7	7	7	7	7	7	7	7	7	7	7	
Assuming 3 flushes per day, 2 person per apartment, 15 apartments in block														
Volume per month	m^3	13.7	12.3	13.7	13.2	13.7	13.2	13.7	13.7	13.2	13.7	13.2	13.7	161.0
Annual demand>supply, then design for total utilisation of the rain water														
Surplus/deficit	m^3	7.7	2.4	-3.3	-7.9	-11.3	-12.5	-13.6	-11.9	-2.8	7.3	8.1	11.2	
Cumulative	m^3	34.3	36.6								7.3	15.4	26.6	
Cistern volume needed for harvesting of all runoff					**36.6**	m^3								
for a Doc F coefficient of					**0.14**									

Table 17: Case Study 2: Block of Apartments

Case Study 3 : Office Block														
	units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Precipitation (mm)	mm	87.75	60.53	42.73	22.1	9.92	3.12	0.49	7.31	42.94	86.28	87.73	102.48	
Roof area	m^2	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	
Runoff Coefficient		0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
Runoff Collected	m^3	94.8	65.4	46.1	23.9	10.7	3.4	0.5	7.9	46.4	93.2	94.7	110.7	598
Days in month		31	28	31	30	31	30	31	31	30	31	30	31	
Number of employees		120	120	120	120	120	120	120	120	120	120	120	120	
Building occupancy	%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	
Toilet water demand														
Flush volume	l	7	7	7	7	7	7	7	7	7	7	7	7	
Flushes per day		21	litres per employee per working day											
Volume per month	m^3	44.64	40.32	44.64	43.2	44.64	43.2	44.64	44.64	43.2	44.64	43.2	44.64	
Add floor washing	m^3	1.11	1.00	1.11	1.07	1.11	1.07	1.11	1.11	1.07	1.11	1.07	1.11	
Add firefighting drills	m^3	0	0	10	0	0	10	0	0	10	0	0	10	
Total 2nd class water demand	m^3	45.75	41.32	55.75	44.27	45.75	54.27	45.75	45.75	54.27	45.75	44.27	55.75	579
Annual supply>annual demand, so design to meet maximum summer deficit														
Surplus/deficit	m^3	49.0	24.1	-9.6	-20.4	-35.0	-50.9	-45.2	-37.9	-7.9	47.4	50.5	54.9	
Cumulative	m^3			-9.6	-30.0	-65.0	-115.9	-161.2	-199.0	-206.9				
Requiring a cistern of capacity			**206.9**	**m3**										
For a Doc F Coefficient of			**0.17**											
% utilisation			97%											

Table 18: Case Study 3: Office Block

Case Study 4A: Manufacturing Facility/Warehouse															
	units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		Totals
Precipitation		87.75	60.53	42.73	22.1	9.92	3.12	0.49	7.31	42.94	86.28	87.73	102.48		
Roof Area	m^2	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500		
Runoff Coefficient		0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9		
Runoff Collected	m^3	197.4	136.2	96.1	49.7	22.3	7.0	1.1	16.4	96.6	194.1	197.4	230.6		1245.1
Cumulative runoff	m^3	916.2	1052.3	1148.5	1198.2	1220.5	1227.6	1228.7	1245.1	1341.7	290.7	488.1	718.7		
Days in month		31	28	31	30	31	30	31	31	30	31	30	31		
Toilet water demand															
Number of employees		30	30	30	30	30	30	30	30	30	30	30	30		
Flush volume	l	7	7	7	7	7	7	7	7	7	7	7	7		
Number of flushes per employee per working day		3	3	3	3	3	3	3	3	3	3	3	3		
Toilet demand, per month	m^3	13.95	12.6	13.95	13.5	13.95	13.5	13.95	13.95	13.5	13.95	13.5	13.95		164.25
Surplus/deficit	m^3	183.5	123.6	82.2	36.2	8.4	-6.5	-12.8	2.5	83.1	180.2	183.9	216.6		1080.9
Cumulative	m^3						-6.5	-19.3							
Annual supply > annual demand, therefore work on capacity needed to meet summer demand												**19.3**	m^3		
											or	**0.01**	**Doc F factor**		
		Rainwater utilisation			164	m3 or	13%								
		Discharge			1080.9	m3 or	87%								

Table 19: Case Study 4A: Manufacturing Facility/Warehouse

Case Study 4B: Manufacturing Facility with use for rain water as process water														
	units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
Precipitation	mm	87.75	60.53	42.73	22.1	9.92	3.12	0.49	7.31	42.94	86.28	87.73	102.48	
Roof Area	m^2	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	
Runoff Coefficient		0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
Runoff Collected	m^3	197.4	136.2	96.1	49.7	22.3	7.0	1.1	16.4	96.6	194.1	197.4	230.6	1245.1
Days in month		31	28	31	30	31	30	31	31	30	31	30	31	
Toilet water demand														
Number of employees		30	30	30	30	30	30	30	30	30	30	30	30	
Flush volume	l	7	7	7	7	7	7	7	7	7	7	7	7	
Number of flushes per employee per working day		3	3	3	3	3	3	3	3	3	3	3	3	
Toilet demand, per month	m^3	13.95	12.6	13.95	13.5	13.95	13.5	13.95	13.95	13.5	13.95	13.5	13.95	
Process Water demand			2	m3/working day										
Process water demand/working day	m^3	5	5	5	5	5	5	5	5	5	5	5	5	
Process water demand/month	m^3	110.7	100.0	110.7	107.1	110.7	107.1	110.7	110.7	107.1	110.7	107.1	110.7	
Total demand	m^3	124.7	112.6	124.7	120.6	124.7	120.6	124.7	124.7	120.6	124.7	120.6	124.7	1467.8
Surplus/deficit	m^3	72.8	23.6	-28.5	-70.9	-102.3	-113.6	-123.6	-108.2	-24.0	69.5	76.7	105.9	
Cumulative	m^3	324.9	348.5									146.2	252.1	
Annual demand > annual supply, therefore work on full utilisation of rainwater												**348.5**	**m^3**	
											or	**0.14**	**Doc F factor**	

Table 20: Case Study 4B: Manufacturing facility with use for rainwater as process water

Case Study 5: Public Garden															
Landscaped area	6200	m^2													
Hard surfaced area	2300	m^2													
plants per m2	5														
	31000														
75% of area being soft landscaped	23250	shrubs													
Irrigation requirement	15	ltr/shrub/week													
	64.5	ltr/shrub/month													
	1499625	ltr/month													
	1499.6	m^3/month													
	49.3	m^3/day													
		units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
Precipitation (mm)		mm	87.75	60.53	42.73	22.1	9.92	3.12	0.49	7.31	42.94	86.28	87.73	102.48	
Hard landscaping area (m2)		m^2	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300	
Soft landscaping area (m2)		m^2	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200	
Runoff Coefficient (hard landscaping)			0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
Runoff Coefficient (soft landscaping)			0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
Runoff from hard landscaped areas		m^3	181.6	125.3	88.5	45.7	20.5	6.5	1.0	15.1	88.9	178.6	181.6	212.1	
Runoff from soft landscaped areas		m^3	27.2	18.8	13.2	6.9	3.1	1.0	0.2	2.3	13.3	26.7	27.2	31.8	
Total Runoff			208.8	144.1	101.7	52.6	23.6	7.4	1.2	17.4	102.2	205.3	208.8	243.9	1317.0
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Ambient temp		C	18.72	19.4	21.97	24.67	29.31	33.59	36.38	35.77	32.39	28.64	24.39	20.42	
% irrigation			0%	4%	18%	34%	60%	84%	100%	97%	77%	56%	32%	10%	
Daily irrigation		m^3	0.0	1.9	9.1	16.6	29.6	41.6	49.4	47.7	38.2	27.7	15.9	4.8	
days/month			31	28	31	30	31	30	31	31	30	31	30	31	
Monthly irrigation		m^3	0.0	53.3	281.8	499.3	918.3	1247.9	1531.4	1478.5	1147.2	860.2	475.8	147.4	8641.1
Surplus/Deficit		m^3	208.8	90.8	-180.1	-446.7	-894.7	-1240.4	-1530.2	-1461.1	-1045.0	-654.9	-267.0	96.5	
Cumulative		m^3	305.3	396.1										96.5	
Annual demand > annual supply, therefore work on full utilisation of surplus (for use in summer)								**396.1**	m^3						
							or	**0.05**	**Doc F factor**						
									based on total footprint of the garden						

Table 21: Case Study 5: Public garden

Case Study 6: Hotel														
	units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
Precipitation	mm	87.75	60.53	42.73	22.1	9.92	3.12	0.49	7.31	42.94	86.28	87.73	102.48	
Roof Area	m^2	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	
Runoff Coefficient		0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
Runoff Collected	m^3	1579.5	1089.5	769.1	397.8	178.6	56.2	8.8	131.6	772.9	1553.0	1579.1	1844.6	9960.8
Days in month		31	28	31	30	31	30	31	31	30	31	30	31	
Number of rooms		400	400	400	400	400	400	400	400	400	400	400	400	
Guests per room		2	2	2	2	2	2	2	2	2	2	2	2	
Occupancy		0.97	0.97	0.95	0.75	0.6	0.45	0.35	0.4	0.5	0.8	0.9	0.97	
No of guests		776	776	760	600	480	360	280	320	400	640	720	776	
Days per month		31	31	30	31	30	31	31	28	31	30	31	30	
Toilet use per guest night per day		4	4	4	4	4	4	4	4	4	4	4	4	
Water use per flush	l	7	7	7	7	7	7	7	7	7	7	7	7	
Water consumption per day	m^3	673.6	673.6	638.4	520.8	403.2	312.5	243.0	250.9	347.2	537.6	625.0	651.8	5877.5
Surplus/deficit	m^3	905.9	416.0	130.7	-123.0	-224.6	-256.3	-234.2	-119.3	425.7	1015.4	954.2	1192.8	
Cumulative	m^3	4494.1	4910.0	5040.8	-123.0	-347.6	-604.0	-838.2	-957.5	425.7	1441.2	2395.3	3588.1	
Annual supply > annual demand, therefore work on capacity needed to meet summer demand									**957.5**	m^3	Rainwater utilisation			59%
								or	**0.05**	**Doc F factor**				
However, if we assume that surplus water can be used for landscaping and swimming pools in summer such that total water														
demand>supply then design for total utilisation and therefore														
		Capacity for full utilisation							**5040.8**	m^3				
									0.25	**Doc F Factor**				

Table 22: Case Study 6: Hotel

10.03

Quality of Stormwater in Malta

A. Runoff Generated on Roofs

1. The GEO-INF Research Project (2011 - 2013)

The quality of runoff generated on roofs in Malta is well documented in the GEO-INF Research Project. This research project was conducted between 2011 – 2013 with the objective of developing, prototyping and testing a GSI technology to divert clean rainwater falling on roofs into the ground to replenish the underlying aquifers, while also mitigating flooding. It is based on the innovative idea of using vertical boreholes drilled in the ground as part of a system to divert runoff from roofs of buildings into the ground. The full name of the Research Project was "Research on the use of infiltration boreholes for flood mitigation and to enhance groundwater recharge - GEO-INF". It was funded by the Malta Council for Science and Technology (MCST) and had Sustech Consulting as Project Co-ordinator, and the Department of Building and Civil Engineering, within the Faculty of the Built Environment of the University of Malta, Solid base Laboratory Ltd., the Malta Resources and St. Theresa College as partners.

One of the research topics was to determine the presence of pollutants on Maltese roofs that would be carried away with runoff generated on the same roofs. The research carried out detailed investigations on the presence of pollutants, their nature and concentrations, and variability by location and timing/intensity of the rain event.

The methodology adopted consisted of the collection and comprehensive laboratory water analyses of runoff generated from 5 school roofs for a suite of heavy metals, organics and microbiology, followed by focused sampling and analyses for a number of rain events from January to April 2012 from 3 sites, these being Fgura, B'Kara and Fleur de Lys (St. Venera).

The main conclusion of this research was that, except for the first (and in some situations, second) rain event, the runoff generated from roofs in urban areas is of a sufficiently good quality that it can be injected into the unsaturated zone of the aquifer, for groundwater recharge, without treatment.

The following describe the results on tests carried out to determine the quality of runoff generated on roofs of public schools in urban areas in Malta.

Results from the Runoff Contamination Tests from the GEO-INF Research Project on the runoff collected from roofs of schools

Runoff samples were collected after the first rain event of the 2011 - 2012 rainy season (on 20/09/2011) and after the third significant rain event of the season (on 04/10/2011) from 4 sites: Fgura, Santa Venera, Bikirkara and Mosta.

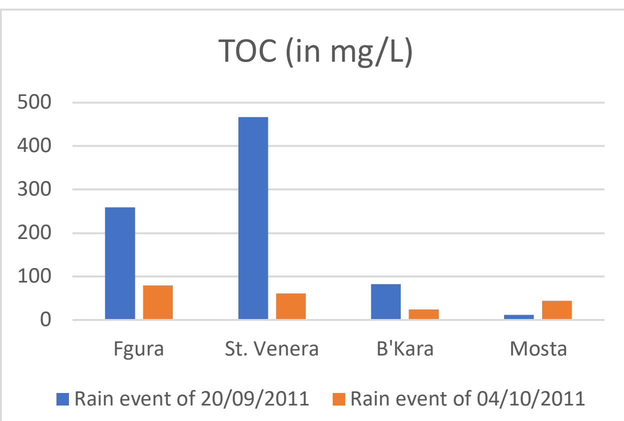
The samples were analysed for Total Organic Carbon (TOC), Total Petroleum Hydrocarbons (TPH), Lead, Nickel, Total Suspended Solids and Total Settleable Solids. It should be pointed out that all schools are located in areas of high traffic density.

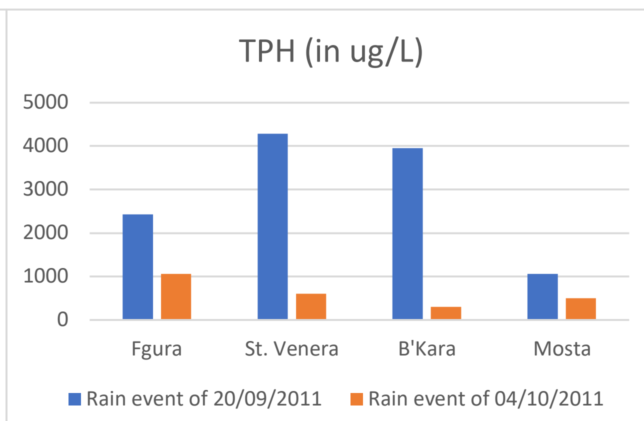
The results of the laboratory analyses are shown in **Figures 103**, **104**, **105**, **106**, **107** and **108**.

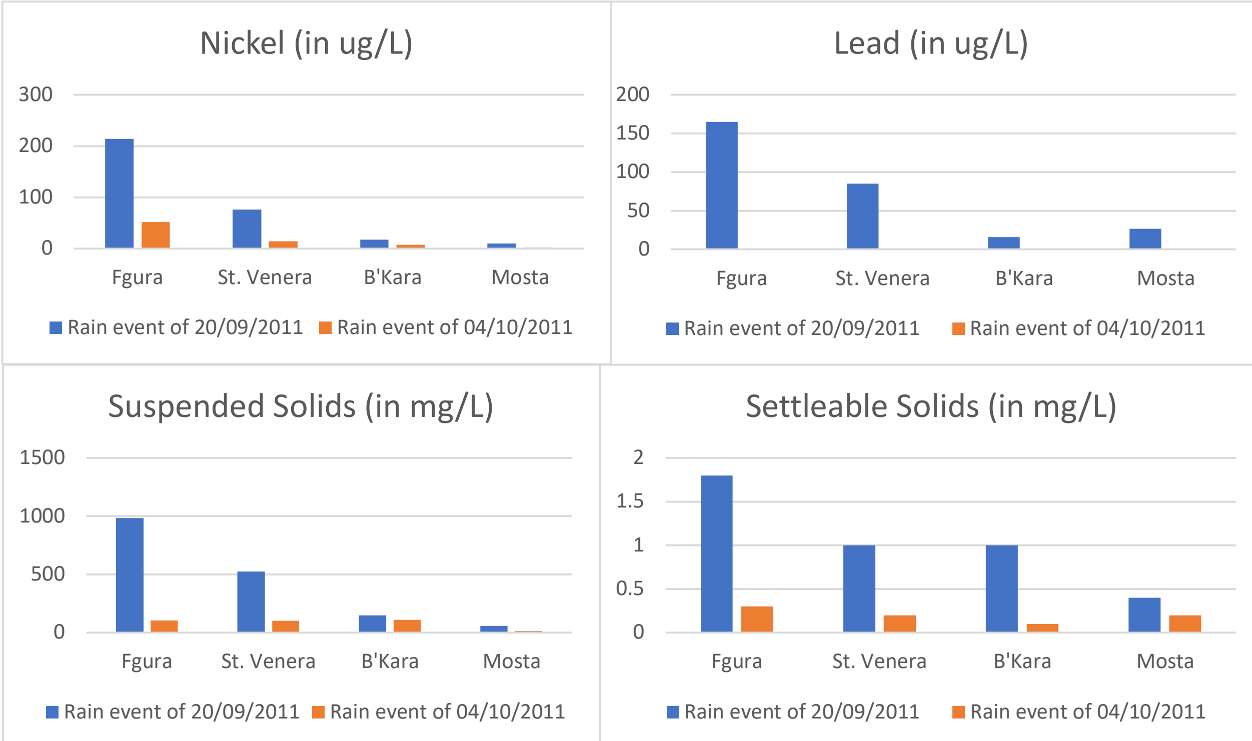
The most polluted runoff was that generated by the very first rain of the wet season and was to be expected as the first rain will carry off the pollutants that accumulated during the dry summer months. This was common for all locations.

In the case of Lead, less than 1 ug/L was detected for all samples collected during the third rain event. This means that the washing-out by the first and second rain events of the season was very effective. Similar results were obtained for other pollutants such as Zinc, Copper, Cadmium and Magnesium – with the concentrations being significantly lower for the third rain event of the season.

The levels of heavy metals (Nickel and Lead) were higher in Fgura than the other three locations – this can be attributed to the additional deposition from the then-operational Marsa Power Station.







Figures 103, **104**, **105**, **106**, **107** and **108:**

Results of samples as part of GEO-INF project during events of 20/9/2011 & 4/10/2011

Runoff samples continued to be collected from October 2011 to April 2012 for three roofs - B'Kara (Sample Point 1), Fgura (Sample Point 2) and Santa Venera (Sample Point 3) – for a more focused investigation on selected pollutants: Nickel, Lead, and TPHs, which were believed to be the pollutants of major concern in runoff from roofs.

The results are shown in **Figures 109**, **110** and **111**.

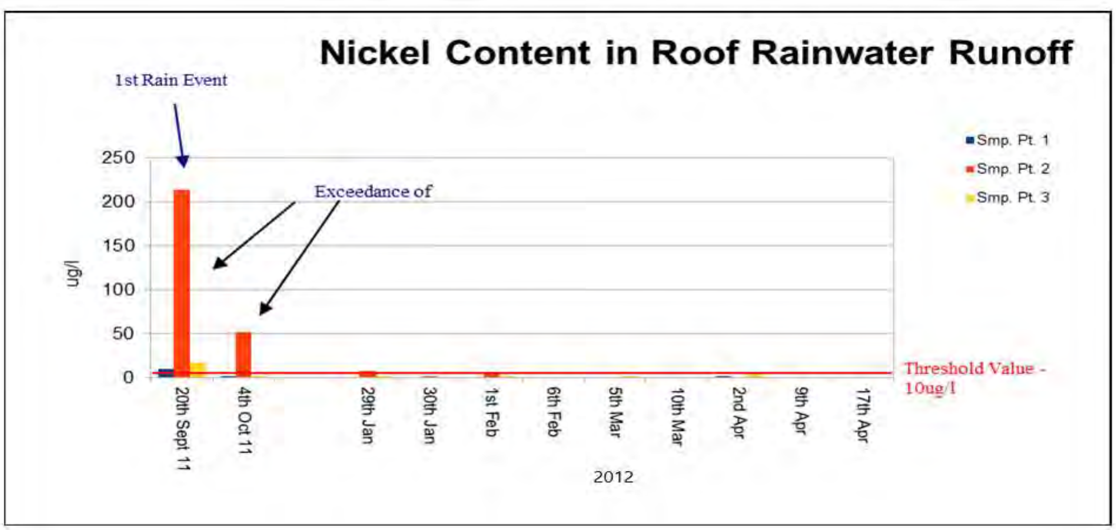


Figure 109: Results for Nickel in rainwater runoff from 3 roofs

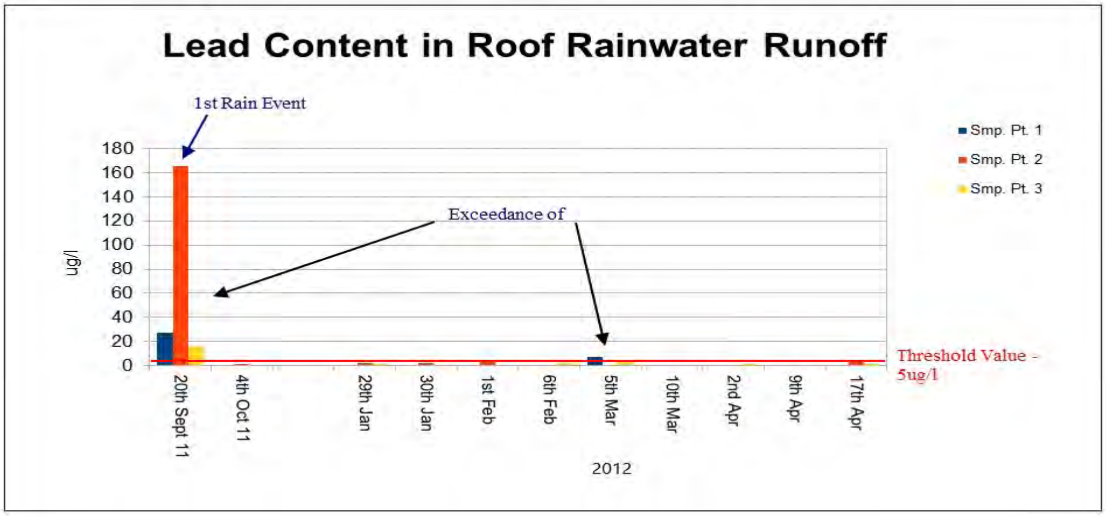


Figure 110: Results for Lead in rainwater runoff from 3 roofs

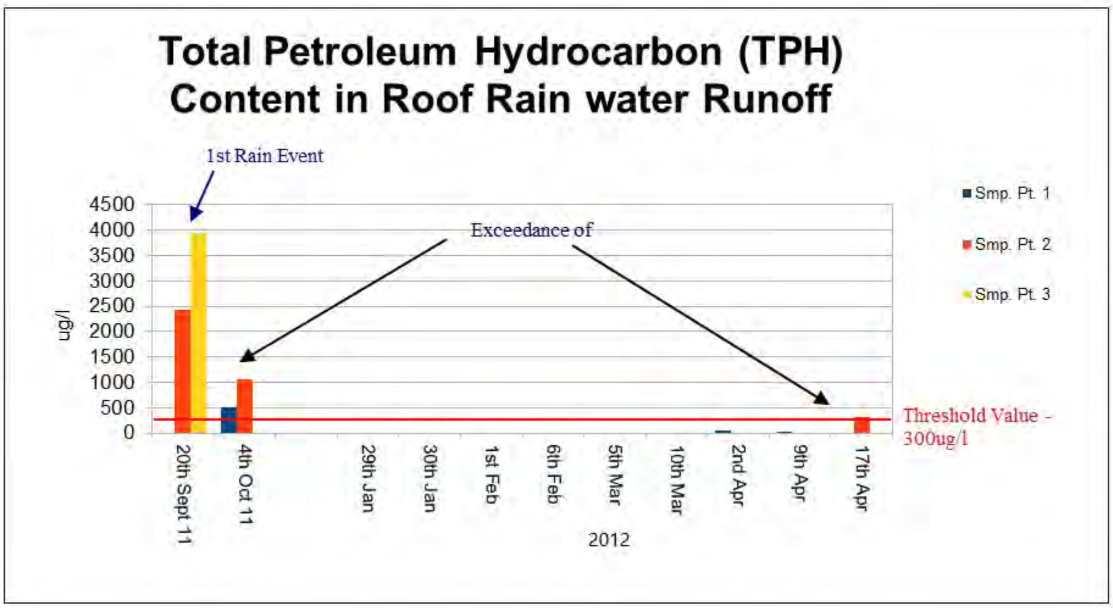


Figure 111: Results for total petroleum hydrocarbon (TPH) in rainwater runoff from 3 roofs

Beyond the second rain of rainy season 2011 - 2012 and all the way through to April 2012 (when the tests were stopped), the pollution levels in the water were very low and below the threshold levels required for injection into the ground.

More frequent samples were tested for Nickel and Lead from rainwater runoff from roof in a single location and results correlated with precipitation to establish whether there is a direct or inverse correlation between rainfall intensity and pollution. The results are shown in **Figure 112**.

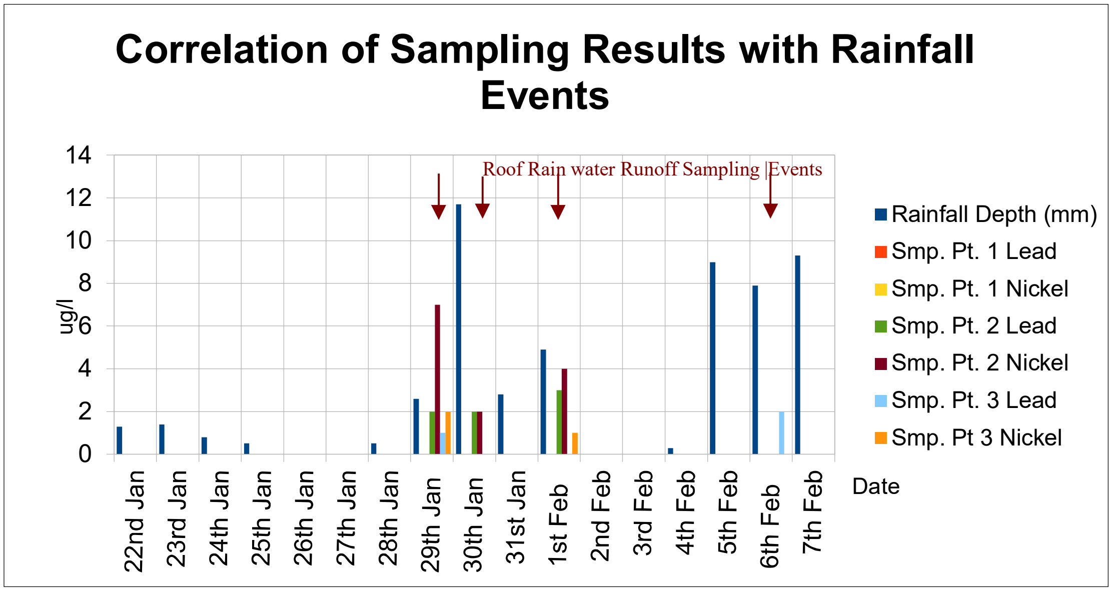


Figure 112: Results for Nickel and Lead collected from a single roof correlated with precipitation

The results show that there is no clear correlation between runoff intensity and the concentration of pollution in runoff. This may be explained by the fact that the higher the intensity of rainfall, the greater the amount of runoff, which then has a diluting effect on the concentration. So, while in absolute terms the amount of pollution (in terms of weight) carried over by a storm may be higher than that by a smaller rain event, in terms of concentration it could actually be less.

Conclusions from the GEO-INF results for runoff generated on roofs

The main conclusions that may be derived from these tests is that, apart from the first (and in some situations, second) rain event, the runoff generated from roofs of schools in Malta is suitable for injecting into the ground, as groundwater recharge, without treatment.

For this reason, a simple filtration system (e.g., a gravel filter) would suffice to pre-treat the runoff from roofs in urban areas for injection in the unsaturated zone of the aquifer.

B. Runoff generated from Roads in Malta

1. **"Storm Water Quality Monitoring and sediment Characterisation for the National Flood Relief Project infrastructure in connection with Environmental Permit 0030/13/A"** (2018)

This report provides results of chemical analyses carried out on sediment and stormwater samples collected at various points along the National Flood Relief Project at a particular moment in time.

The conclusions that may be derived from these analyses are that the stormwater samples showed low levels of contamination while the sediment collected at different separators showed severe contamination. However, these results pertain to a single sampling exercise carried out in April - May 2018, at the end of the rainy season, by which time the rains had subsided and settling/sedimentation was complete. Therefore, the stormwater quality results cannot be interpreted as being representative of the stormwater that is generated at this catchment during the rainy season, when the bulk of the runoff is actually generated.

Other conclusions from this report are:

- The stormwater reaching the NFRP carries contamination (particularly heavy metals), which are subsequently deposited as sediment, and not present in a dissolved form in the retained stormwater itself;
- The separators are somewhat effective in collecting sediment, but it cannot be ascertained that there is no carry over of sediment (to a small or high degree) to the sea during the actual storm.

The sediment analysis showed high levels of Zinc and Barium, but relatively low levels of Chromium, Tin and Beryllium. Cadmium, Mercury, Nickel, Copper, Manganese and Lead, as well as Boron, Arsenic, Fluoride, PAHs were detected in varying amounts. The organochlorides Hexachlorobenzene and Hexachlorocyclohexane, Pentachlorobenzene, Hexachlorobutadiene, C10-C13 Chloroalkanes, TBTs, Brominated diphenyl ether and PCBs were not detected in any of the sediments.

2. **"Development for Sustainable Urban Stormwater Reuse in Malta"** by Alison J. Gauci (2017)

This document is essentially a proposal to develop a decision-tool to facilitate planning of sustainable at-source catchment management programmes. It recognises the lack of stormwater quality information available locally (indeed it does not present or make reference to any data) and provides information from other parts of the world. It recognises the difficulty presented by the variability of rain events in determining reuse, and proposes the following potential non-potable reuses of stormwater runoff:

- Creation of wetlands (issues of sufficient runoff volumes, space, mosquitoes);
- Irrigation of non-recreational landscapes and water features (requires storage);
- Irrigation of recreational landscapes and water features (requires storage);

- Groundwater recharge (though risks to groundwater quality, especially in areas where groundwater is a main source of the drinking water supply) ;
- Agricultural irrigation (requires storage);
- Water for livestock;
- Mixing with other treated water such as from wastewater, to enhance water quality and it's fit for purpose (requires transportation, seasonal issues, and may not improve quality at all).

3. **"Promoting the reuse of stormwater runoff in the Maltese Islands"** by Kevin Gatt and Elaine Stephania Farrugia (2011)

This paper reports on an attempt to characterise the quality of stormwater derived from one of Malta's most urbanised catchments in Malta (Birkirkara-Msida) with a view to determine its suitability for reuse and recharge. The study involved the collection and analyses of stormwater samples from 5 sampling points along the catchment during 6 storm events during the rainy season. The samples were tested for basic parameters such as electrical conductivity, Nitrate, Total Suspended Solids (TSS), Total Organic Carbon (TOC), Boron.

These samples were carried out in a very urbanised area, with high intensity of traffic, littering (including industrial), possibility of sewage surcharges – though high volumes of runoff also have a diluting effect. The report concludes that the quality of urban stormwater is adequate for recharge when tested for salinity, pH, hardness, Boron, Nitrate, Total Organic Carbon (TOC). The stormwater may need treatment for Total Settleable Solids (TSS). However, the water was not tested for hydrocarbons, heavy metals, pathogens, PAHs or other toxins that may be polluting in low concentrations.

4. **Analyses of Stormwater Samples collected by Sustech Consulting between 2005 - 2007**

Stormwater was collected from:

A. Road runoff from Naxxar, Balzan, B'Kara and Msida – March 2007

B. Miscellaneous roadside reservoirs, soakaways and Wied il-Qlejgħa – January 2006

C. Wied il-Qlejgħa and Torri Cumbo (Ta' Qali) – November 2005

The samples were analysed for heavy metals and other contaminants. The results are presented in **Tables 23**, **24** and **25.**

Summary of Results:

Analysis A: The samples of road runoff collected from Naxxar, Balzan, B'Kara and Msida in March 2007 all demonstrated low levels of salinity, Nitrate, and Boron. All samples were severely contaminated with pathogens from sewage (probably through manhole surcharges). The samples contained large amounts of sediment (expressed as Suspended Solids), which decreased downstream, possibly because of dilution.

Analysis B: The samples collected in January 2006 from miscellaneous roadside reservoirs and soakaways, namely Wied Garnaw surface water reservoir (Santa Luċija), Upper ta' Garibaldi surface water reservoir (Luqa), Valley Road Msida soakaway, Ħas-Saptan soakaway (Gudja), and Wied il-Qlejgħa, demonstrated low levels of Lead and sewage (bacteriological contamination) with the exception of Valley Road, Msida soakaway. The results for Lead were within the parametric limit set for water intended for human consumption. Note that leaded petrol was already phased out then.

Analysis C: Wied il-Qlejgħa and Torri Cumbo (ta' Qali) – November 2005: This analysis showed the quality of the water that may be expected from water collected in dams in valleys (rural areas). The water had moderately high salt/hardness content (but still suitable for irrigation), was contaminated with coliforms (probably from manure heaps in fields in the valley) and had high Nitrate content (making it unsuitable for recharge). This sample was collected at the end of November.

Analysis A

Date of Collection: 10/03/2007

A) Runoff water collected on 10/03/2007 from the points listed below and submitted on 12/03/2007.

07-1096 Naxxar, 07-1097 Balzan, 07-1098 B'Kara, 07-1099 Msida

B) Bacteriological samples collected from runoff water collected on 13/03/2007:

07-1165 Naxxar, 07-1166 Balzan, 07-1167 B'Kara, 07-1168 Msida

RESULTS:

PARAMETER	**07-1096**	**07-1097**	**07-1098**	**07-1099**
CHEMICAL AND PHYSICAL ANALYSIS	***Naxxar***	***Balzan***	***B'Kara***	***Msida***
TURBIDITY (N.T.U.)	72	87	93	69
CONDUCTIVITY (μScm^{-1})	203	247	254	342
pH	8.31	8.2	8.08	7.87
TOTAL HARDNESS (as mgL^{-1} $CaCO_3$)	322	446	480	1432
CALCIUM HARDNESS (as mgL^{-1} $CaCO_3$)	98	98	102	1168
MAGNESIUM HARDNESS (as mgL^{-1} Mg)	54.43	84.56	91.85	64.15
CHLORIDES (as mg/L Cl^-)	20	20	30	40
NITRATES (as mg/L NO_3^-)	5.32	6.2	6.2	8.86
SPOT TEST AMMONIA *	No sample volume left **	0.78	0.63	0.71
SPOT TEST NITRITES	Trace (approx. 0.1 mg/L)	Trace (approx. 0.1 mg/L)	Trace (approx. 0.1 mg/L)	Trace (approx. 0.1 mg/L)
SPOT TEST PHOSPHATES *	No sample volume left **	0.34	0.64	1.10
TOTAL ALKALINITY (mg/L $CaCO_3$)	100	84	90	108
TOTAL DISOLVED SOLIDS (mg/L)	70	95.33	117.33	168
TOTAL SOLIDS (mg/L)	1631	368	728	410

TOTAL SUSPENDED SOLIDS (mg/L)	1561	272.7	610.7	242
*Settleable solids (Volumetric) (ml/L)	1.6	1	1.6	3
*COD (mg/L)	331.82	31.56	27.44	374.77
*Boron (mg/L B)	0.22	0.24	0.25	0.56
*Fluorides (mg/L F-)	0.08	0.16	0.21	0.22
*Iron (mg/L Fe)	No sample volume left	0.2	0.13	0.18
*Silica mg/L SiO_2	1.24	1.51	1.43	2.14
*Sulphates mg/L SO_4^{2-}	19.71	22.01	19.38	25.94
BACTERIOLOGICAL ANALYSIS	***07-1165***	***07-1166***	***07-1167***	***07-1168***
*TOTAL COLIFORMS (c.f.u./100ml)	>300	>300	>300	>300
*FAECAL COLIFORMS (c.f.u./100ml)	>300	>300	>300	>300
*FAECAL STREPTOCOCCI (c.f.u./100ml)	>300	>300	>300	>300
*TOTAL BACTERIAL COUNT (c.f.u./ml) @ 37°C	>300	>300	>300	>300
*TOTAL BACTERIAL COUNT (c.f.u./ml) @ 22°C	>300	>300	>300	>300

Opinions/ Interpretation

** From a visual spot test performed the Ammonia and Phosphate values for Naxxar are approximately 0.5 mg/L and 0.4 mg/L respectively. These are however based only on visual comparison.

Calculating % sewage input				
Turbidity (NTU)	72	87	93	69
Total Suspended Solids	1561	1	610.7	
Conductivity (uS/cm)	203	247	254	342
% sewage (based on mains cond of 1500 uS/cm	7.36%	10.50%	11%	17.20%
Chlorides (mg/L)	20	20	30	40
Nitrate (mg/L)	5.32	6.2	6.2	8.86
% sewage (based on mains nitrate of 50mg/l)	11%	12%	12%	18%

Table 23: Analysis A

Analysis B

Date of Collection: 03/01/2006

Description of Sample: 06/0037 - Wied il-Qlejgħa

06/0038 - Valley Road, Msida soakaway

06/0039 - Wied Garnaw, St Luċija surface water reservoir

06/0040 - Upper Ta' Garibaldi, Luqa surface water reservoir

06/0041 - Ħas-Saptan, Gudja soakaway

Result:

PARAMETER	VALUE	VALUE	VALUE	VALUE	VALUE
CHEMICAL AND PHYSICAL ANALYSIS	***06/0037***	***06/0038***	***06/0039***	***06/0040***	***06/0041***
TOC (mg/L C)	10.44	10.75	4.44	5.21	6.77
Lead (as μgL^{-1} Pb)	<5	20.23	<5	<5	<5
BACTERIOLOGICAL ANALYSIS					
FAECAL COLIFORMS (c.f.u./100ml)	70	21600	52	0	320

Date: **13/01/2006**

Table 24: Analysis B

Analysis C

Date of Collection: 25/11/2005

Description of Sample: 05/4200 - Wied il-Qlejgħa

05/4201 - Torri Cumbo, ta' Qali

RESULT:

PARAMETER	VALUE	VALUE
CHEMICAL AND PHYSICAL ANALYSIS	***05/4200***	***05/4201***
TURBIDITY (N.T.U.)	1.4	>100
CONDUCTIVITY (μScm^{-1})	2190	2180
pH	7.55	8.32
FREE CHLORINE (mgL^{-1})	NIL	NIL
COMBINED CHLORINE (mgL^{-1})	0	0
TOTAL RESIDUAL CHLORINE (mgL^{-1})	NIL	NIL
TOTAL HARDNESS (as mgL^{-1} $CaCO_3$)	655	585
CALCIUM HARDNESS (as mgL^{-1} $CaCO_3$)	410	4445
MAGNESIUM HARDNESS (as mgL^{-1} $CaCO_3$)	245	140
CALCIUM HARDNESS (as mgL^{-1} Ca)	164	178
MAGNESIUM HARDNESS (as mgL^{-1} Mg)	59.5	34.02
CHLORIDES (as mg/L Cl^-)	360	440
NITRATES (as mg/L NO_3^-)	155.94	69.46
COD	9.18	131.51
SPOT TEST AMMONIA	NEG	TRACE
SPOT TEST NITRITES	TRACE	TRACE
SPOT TEST PHOSPHATES	TRACE	TRACE
BACTERIOLOGICAL ANALYSIS		
FAECAL COLIFORMS (c.f.u./100ml)	66	TNTC

Table 25: Analysis C

5. Analyses of Stormwater Samples collected by Sustech Consulting between 2021 - 2022

In order to establish whether there was a change in the quality of urban runoff from 2007 to 2021 - 2022, it was considered useful to collect water samples of urban stormwater in 2021 and 2022 and test these samples for contamination by heavy metals.

Samples were collected on 28th October 2021 (at the start of the rainy season 2021 - 2022) and on the 10th January 2022 (in the middle of the rainy season 2021 - 2022) from three sampling points at two locations:

- Sampling point 1 was the point of entry of flowing runoff into Msida Valley Road soakaway
- Sampling point 2 was from the receiving sump of the Gzira (NFRP) soakaway
- Sampling point 3 was the Msida, Valley Road soakaway

The first lot of samples was collected on 28th October 2021, when it rained 25.4mm. 55.2 mm of rainfall was recorded in the previous 3 days.

The second lot of samples was collected on 10th January 2022, when 8.2 mm of precipitation was recorded, and which followed 4 days of rain with a total of 14.0 mm precipitation. Prior to these 4 days, there were 23 days of no rainfall.

The results are shown in **Tables 26**, **27** and **28**.

The sampling points are shown in **Figures 113**, **114** and **115**.

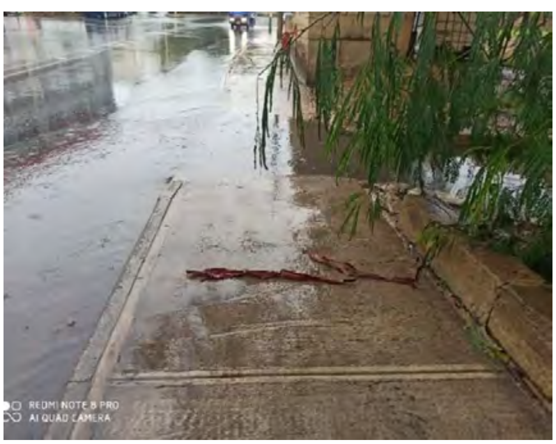


Figure 113:

Sampling point 1: Runoff in Valley Road, Msida

Figure 114:

Sampling point 2: Gzira NFRP Soakaway

Figure 115:

Sampling point 3:

Msida, Valley Road soakaway

Onsite measurements of electrical conductivity showed salinity levels of 200 – 250 uS/cm. Sample 1 (flowing runoff, that is, no settling) had high turbidity.

		28/10/2021	10/01/2022	Threshold values
Location 1				
Flowing Runoff, Valley Road, Msida				
Metals				
Arsenic (dissolved)	µg/L	3.4	10	5
Beryllium (dissolved)	µg/L	0.4	< 0.2	
Boron (dissolved)	µg/L	78	51	500
Cadmium (dissolved)	µg/L	0.23	0.11	
Chromium (dissolved)	µg/L	22	5.5	
Copper (dissolved)	µg/L	25	13	2000
Lead (dissolved)	µg/L	5.1	5.5	10
Manganese (dissolved)	µg/L	3	13	
Mercury (dissolved)	µg/L	< 0.5	µg/L	
Nickel (dissolved)	µg/L	7.5	4.2	
Tin (dissolved)	µg/L	2.1	< 1.0	
Inorganics				
Fluoride	µg/L	73	71	1500
Total PAHs	µg/L	< 0.16	µg/L	
Groundwater Threshold Values -extracted from 2nd Water catchment Management Plan (Pgs 257-261)				
Results highlighted in **red** denote exceedences				

		28/10/2021	10/01/2022	Threshold values
Location 2				
Receiving sump, Gzira NFRP soakaway				
Metals				
Arsenic (dissolved)	µg/L	3.7	12	5
Beryllium (dissolved)	µg/L	0.4	0.3	
Boron (dissolved)	µg/L	37	35	500
Cadmium (dissolved)	µg/L	0.15	0.15	
Chromium (dissolved)	µg/L	1.4	1.9	
Copper (dissolved)	µg/L	6.7	5.1	2000
Lead (dissolved)	µg/L	3.2	2.8	10
Manganese (dissolved)	µg/L	2.3	0.64	
Mercury (dissolved)	µg/L	< 0.5	µg/L	
Nickel (dissolved)	µg/L	5.4	4.6	
Tin (dissolved)	µg/L	1.2	< 1.0	
Inorganics				
Fluoride	µg/L	<50	53	1500
Total PAHs	µg/L	< 0.16	µg/L	
Groundwater Threshold Values -extracted from 2nd Water catchment Management Plan (Pgs 257-261)				
Results highlighted in **red** denote exceedences				

		28/10/2021	10/01/2022	Threshold values
Location 3				
From soakaway, Valley Road, Msida				
Metals				
Arsenic (dissolved)	ug/L	5.4	11	5
Beryllium (dissolved)	ug/L	0.4	< 0.2	
Boron (dissolved)	ug/L	50	62	500
Cadmium (dissolved)	ug/L	< 0.08	0.26	
Chromium (dissolved)	ug/L	2.5	1	
Copper (dissolved)	ug/L	8.8	1.9	2000
Lead (dissolved)	ug/L	3.3	3.4	10
Manganese (dissolved)	ug/L	45	13	
Mercury (dissolved)	ug/L	< 0.5	ug/L	
Nickel (dissolved)	ug/L	5.7	8.4	
Tin (dissolved)	ug/L	4.3	< 1.0	
Inorganics				
Fluoride	ug/L	<50	68	1500
Total PAHs	ug/L	< 0.16	ug/L	
Groundwater Threshold Values -extracted from 2nd Water catchment Management Plan (Pgs 257-261)				
Results highlighted in **red** denote exceedences				

Tables 26, 27 and 28: Results of the analyses carried out on urban stormwater samples collected in October 2021 and January 2022

Interpretation of Results

The results indicate that the quality of the stormwater collected from these locations, which are representative of urban runoff generated in densely populated high-traffic areas in Malta, is not as contaminated as one would have believed.

The contamination levels of most parameters are rather low, and comparable to the limits set for water for drinking consumption.

The 2021 and 2022 results are comparable, in terms of the degree of magnitude, with the results of 2007 samples of road runoff from Naxxar, Balzan, B'Kara and Msida. However, the 2007 samples showed a higher level of contamination (for Boron and Fluoride). The samples collected in 2007 were all flowing stormwater and did not include still water which may explain the lower concentrations for 2021 and 2022.

All samples demonstrated concentrations for heavy metals and for Polycyclic Aromatic Hydrocarbons (PAHs) below the quality standards and threshold values listed under the EU Groundwater Directive (GWD).

The results obtained for the samples collected in January 2022 are similar to those collected in October 2021. With a few exceptions, there was a general decrease in the concentration of most parameters, though there was a general increase in the concentration of Arsenic.

The stormwater samples were not analysed for Chloride, Sodium, Sulphate and Conductivity because onsite results for conductivity of the runoff between 250 - 300 uS/cm suggested that the concentration levels of runoff for these parameters would be well within the threshold levels of 1000 mg/L, 450 mg/L, 475 mg/L and 4500 uS/cm respectively.

In conclusion, the results show that the quality of stormwater from highly urbanised areas, with lots of traffic and a high potential for contamination, is generally satisfactory for indirect aquifer recharge for different storm events.

C. The Quality of Runoff in Rural Areas

Rural areas make up two-thirds of Malta's surface area with areas being intensively cultivated, others to a lesser degree or natural (e.g., garigue).

Chapter 6.02 describes how, except for three aquifers, namely Miżieb Mean-Sea Level Aquifer, Mellieħa Coastal Aquifer and Comino Mean-Sea Level Aquifer, all Malta's ground water bodies fail to reach the EU's good quality status.

The groundwater qualitative status is determined on the basis of tests carried out for Nitrate, pesticide, seawater intrusion (salinity) and other chemicals (Chloride, Sodium, Sulphate, Boron and heavy metals).

With the exception of seawater intrusion, the origin of the other contaminants is percolated rainwater. Analysis for pesticides and heavy metals undertaken during the 1st Water Catchment Management Cycle did not record any occurrences of detection of pollution by pesticides and heavy metals in groundwater samples, leaving Nitrate as the major pollutant in groundwater.

As part of the implementation of the 1st Water Catchment Management Plan, threshold values were set for Chloride, Sulphate, Ammonium, Lead, Arsenic and conductivity, since these parameters have been detected in groundwater and are therefore believed to have originated from infiltrated water (with the exception of conductivity). Threshold values were also established for Copper and Zinc, which are not included in the minimum list of the EU Groundwater Directive, due to the presence of these metals in the overlying soils.

The 2nd Water Catchment Management Plan provides some data on the quality of runoff in some selected valleys/watercourses of Wied il-Luq, Baħrija and Lunzjata. **Figure 116** shows how Nitrate levels in the three watercourses were consistently high throughout the year spanning from February 2012 to January 2013. In fact, Nitrates were in the range of 110 – 200 mg/l throughout the year. This is attributed to over-fertilization and points to the link that exists between infiltration from rural cultivated areas and groundwater quality. Levels of Nitrate exceeding 50 mg/l render the groundwater unfit for human consumption.

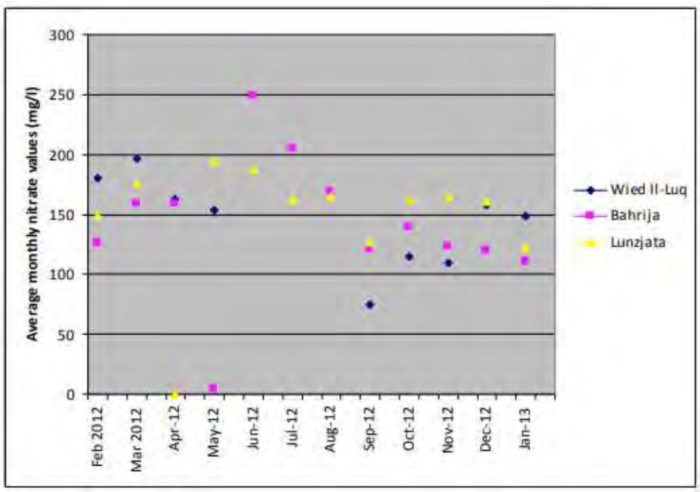


Figure 116:

Average Nitrate levels in three watercourses throughout 2012

Higher nutrient loading (Nitrogen, Phosphorous and Potassium) was observed in late Spring 2012, when the rain subsided, runoff stopped flowing along the valley watercourses and stagnant pools of surface water formed in depressions along the water courses. **Figures 117** and **118** show the degree of eutrophication in ponds in Malta’s valleys.

Figure 117: Wied il-Qlejgħa

Figure 118: Wied tal-Isqof

Another study of the quality of water flowing along five major valley systems was carried out between March - April 2012 by Martha Anne Zammit and Lucia Farrugia. The results showed that the runoff was high in Nitrate, Ammonia Nitrate, Phosphorus, with nitrate levels averaging 180 mg/l within a range that spanned from 90 to 330 mg/l, as shown in **Figure 119**.

There is significant scientific evidence to show that the quality of the runoff water flowing along valleys in rural cultivated areas is significantly polluted with nutrients, particularly Nitrate. This is a matter of concern since valleys, and especially valleys with dams, are important areas of groundwater recharge.

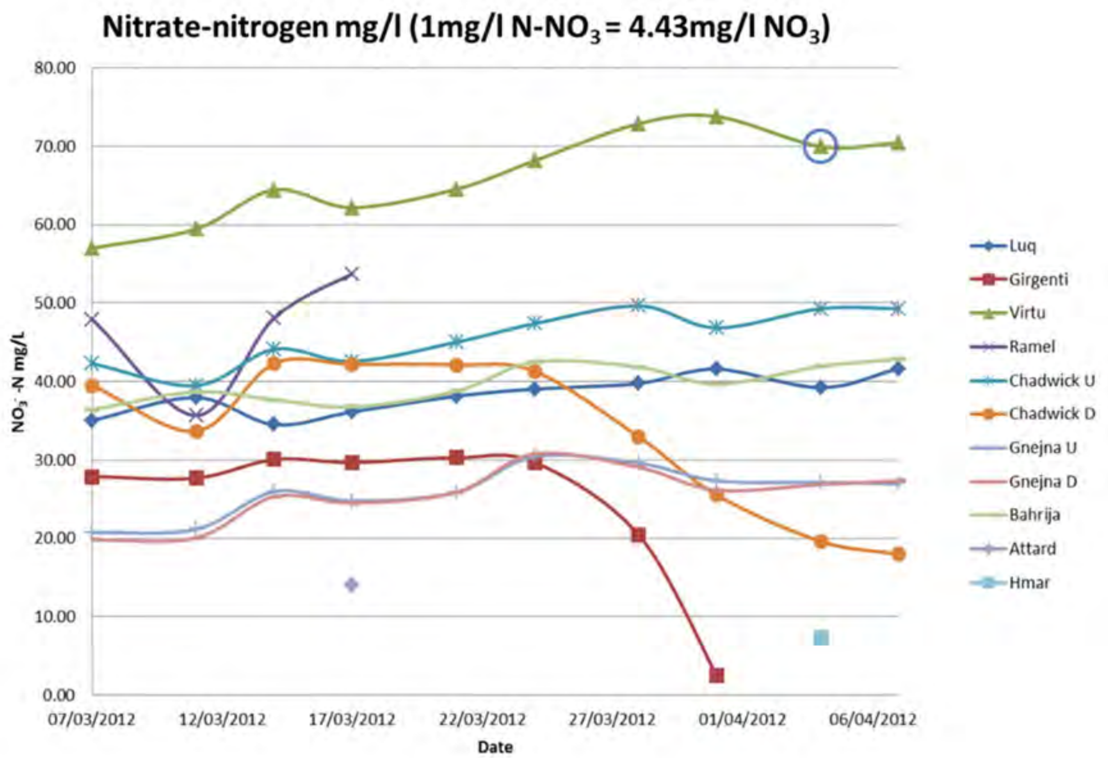


Figure 119:

Nitrate-Nitrogen levels in runoff flowing along selected valleys

10.04

Stormwater Governance and Statutory Stakeholders

1. Building and Construction Authority (BCA)

The only entity requiring the implementation of GSI is the Building and Construction Authority (BCA) which is responsible for "the design, implementation and dissemination of policies together with the consolidation and review of laws and regulations, in the form of a national building code". The Building Code at present incorporates Subsidiary Legislation 513.04 (Legal Notice 434 of 2015) which in clause 2 specifically refers to Documents F Part 1: Minimum Energy Performance Requirements for Buildings in Malta (Doc F) which is applicable as from 1 January 2016. Doc F incorporates 2 pages in Section 6 dealing exclusively with conservation of rainwater that falls on roofs and the need to provide "suitable wells or cisterns within the site of the building" (paragraph 6.01). It further goes on to specify the re-use of this stored water:

> 6.07.1 "For every newly constructed building, a separate water circulation system together with associated draw off points for providing water for flushing of toilets and watering of planted areas should be provided."
>
> 6.07.2 "In those buildings with multi-owner occupancies, the requirement of paragraph 6.07.1 should be provided to at least one of the occupancies."

2. Environment and Resources Authority (ERA)

ERA is responsible for inland surface waters protected under the Environment Protection Act, coastal and transitional waters. Under Subsidiary Legislation (Legal Notice 345 of 2015) the Environment and Resources Authority (ERA) is empowered under clause 12 (f) to establish a basic programme of measures to effect "controls, including a requirement for prior authorisation of artificial recharge or augmentation of groundwater bodies. The water used may be derived from any surface water or groundwater, provided that the use of the source does not compromise the achievement of the environmental objectives established for the source or the recharged or augmented body of groundwater. These controls should be periodically reviewed and, where necessary, updated."

Given the fact that in Malta the groundwater bodies are omnipresent, any GSI that dissipates water to the ground on land would thus require prior scrutiny by ERA under this item of the law.

3. Energy and Water Agency (EWA)

EWA is a government agency legally constituted by LN 340 of 2016, whose main functions include the formulation, evaluation, monitoring and implementation of national policies concerning the use of energy and water in sustainable manner, the preparation and update of plans to meet National and EU energy and water resources management targets and the implementation of projects conducive to the achievement of such targets through energy efficiency initiatives, renewable energy penetration and water conservation measures. EWA took over the role of policy agency from the Malta Resources Authority (MRA) following an administrative reform aimed at separating policy and regulatory functions in different public agencies.

EWA is the designated lead Competent Authority for the implementation of the Water Framework Directive (WFD) with direct responsibilities on inland waters, a role which it shares with the Environment and Resources Authority (ERA). In this role, EWA coordinates the National Implementation Process of the WFD and chairs the National Coordination Committee which brings together all the Ministries and public agencies who have a direct role in the implementation of this Directive.

4. Water Services Corporation (WSC)

The sanitary sewers were initially laid and managed by the Public Works Department (PWD) but were taken over and are now laid and managed by the body corporate Water Services Corporation (WSC). Sewers have always been sized solely to take water borne effluents of human wastes, and disposal of rainwater to sewers has always been illegal. However, for many years it has been evident that rainwater connections have often been made to the sewers, creating periodic overflows out of sewer manhole covers and backflows in pipes, corresponding to heavy stormwater events. These overflows create massive problems for the sector which WSC is managing not least in public health hazards, but also damage to properties, vehicles in streets and financial losses due to insurance claims and settlements.

WSC still maintains this regulation in place but is not known to be actively enforcing it. *Periti* are requested to certify that the runoff of a permitted development under their responsibility is not connected to the sewers to obtain WSC clearance through the Planning Authority compliance procedure. However, this is a one-off declaration and buildings are not required to be re-certified over time unless requests for compliance are re-submitted.

WSC maintains in its Act “to provide as appropriate for the use of stormwater runoff from urban and rural areas”; and “to promote the proper disposal of … stormwater runoff”, where ‘"stormwater runoff" shall include rainwater which is not absorbed by the ground or which does not evaporate and which is not collected in cisterns’.

Moreover, WSC apparently has title over any "public undertaking" means any undertaking or installation, and any apparatus, instrument, device or plant and all things accessory or ancillary thereto which, immediately before the appointed day, were vested in or belonged to the Government by whatever title and were operated by it for the purposes of … collecting and disposing of ... stormwater runoff’. It would appear that the legislation is explicitly intended for WSC to be in control of the provision of all State runoff networks. It is not clear if these aspects have been brought into force, and in practice WSC has been absent from any runoff infrastructural works since its inception in 1991.

5. Public Works Department (PWD)

In the absence of WSC, PWD carries out flood relief by implementing runoff infrastructural works and specifically continues to manage the infrastructure of the National Flood Relief Project (NFRP) built between 2013 and 2015.

6. Infrastructure Malta (IM)

IM is entrusted with the development, maintenance and upgrading of roads and other public infrastructure in the Maltese Islands.

7. Parks Malta

Parks Malta is “responsible for the maintenance of valleys” and is the co-ordinating beneficiary of *RainWiin* project for a planning framework with action plans for the establishment of an integrated infrastructure network for rainwater management in five major catchments and development of the natural water retention systems for aquifer recharge at Wied il-Għasel. As such it maintains dams, and thus has an operational role in the non-urban environment.

10.05

Status of Rainwater Harvesting in Occupied Maltese Dwellings

The Census of Population and Housing 2011[33], among other things, asked respondents to state whether there were 'wells' in their dwellings.

The respondents were also asked questions about:

- The type of dwelling they lived in (e.g., townhouse) and
- Location by district (e.g., Southern Harbour).

However, although the Census collected data on the number of cisterns in occupied dwellings, it did not investigate whether the cisterns were in use, the extent of their use, what the water was used for (e.g., gardening), the capacity of the cisterns, the age of the cisterns or whether the cisterns were filled by rainwater or water from springs/groundwater (*spiera*). The Census's information on cisterns is represented in **Table 29, Figures 120** and **121**, and show information about occupied dwellings having a cistern.

Type of Residence	Wells	No. of Residential Buildings	% of Residences having a well by type	Residences by type
Terraced house/Townhouse	32,577	52,519	62%	34%
Semi-detached house	4,569	5,812	79%	4%
Fully-detached house	2,708	3,383	80%	2%
Maisonette/Ground Floor tenement	12,020	44,145	27%	29%
Flat/Apartment/Penthouse	2,005	44,919	4%	29%
Semi-/Fully-detached farmhouse	786	1,306	60%	1%
Other	138	686	20%	0%
Totals	54,803	152,770	36%	

Table 29: Statistical data on occupied dwellings having wells, by occupied dwelling type (2011)

[33] Census of Population and Housing, 2011 Final Report - NSO 2014

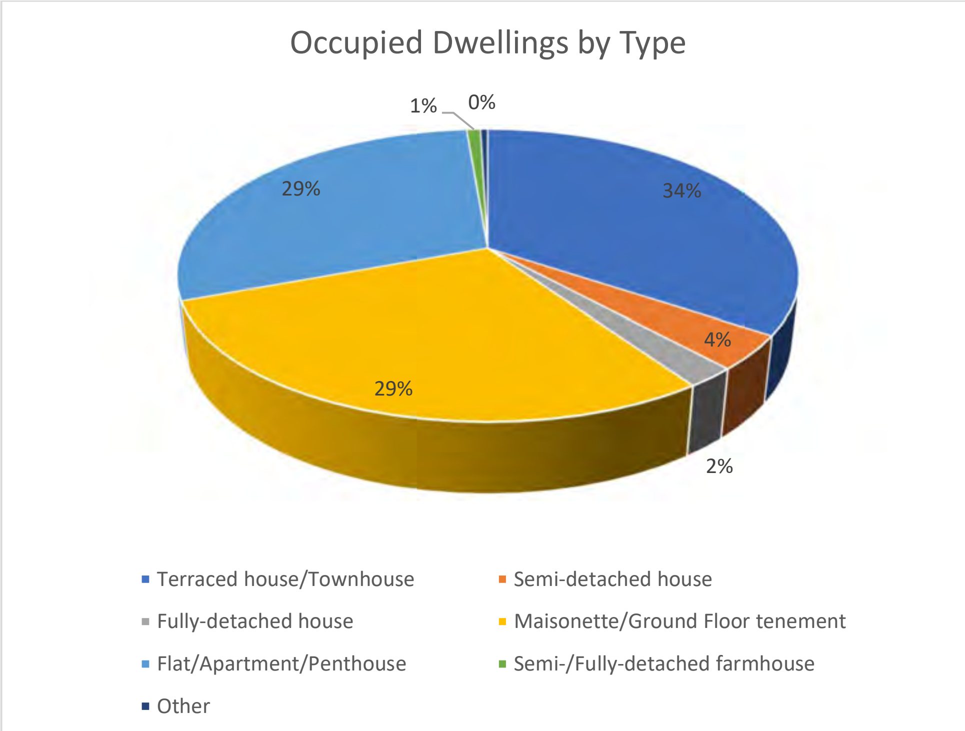


Figure 120: Occupied dwellings by type (2011)

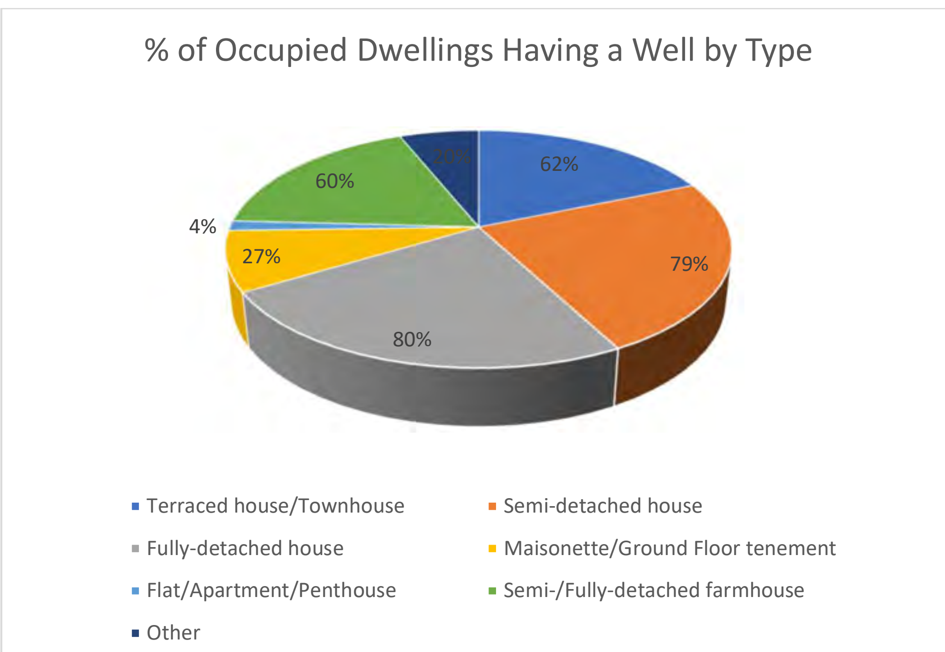


Figure 121: Percentage of occupied dwellings by type having a well (2011)

Table 30 shows the number and percentage of occupied dwellings by type having a cistern by regions.

Region	Number of dwellings		% of dwellings having a cistern
	having a cistern	by region	
Southern Harbour	9,459	29,107	32%
Northern Harbour	12,438	46,181	27%
South Eastern	11,573	22,279	52%
Western	9,531	19,584	49%
Northern Harbour	8,924	23,989	37%
Gozo	2,878	11,630	25%
	54,803	152,770	36%

Table 30: Number and percentage of occupied dwellings by type having a cistern by region (2011)

From the Census, it could be concluded that in 2011:

- 36% of respondents had a cistern in their home (54,803 wells in 152,770 dwellings). This may be broken down into 36.8% in Malta and 24.7% in Gozo.

- 79 - 80% of semi- and fully-detached occupied dwellings had a cistern, followed by terraced houses and townhouses (62%), farmhouses (60%), maisonettes (at a distant 27%), and lastly apartments (at a very distant 4%). It is very clear that cisterns were mostly constructed for particular types of dwellings (detached houses, including villas which may have a garden and/or pool) and not for others (apartments). And this notwithstanding the legal requirement to have a rainwater cistern is applicable for all types of buildings.

- The regions having the highest percentages of cisterns were the South Eastern and Western, where the housing stock was (and still is) mainly townhouses and maisonettes. The Northern Harbour region (which includes Sliema, Gzira), where the housing stock was mainly apartments, had the lowest percentage of cisterns (after Gozo).

It is significant and of concern that, cisterns are not being built in blocks of apartments where more and more people are living, and terraced houses having cisterns are being demolished to make way for blocks of apartments (without cisterns). This suggests that Malta is losing its rainwater harvesting capacity at a fast rate. This hypothesis may be confirmed when the results of the 2021 Household Budgetary Survey are published.

10.06

Notification Procedure Prior to Operate an Indirect Aquifer Recharge Facility

LEGAL FRAMEWORK - Background

Directive 80/68/EEC - Groundwater Directive
Article 6
Notwithstanding Articles 4 and 5, artificial recharges for the purpose of groundwater management shall be subject to a special authorization issued by the Member States on a case-by-case basis. Such authorization shall be granted only if there is no risk of polluting the groundwater.

Directive 2000/60/EC - Water Framework Directive
Article 11(3)(f)
'Basic Measures' are the minimum requirements to be complied with an shall consist of:
(f) controls, including a requirement for prior authorisation of artificial recharge or augmentation of groundwater bodies. The water used may be derived from any surface water or groundwater, provided that the use of the source does not compromise the achievement of the environmental objectives established for the source or the recharged or augmented body of groundwater. These controls shall be periodically reviewed and, where necessary, updated.

Directive 2006/118/EC - Groundwater Directive
Article 6(3)(d)
Without prejudice to any more stringent requirements in other Community legislation, Member States may exempt from the measures required by paragraph 1, inputs of pollutants that are:
(d) the results of artificial recharge or augmentation of bodies of groundwater authorised in accordance with Article 11(3)(f) of Directive 2000/60/EC.

BACKGROUND DOCUMENTATION

The applicant shall notify the Environment and Resources Authority (ERA) of the intention to operate an Indirect Aquifer Recharge Facility. ERA shall decide whether an environmental permit is needed.

Technical Details

Applicant is required to submit the following information:

(i) Official PA site-plan with the location where the works proposed are clearly identified;
(ii) Proposed details of indirect aquifer recharge facility;

(iii) Exact location of indirect aquifer recharge facility: Northing, Easting (UTM)(WGS84);
(iv) Total proposed depth of indirect aquifer recharge facility (below existing ground level) in m; and
(v) Depth to groundwater in m.

Regulatory Issues

Applicant is required to submit:

(i) copy of the relative Planning Permission (including an approved Environmental Impact Statement, where applicable) issued by the Planning Authority, or
(ii) confirmation from the Planning Authority that the proposal does not require planning permission

Qualitative Issues

Applicant is required to provide:
(i) a block-plan of the site (scale 1:1000) clearly identifying the surface catchment areas from which runoff water intended for artificial recharge is being collected;
(ii) a risk-assessment outlining the presence of any potential pollution sources in the identified runoff catchment area; and
(iii) any proposed pre-treatment facilities for the runoff water prior to its ingress to the proposed indirect aquifer recharge facility.

Quantitative Issues

Applicant is required to provide the following information:

(i) An estimate of the runoff generated from the identified areas during a typical 1 in 1 and 1 in 5-year storm. Backing data and calculations should be provided.
(ii) An estimate of the water absorbance rate (hydraulic conductivity) achievable by the proposed indirect aquifer recharge facility;
(iii) Details of any proposed water catchment (storage) facilities
(iv) Details of back-up drainage plans, intended to safely convey and discharge runoff water to/from the proposed indirect aquifer recharge facility.

10.07

Bibliography

Water Policy

The 2nd Water Catchment Management Plan for the Malta Water Catchment District 2015 – 2021, Sustainable Energy and Water Conservation Unit (SEWCU) and Environment and Resources Authority (ERA), 2016

https://era.org.mt/wp-content/uploads/2019/05/2nd_Water_Catchment_Management_Plan-Malta_Water_in_Maltese_Islands-3.pdf

The 1st Water Catchment Management Plan for the Maltese Islands, Malta Environment and Planning Authority (MEPA) and Malta Resources Authority (MRA), March 2011

A Water Policy for the Maltese Islands, MRA, June 2012
https://www.parlament.mt/media/72581/10177.pdf

Flood Management

Preliminary Flood Risk Assessment for the Malta River Basin District, Energy and Water Agency (EWA), 2019
https://www.preventionweb.net/files/33946_33946preliminaryfloodriskassessment.pdf ;
https://mk0energywaterabbylt.kinstacdn.com/wp-content/uploads/2020/09/Preliminary-Flood-Risk-Assessment-for-the-Malta-River-Basin-District-2019.pdf

National Flood Relief Project (NFRP): CBA Study and Technical Assistance, Politecnica, Feb 2010

National Flood Relief Project: Feasibility Study Report, 2010 (Politecnica), 2010

Flood Hazard Maps and Flood Risk Maps for the Malta Basin District, Energy and Water Agency (EWA), 2020

Reference Design Manuals

Guidance on the construction of SuDS (C768), Illman, S, Wilson, S, Construction Industry Research and Information Association (CIRIA), December 2017

The SuDS Manual (C753), Woods Ballard, B, Wilson, S, Udale-Clarke, H, Illman, S, Scott, T, Ashley, R, Kellagher, R, Construction Industry Research and Information Association (CIRIA), December 2015

Sustainable Drainage Systems Design Guide, Essex County Council, May 2019

Water Legislation

Water Governance:

Sustainable Energy and Water Conservation Unit (Establishment as an Agency) (Amendment) Order, 2016.

Environment Protection Act.

Regulator for Energy and Water Services Act Water Services Corporation Act.

Water Services Corporation Act (Amendment) Order, 2010 (L.N. 42 of 2010).

Water supply and sewerage:

Water Supply and Sewerage Services (Amendment) (No. 2) Regulations, 2010 (L.N. 38 of 2010).

Water Supply and Sewerage Services (Amendment) Regulations, 2010 (L.N. 31 of 2010).

Water Supply and Sewerage Services (Amendment) Regulations, 2009 (L.N. 337 of 2009).

Water Supply and Sewerage Services Regulations, 2004 (L.N. 525 of 2004).

Sewer Discharge Control Regulations, 2002 (L.N. No. 139 of 2002).

Urban Waste Water Treatment (Amendment) Regulations (Legal Notice 192 of 2004).

Urban Waste Water Treatment Regulations, 2001 (L.N. No. 340 of 2001).

Water Pollution:

Protection of Groundwater against Pollution and Deterioration (Amendment) Regulations, 2015 (L.N. 223 of 2015).

Protection of Groundwater against Pollution and Deterioration Regulations, 2009 (L.N. 108 of 2009).

Protection of Waters against Pollution caused by Nitrates from Agricultural Sources Regulations, 2001 (L.N. No. 343 of 2001).

Quality required of Surface Water intended for the Abstraction of Drinking Water Regulations, 2001 (L.N. No. 339 of 2001).

Nitrates Action Programme (Amendment) Regulations, 2018 (L.N. 104 of 2018).

Nitrates Action Programme (Amendment) Regulations, 2015 (L.N. 94 of 2015).

Nitrates Action Programme (Amendment) Regulations, 2013 (L.N. 77 of 2013).

Protection of Waters against Pollution caused by Nitrates from Agricultural Sources (Amendment) Regulations, 2013 (L.N. 78 of 2013).

Nitrates Action Programme Regulations, 2011 (L.N. 321 of 2011).

Protection of Waters against Pollution caused by Nitrates from Agricultural Sources (Amendment) Regulations, 2004 (L.N. 233 of 2004).

Limit Values and Quality Objectives for Cadmium Discharges Regulations.

Limit Values and Quality Objectives for Hexachlorocyclohexane Discharges Regulations.

Flood management:

Assessment and Management of Flood Risks (Amendment) Regulations, 2011 (L.N. 477 of 2011).

Assessment and Management of Flood Risks Regulations, 2010 (L.N. 264 of 2010).

Regulation of groundwater:

Borehole Drilling and Excavation Works within the Saturated Zone (Amendment) Regulations, 2012 (L.N. 147 of 2012).

Borehole Drilling and Excavation Works within the Saturated Zone Regulations (L.N. 254 of 2008).

Notification of Groundwater Sources (Amendment) Regulations, 2009 (L.N. 204 of 2009).

Notification of Groundwater Sources (Amendment) Regulations, 2008 (L.N. 274 of 2008).

Notification of Groundwater Sources Regulations, 2008 (L.N. 255 of 2008).

Users of Groundwater Sources (Application) Regulations, 2010 (L.N. 395 of 2010).

Water Management:

Quality required of Surface Water intended for the Abstraction of Drinking Water Regulations, 2001 (L.N. No. 339 of 2001).

Water Policy Framework Regulations, 2015 (L.N. 345 of 2015).

Dissertations and Research Papers:

BRGM, 1991. Study of the freshwater resources of Malta, Bureau de Recherche Géologique et Minière, France

Kevin Gatt & Elaine Stephania Farrugia (2012) Promoting the reuse of stormwater runoff in the Maltese islands, Urban Water Journal, 9:4, 223-237, DOI: https://www.tandfonline.com/doi/abs/10.1080/1573062X.2012.654802

Cecilia Camilleri (2016) Evaluating the suitability of sustainable urban drainage systems in the context of the Maltese Islands, https://www.um.edu.mt/library/oar/handle/123456789/18832

Micallef, S. (2018). An analysis of the legal implementation of the EU water framework directive in Malta (Master's dissertation), 2018. https://www.um.edu.mt/library/oar/handle/123456789/38793

Bartolo, E. (2001). A geological investigation of the Xewkija-area, Gozo (Bachelor's dissertation). https://www.um.edu.mt/library/oar/handle/123456789/68294

David Spiteri, Scerri Chris, Vasilis Valdramidis (2015): The current situation with water resources on the Maltese Islands https://www.um.edu.mt/library/oar/handle/123456789/5050

Muscat Christian (2012): The influence of European directives on the national policy making: The case of Malta's water resource, https://www.um.edu.mt/library/oar/handle/123456789/4905

Micallef, S. (2018). An analysis of the legal implementation of the EU water framework directive in Malta (Master's dissertation). https://www.um.edu.mt/library/oar/handle/123456789/38793

Sapiano, M., Micallef, P., Attard, G., & Zammit, M. L. (2008). The evolution of water culture in Malta: an analysis of the changing perceptions towards water throughout the ages. Options Méditerranéennes, 83, 97-109. https://www.um.edu.mt/library/oar//handle/123456789/21980

Gatt, K., & Gatt, S. (2011). Eco-innovation in Malta. European Union: Eco-Innovation Observatory. https://www.um.edu.mt/library/oar/handle/123456789/20830

How can runoff agriculture and soil and water conservation practices contribute to sustainable agriculture for Malta and other similar dry and arid regions? Peppi Gauci, M.Sc. Architecture: Advanced Environmental and Energy Studies, Centre for Alternative Technology, UK, January, 2011

Young Reporter, rainwater harvesting (undated): https://www.yremalta.org/wp-content/uploads/2014/04/Harvesting-Rain-water-a-luxury-or-a-necessity.pdf

M.E.Stuart, L. Maurice, THE Heaton, M. Sapiano, M. Micallef Sultana, D.C. Gooddy and P.J. Chilton British Geological Survey (2008) : Groundwater residence time and movement, a geochemical approach http://nora.nerc.ac.uk/id/eprint/9619/1/Malta_residence_time_NORA.pdf

Haslam Sylvia, Borg Joseph (1998): A study of the Land Use of Wied il-Qlejgha; Commissioned by the Department of Agriculture and submitted to the Planning Authority.

Haslam Sylvia, Borg Joseph (1998): The River Valleys of the Maltese Islands - Islands and Small States Institute of the Foundation for International Studies, Malta, in collaboration with CIHEAM, Bari, Italy.

National Agricultural Policy for the Maltese Islands 2018 – 2028 Final Report : prepared for the Ministry for the Environment, Sustainable Development and Climate Change, February 2018

Storm Water Quality Monitoring and Sediment Characterisation for the National Flood Relief Project Infrastructure in connection with Environmental Permit 0030/13/A: Ecoserv Ltd., Report submitted to MTIP, November 2018

Investing in the Multi-functionality of Green Infrastructure (GI) – An Information Document to support GI Thinking in Malta: Environment and Resources Authority (ERA), 2019

Climate Change Adaptation Strategy, 2012 https://climate-adapt.eea.europa.eu/metadata/publications/national-adaptation-strategy-malta

Census of Population and Housing, 2011 Final Report (NSO 2014)

Census of Agriculture 2001 (NSO, 2003)

Census of Agriculture 2010 (NSO, 2012)

WSC Annual Report 2020

Sewerage Master Plan for Malta and Gozo - Volume 1: COWI Consult. Ministry for the Environment (1992)

Unauthorised water in sewers – Stephen Zerafa WSC PRO, Times of Malta 29/1/2012

Our Ancestral Country Allies: The Rubble Walls: Vella & Garrido. Integrated Resources Management (IRM) Co. Ltd. Malta

Article 284 PL manifesto 2022 https://robertabela.mt/wp-content/uploads/2022/03/MALTA-FLIMKIEN-MANIFEST-ELETTORALI-2022.pdf

Article 62 PN manifesto 2022 https://assets.nationbuilder.com/pn/pages/3115/attachments/original/1646670856/PN_Manifesto_22.pdf?1646670856

Technical Document F: Minimum Energy Performance Requirements for buildings in Malta Part 1; Building Regulation Office, Ministry for Transport and Infrastructure, Malta, 2006

Guidelines for the use of domestic well water – Regulator for Energy and Water Services (REWS) https://www.rews.org.mt/#/en/rewsfa/74

Rural Policy and Design Guidance, 2014 – Malta Environment and Planning Authority (MEPA), 2014

Guidelines for Good Forestation Practices for the Maltese Islands Public Consultation Document – Environment and Resources Authority (ERA), 2022

The Climate of Malta: statistics, trends and analysis 1951 - 2010, Charles Galdies, NSO, 2011

Development Control Design Policy, Guidance and Standards 2015 (DC15) – Malta Environment and Planning Authority (MEPA), 2015

State of the Environment Report, 2018 - Environment and Resources Authority (ERA), 2018

T.O. Morris (1952): The water supply resources of Malta

Chadwick Osbert (1894): Report on the Water Supply of Malta- with recommendations as to extensions thereof. Malta Gov. Printing Office