PRELIMINARY FLOOD RISK ASSESSMENT

Final Report

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MALTA RESOURCES AUTHORITY

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1. Introduction

In the Floods Directive floods are defined as the temporary covering by water of land not normally covered by water. This term is a generic term to include floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude floods from sewerage systems. Floods occur when the natural or man-made channels are unable to carry all the water, leading to rising water flows that flow over the banks and flood the surrounding dry land.

Malta does not have any natural surface water bodies. The physical characteristics of the island together with the uneven distribution of rainfall do not allow for the formation of natural surface water bodies. Malta however does have a number of dry valley systems that are dry throughout most of the year. These dry valley systems act as a conveyance channel for the surface water that accumulates as a result of a rainfall event. Water flows along the valley bed for only a couple of hours as this is quickly discharged into the sea. As a result of this rapid discharge of water into the sea, there is no accumulation of water flow within the valley channel and no water flows over the valley channel and onto the surrounding dry land.

Along the years, some of these dry valley systems have been built-up and the valley channel incorporated into the main roads. This results in water flowing through the main roads once the valley channel is reactivated following a rainfall event. This has led to the general public perceiving the reactivation of the valley channel as a flood event whereas in reality this is the natural mechanism by which surface water flow is conveyed along the valley bed.

1.1 The Role of a Preliminary Flood Risk Assessment

Floods have been recognised as potentially undermining Europe's drive towards sustainable development with the adverse effects they have on the economy. Directive 2007/60/EC on the assessment and management of flood risks (European Floods Directive) aims to manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. This directive was transposed as the Assessment and Management of Flood Risks Regulations (L.N. 264 of 2010).

Article 4 of the Floods Directive requires all Member States to undertake a Preliminary Flood Risk Assessment (PFRA) for each river basin district, unit of management of the portion of an international river basin district or unit of management lying within their territory. The objective of the PFRA is to identify areas where the risks associated with flooding might be significant. Following the completion of the PFRA, Article 5 requires member states to identify areas for which significant flood risks exist (APSFR).The identification of floodable areas is not due under Article 4, but under Article 6 of the Directive, through the production of the flood hazard and flood risk maps for all areas identified as APSFR. Areas with a significant flood risk will then be assessed further to develop measures to manage and reduce the flood risk through the creation of a flood risk management plan.

The identification of areas with potential significant flood risk has to be based on available or readily derivable information adhering to the requirements specified in the directive (Article 4). The Directive gives no definition for the term 'significant' therefore each Member State has the flexibility to determine which areas are considered to have a significant flood risk potential within a national context.

In accordance with the requirements of the directive, the assessment presented in this report has considered all types of flooding, including natural sources, such as that which can occur from rivers, the sea and estuaries, heavy rain and groundwater, and the failure of built infrastructures. It has also considered the impacts that flooding can have on people, property, business, the environment and cultural heritage.

1.2 Structure of this report

The report is structured as follows, to ensure that all the requirements of Article 4 are met:

- An overview of the river basin district (Chapter 2)
- An analysis of the potential sources of flooding (Chapter 3)
- A description of the past sources of flooding (Chapter 4)
- An assessment of the potential adverse consequences of future floods which includes the impacts of climate change on the occurrence of floods (Chapter 5)
- An overall summary and conclusions of the PFRA (Chapter 6)

2. The Malta Water Catchment District

The Malta Water Catchment District comprises of 76 valleys in Malta and 33 in Gozo. The management of these valleys has often been fragmented. This, together with illegal dumping activities and lack of sustainable land use planning has restrained the water carrying capacity of the valleys. In 2003, following a major rainfall event, the Government of Malta decided to tackle the problems that arise as a result of uncontrolled street surface water runoff by adopting a catchment based approach to storm water management and as much as possible encourage the re-use of rain water. This led to the formulation and adoption of the Storm Water Master Plan (SWMP) in December 2008.

This chapter is based on the characterization of the Malta river basin district as described in the Storm Water Master Plan.

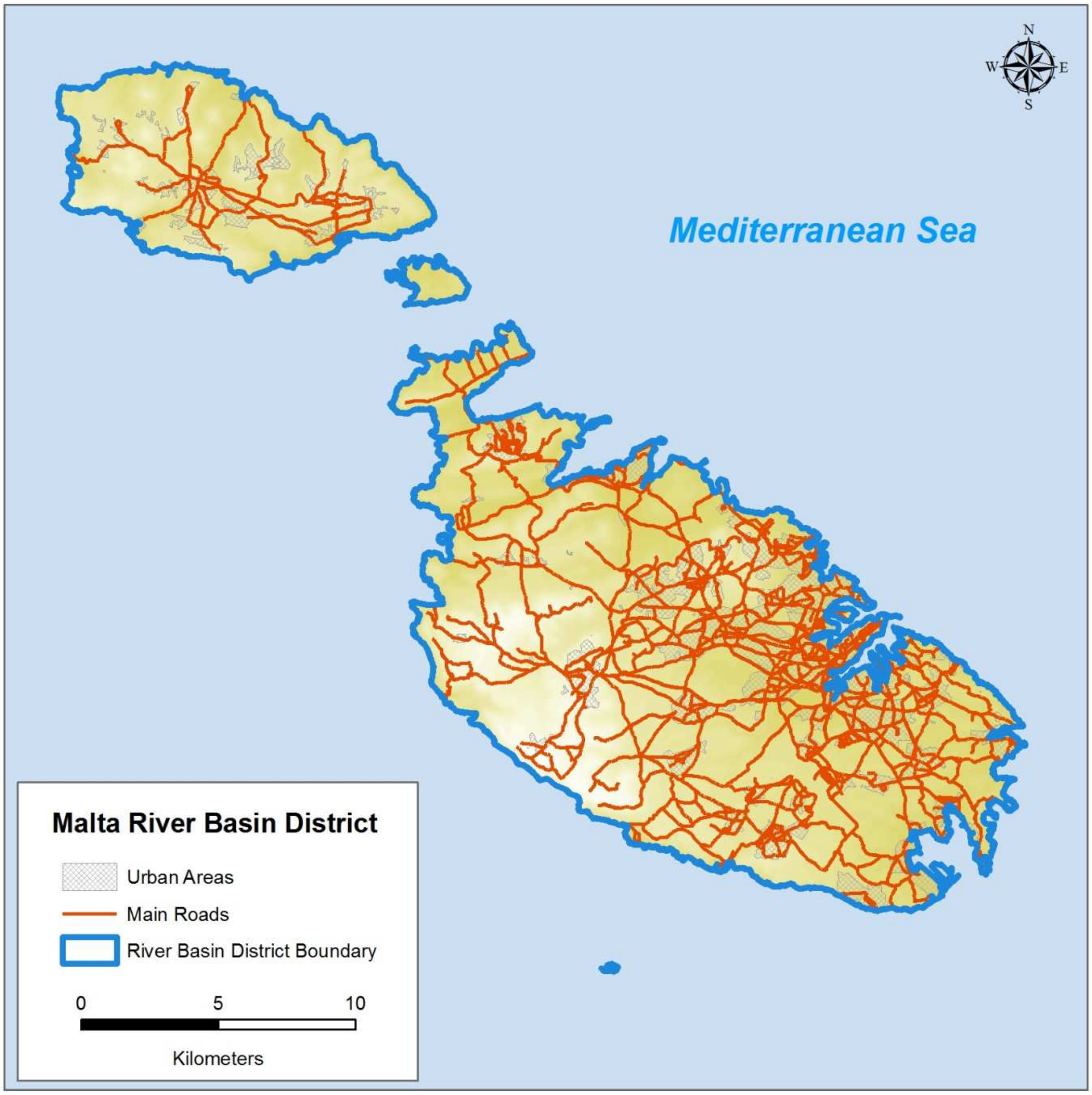

Figure 1: The Malta River Basin District

Figure 2: The catchment areas in the Malta River Basin District

2.1 Geology

The islands are built of Oligocene to Miocene carbonate rocks, which are divided into five formations from top to bottom as follows:

- Upper Coralline Limestone
- Greensand Formation
- Blue Clay Formation
- Globigerina Limestone Formation
- Lower Coralline Limestone Formation

The typical lithology, thickness and hydrogeological characteristics of these formations are presented in Table 2.1.

Formation	Typical Lithology	Thickness (m)	Hydrogeological Unit	Type of Aquifer
Upper Coralline Limestone	Algal reef limestone with scattered corals, mainly in the west, changes to more dense chalky and marly limestone in the lower parts	7 to 82	Upper phreatic aquifer	Perched aquifer, drained by springs
Greensand	Marly dense limestone with green glauconitic grains, filling pockets and depression on the blue clay	2 to 12	Aquiclude	
Blue Clay	Blue-grey clay and marl that weathers to brown-yellow	18 to 75	Aquitard transmits water from surface into the regional lower aquifer along joints and	

			fractures	
Globigerina Limestone	Fine-grained white calcarenite in the lower part, chalky and marly white or blue limestone in the middle and fine-grained yellow limestone and marl at the top	30 to 70	Regional lower aquifer	Local phreatic aquitard (permeability through fissures)
Formation	Typical Lithology	Thickness (m)	Hydrogeological Unit	Type of Aquifer
Lower Coralline Limestone	Algal coarse grained, grey to yellowish limestone, with corals, that changes to massive marly limestone and mudstone at the base	over 100		Regional phreatic aquifer (commonly referredto as the Mean Sea Level Aquifer)

Table 1: Typical lithology, thickness and hydrological characteristics of Maltese Formations

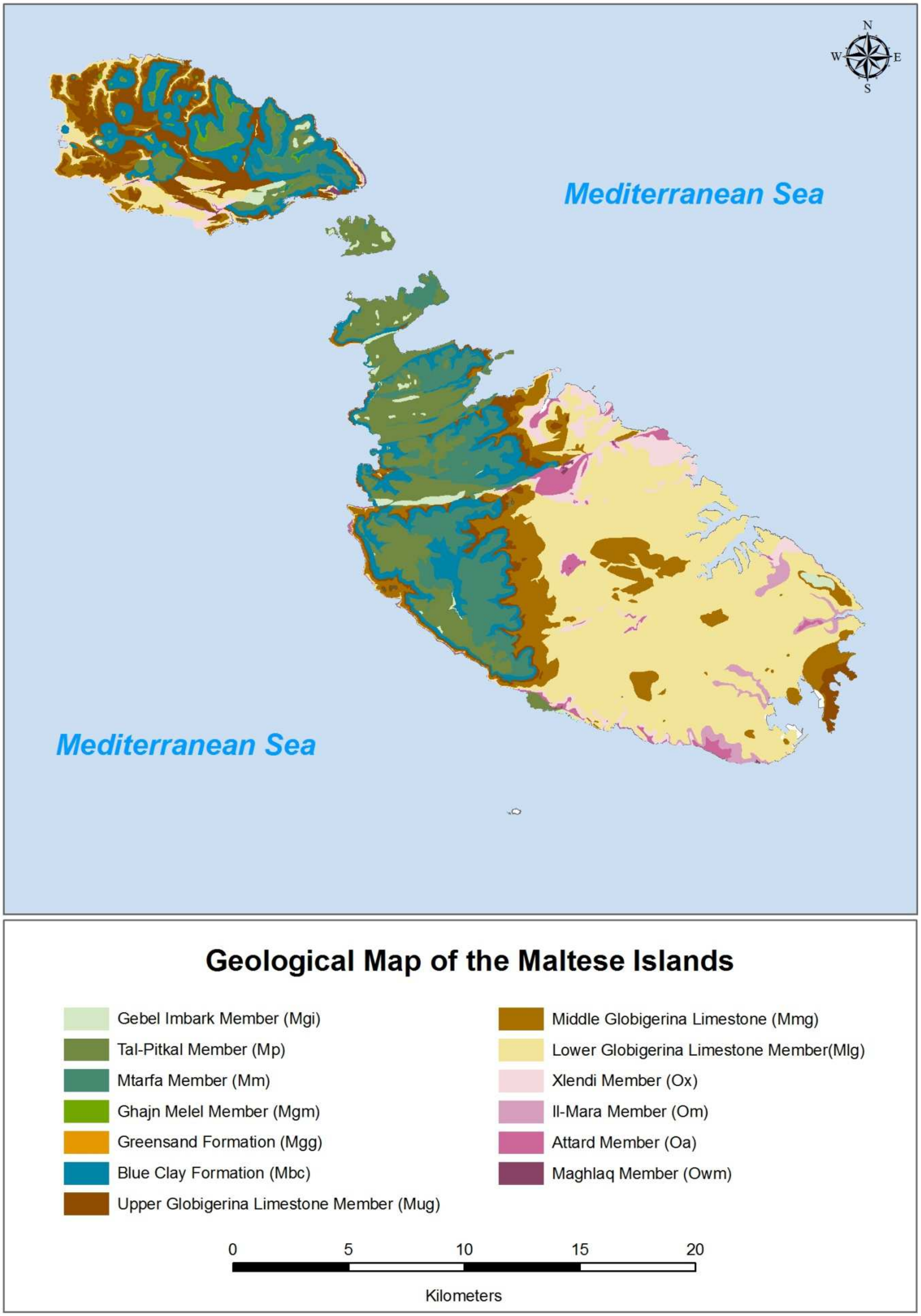

Figure 3: The Geology of the Maltese Islands

2.2 Geomorphology

Malta's morphology is strictly related to differentiated erosion of rock formation and to structural patterns. The first factor to be considered is the different resistance that each of the five formations has to erosion. The Globigerina Limestone is chalky and fairly soft, but has several harder bands hence it weathers into flat-lying layers which form steps in the landscape at beach band.

The second factor affecting erosion is the amount of vertical displacements of the many faults. Areas that have dropped down between faults form surface grabens, resulting in flat-floored valleys with parallel sides. Many of the SW-NE faults are not single plane surfaces, but narrow belts of shattered rock thus forming lines of weak resistance to the forces of erosion. The shattered rock in these fractures allows for easier erosion and thus the line of many faults has been enlarged into narrow valleys.

The third factor having influence on the pattern of the landscape is the fact that the entire rock sequence is not quite horizontal but tilted towards NE. This results from the overall tilt of the uplifted north-eastern flank of the major Malta-Pantelleria graben complex. This slope has, from the first emergence of the Maltese rock sequence above sea level, ensured that most of the drainage of surface water has been directed down that tilted surface. For this reason many valleys are essentially aligned along or sub-parallel to the SW-NE faults that break up the layers.

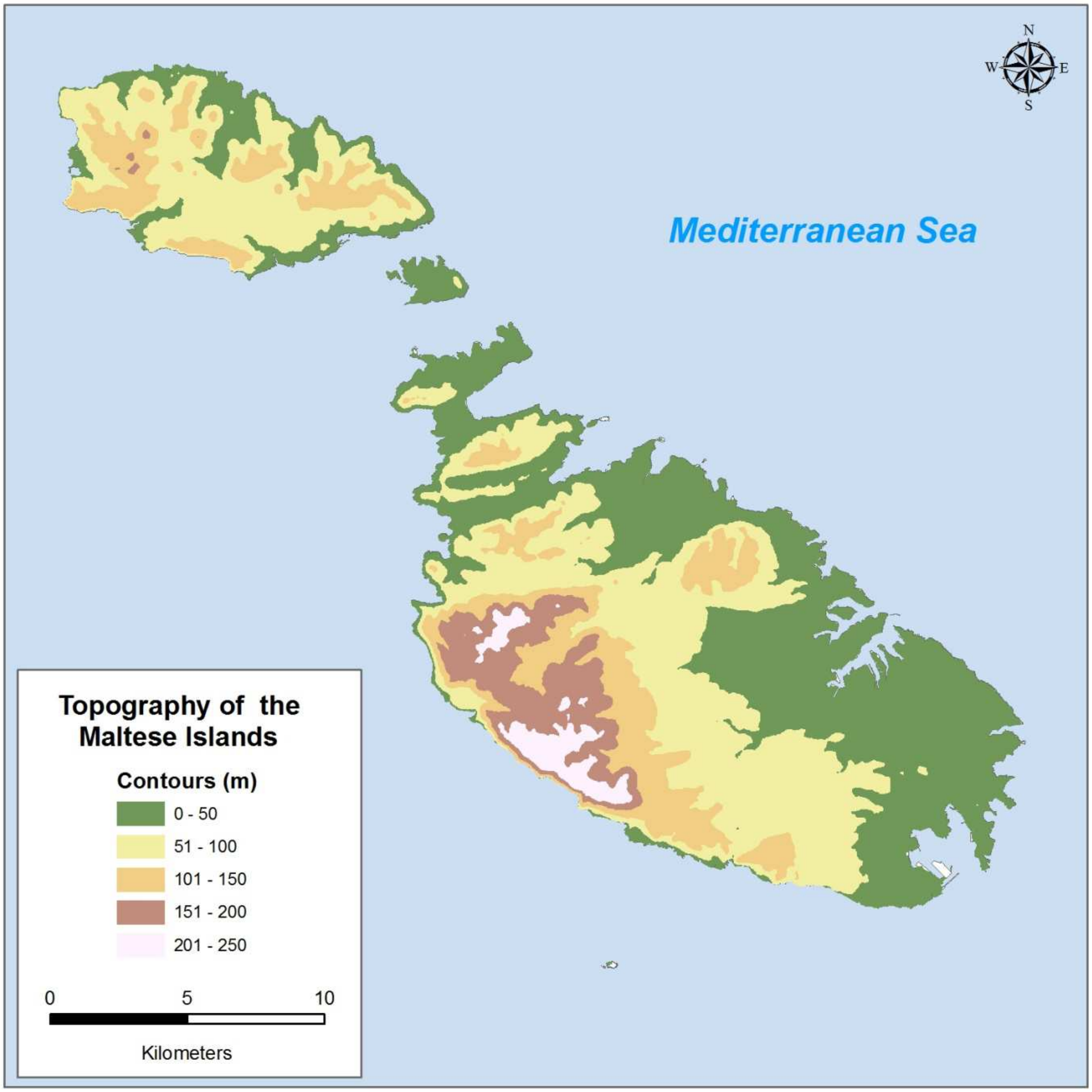

Figure 4: Topography of the Maltese Islands

2.3 Land-use

Malta's population density exceeds 1,200 persons per square kilometre. This makes Malta one of the most densely populated countries per square kilometre in the world. Between 1956 and 1997, the percentage of built-up area on the Maltese Islands increased from 4 percent to 22 per cent of the total land area[1]. The sustainable use of land is thus one of Malta's most pressing priorities.

While earlier attempts to formalize planning in Malta have been futile, a comprehensive planning system was legislated in the late 1980s/1990s.This aimed at consolidating development within urban areas to avoid urban sprawl into the countryside; an approach which possibly increased the concentration of hard surfaces around densely populated areas, without due consideration of infrastructure required to capture and manage run-off.

Due to the tilt of the islands most of the land most suitable for development is located on the flatter, low-lying areas. Urbanization was also facilitated by the location of a number of natural harbour areas. This has led to a historical trend towards greater urbanization of the low-lying areas. Consequently this has in many circumstances led to the urbanization of natural water channels, with valley beds being transformed into main traffic thorough fares, thus leading to a greater vulnerability to flash floods as more areas on the valley sides were transformed into hard, impermeable surfaces.

[1] Ministry for Investment, Industry and Information Technology and Water Services Corporation, (2008), Consultancy for the Formulation of a Storm Water Master Plan for the Maltese Islands.

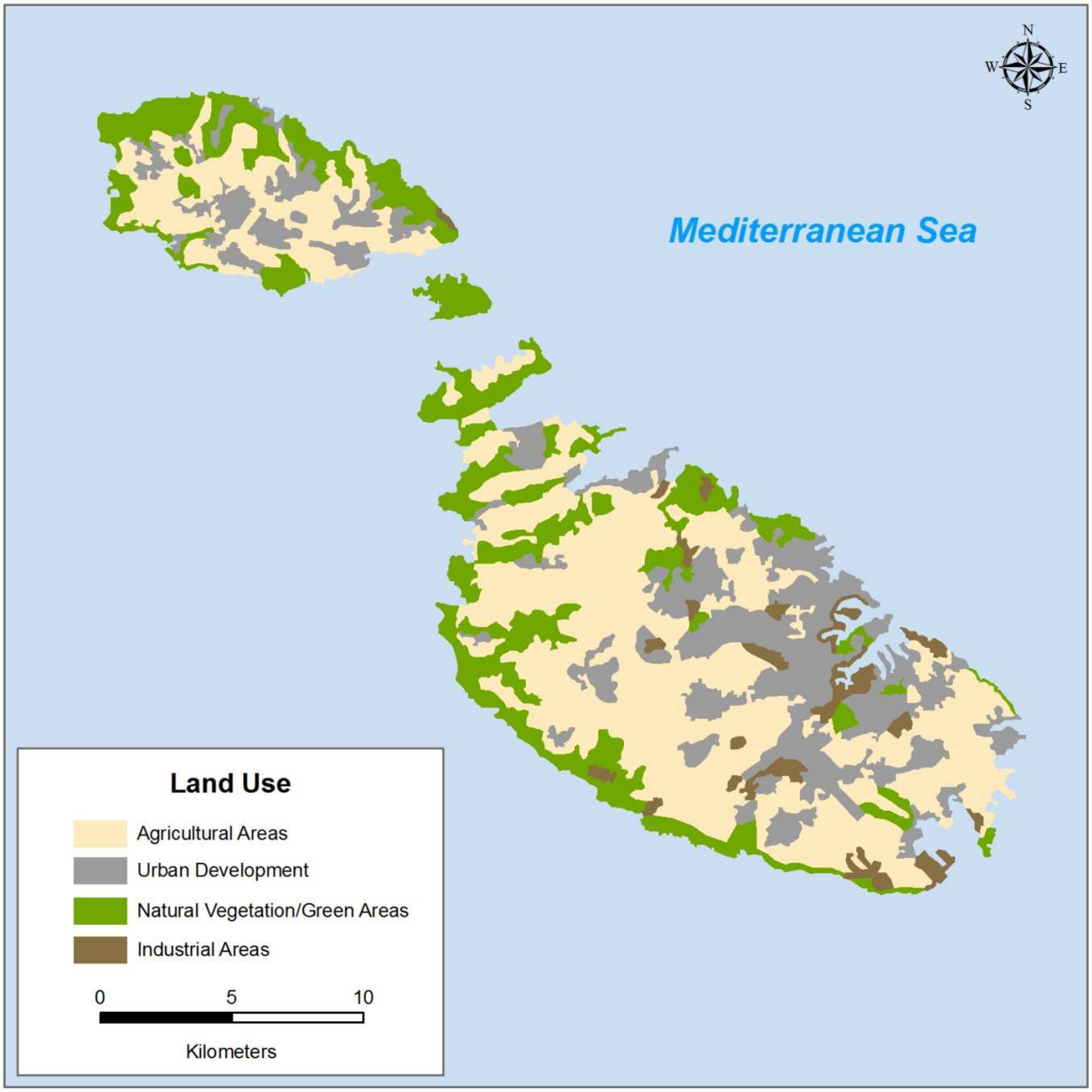

Figure 5: Land use in the Maltese Islands

2.4 Climate

Malta's weather and climate is typically Mediterranean, with hot, dry summers, warm and sporadically wet autumns, and short, cool winters with adequate rainfall. The temperature is stable, ranging from 12.4 degrees Celsius during the winter period to 26.3 degrees Celsius during the summer period[2]. Winds are strong and frequent; the most common are the cool north-westerly (majjistral), the dry north easterly (gregale), and the hot humid south-easterly (sirocco). The relative humidity is consistently high and rarely falls below 40%.

The average annual precipitation is 550mm. Rainfall is highly variable from year to year; some years are excessively wet while others are extremely dry when compared to the average annual precipitation. Total rainy days, of any intensity, are between 50 and 120 days per year and on average 80 per year. The seasonal distribution of rainfall defines a wet period from October to March (with 85% of the total annual rainfall) and a dry period from April to September.

Month	J	F	M	A	M	J	J	A	S	O	N	D
Average Rainfall (mm)	89	61	41	23	7	3	0	7	40	90	80	112

Table 2: Average rainfall depth (Malta Airport MetOffice for the climate period 1961-1990)[3]

2.5 Hydrogeology

Within the Maltese Water Catchment District, the Upper and Lower Coralline Limestone formations are considered to function as the main aquifer rocks. The Globigerina Limestone is thought to function only locally as an aquifer, normally transmitting water from the surface into the main groundwater bodies along fractures. The Blue Clay and the Greensand are normally impermeable and underlie the perched Upper Coralline Limestone aquifer formation. Faulting, sinkholes and patch reefs however partially penetrate these impermeable layers. The soils have a high water storage capacity; but these are generally present as thin layers.

[2] National Statistics Office, Malta,(2011). The Climate of Malta: statistics, trends and analysis (1951-2010).
[3] National Statistics Office, Malta,(2011). The Climate of Malta: statistics, trends and analysis (1951-2010).

Replenishment of these groundwater bodies is mainly by rainfall. Surface run-off into the sea is comparatively small as compared to the total rainfall. Factors limiting the amount of surface runoff that ends up in the sea are the morphology, good water absorption properties of the soil and infiltration into the rock, and run-off interception by numerous dams, walls and terraces built over centuries. The major surface water loss is by evapotranspiration. Aquifer recharge varies according to the rainfall.

Based on an average annual rainfall of 550mm it is estimated that each year, the total precipitation amounts to 174 hm^3 of water, of which 24 hm^3 ends up as surface runoff to the sea, 105 hm^3 are lost as evapotranspiration and 45 hm^3 end up as natural aquifer recharge[4].

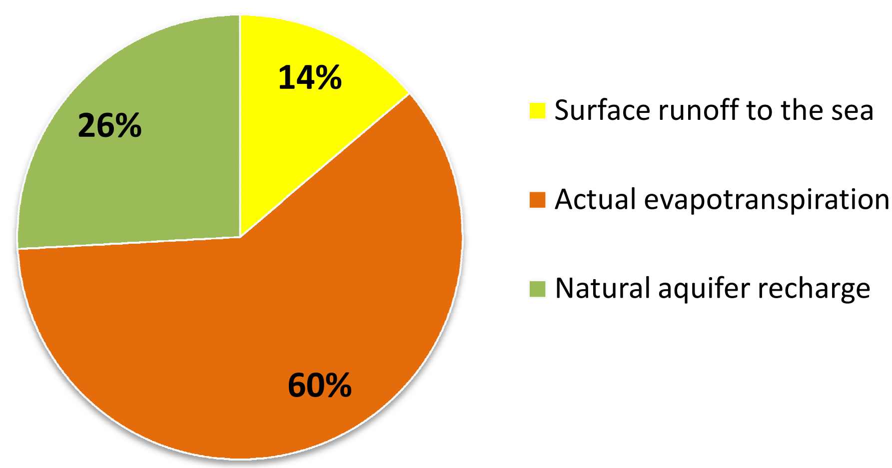

Figure 6: Distribution of precipitation based on an average annual rainfall of 550mm[5]

[4] Food and Agriculture Organization of the United Nations, (2006). Malta Water Resources Review.

[5] Food and Agriculture Organization of the United Nations, (2006). Malta Water Resources Review.

Figure 7: The main aquifers in the Maltese Islands

2.6 Surface waters

In the Malta Water Catchment District there are no rivers or lakes. However Malta has a number of valley systems that are dry throughout most of the year. Following rainfall events surface water runoff flows for a couple of hours within the valley bed and is discharged into the sea. To retain the discharge generated as a result of rainfall events, small dams have been constructed across the drainage lines. These dams also serve the purpose of reducing the rate of soil erosion.

2.7 Existing flood defence structures

Proper flood defence structures in Malta do not exist. In many areas runoff water converges to the main road of the urban areas, i.e. the former natural river bed, flooding low lying areas and the areas close to the sea. Small reservoirs collecting storm water from the roofs or from the streets for storage and reuse are relatively common in both rural and urban areas, but they have little effect on flood relief since once they are full of water, they do not act as flood preventing measures and their capacity is normally negligible with respect to the runoff volume produced by an extreme rainfall. In some localities channels have been constructed to collect and divert the uncontrolled street surface runoff but these do little to solve the problems caused in the worst hit areas.

3. Sources of Flooding

Article 2 of the Floods Directive defines ‘floods’ as the temporary covering by water of land not normally covered by water. This term is a generic term to include floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude floods from sewerage systems. Article 2 also specifies that for a flood risk to exist there must be the combination of a flood event and relevant receptors (human health, economic activity, the environment and cultural heritage).

3.1 Flooding from Rivers

The directive defines rivers as a body of inland water flowing for the most part on the surface of the land but which may flow underground for part of its course. The geomorphological and hydrogeological setting of the Islands do not allow the formation of rivers therefore there is no source of fluvial or river flooding present.

3.2 Rainfall Flooding

Malta has no river basins as defined by the Water Framework Directive (DIRECTIVE 2000/60/EC) but a number of valley systems that are dry throughout the year. Rainstorms occurring in the areas of the various catchments of the Maltese Islands generate surface water runoff that converges and flows through the dry valley channels. This is a result of the specific climate and watershed characteristics found in the Maltese islands.

Rainfall events normally last a couple of hours and given that all watersheds are small in size, have deep incised topographies and the range in elevation between the highest and lowest point of the watershed is small, accumulation of surface water runoff is invariably restricted to the original valley channel and there is no overflow of water from the valley channel to the surrounding areas.

During the rainy season, there is a reactivation of the valley channel but all water courses are ephemeral, leading to the development of temporary watercourses with runoff water flowing for a couple of hours in some areas following the end of the a rainfall event. It is further noted that the lower parts of some of the larger catchments have become urbanized around the low-lying coastal areas. The original watercourses have become incorporated into the development footprint and most of these valley beds were turned into roads precisely because of the temporal nature of these watercourses. The reactivation of the valley channel following a heavy storm inevitably leads to surface runoff flowing through these urbanised areas. These storms normally last a few hours and any water runoff within the urbanized areas drains away in a couple of hours, even after large storms.

Nonetheless some low-lying and populated areas, such as Msida, Marsa and Qormi, have become susceptible to uncontrolled street surface runoff. This is accounted for by the unprecedented development that took place in the post-war era, the urbanization of the lower parts of some of the sub-basins and the lack of storm water infrastructure from streets. No populated areas in Malta suffer from prolonged flooding as there are no rivers or permanent streams in these areas. Some urban areas have been made susceptible to accumulation of surface water runoff due to lack of foresight and failure to provide rainwater infrastructure alongside the advance of urban sprawl and other areas that formerly provided areas of percolation.

3.3 Flooding from the sea

Seawater flooding is rather uncommon in Malta but can sometimes occur where there is a combination of high tide and heavy rainfall or as a result of atmospheric gravity waves. Flooding from seawater can never occur from high tide alone since like other Mediterranean countries the tide in Malta is very low. Flooding from coastal waters usually results in the formation of puddles of sea water along some of the roads that are located directly at the water's edge. Normally these puddles of water only last for a couple of hours as they eventually dry out. Malta's coastal geomorphology drastically limits the area that can be flooded with seawater. A large proportion of Malta's coastline is made up of coastal cliffs that makes it almost impossible for seawater flooding to occur.

3.4 Flooding from groundwater

Groundwater flooding does not occur in Malta and there have been no recorded incidents of flooding from this source. The large difference between the ground level and the depth of the groundwater bodies prevents flooding from groundwater sources.

3.5 Flooding from infrastructural failure

Dams located along the main valley lines collect storm water runoff and the water collected is mainly used for agriculture, recharging the sea-level aquifers and to reduce soil erosion. The dams are small in size and are not designed for flood prevention purposes. The total dam capacity of the Island is estimated at 154000 m^3. A number of open reservoirs have been constructed along roads to catch flowing runoff water. Their total volume is estimated at 250000 m^3. Should any of these structures fail, the risk of flooding is not significant because of the low volumes of water involved. As previously stated, proper flood defence structures in Malta do not exist.

4. Flooding History

Flooding problems as a result of uncontrolled street surface runoff occur in the urbanised areas of various basins of the Maltese Islands. Most of the arising from uncontrolled street surface runoff occurs in the catchments presented in Figure 8. The flash flooding usually occurs in the lower parts of these catchments, as a result of heavy storms which cause a reactivation of the valley channel leading to uncontrolled street surface runoff passing through the low lying

Figure 8: Catchments that have experienced previous pluvial flooding

urbanised areas.

4.1 Rainfall Flooding

Malta has experienced a number of flash floods in recent years, during which time intense rainfall has caused surface runoff to flow within urban areas. There is currently no formal database of flooding records to draw upon. Instead this section presents the flooding events that have been reported in newspaper records between 1979 and 2012. Information was sought from more than one newspaper so as to obtain more detail on the areas hit by the floods and the associated consequences.

The consequences resulting from each flood event were classified either as traffic disruption, damage to infrastructure, fatalities and damage to private property. The table only lists the consequences reported by newspaper records for each flood event. In all cases no information on economic, environment and cultural consequences were reported.

Flood Event Date	Source of Flooding	Areas Affected	Source of Information	Consequences
25th October 1979	Pluvial	Qormi, Birkirkara, Marsa, Attard and Xlendi	Newspaper Articles	Traffic disruption, damage to the infrastructure, fatalities (5) and damage to private property
22nd October 1982	Pluvial	Msida	Newspaper Articles	Traffic disruption and damage to private property
10th November 1988	Pluvial	Attard, Balzan, Birkirkara, Marsa, Msida	Newspaper Articles	Traffic disruption, damage to the infrastructure and damage to private property

5th January 1990	Pluvial	Qormi, Birkirkara	Newspaper Articles	Traffic disruption
12th August 1990	Pluvial	Msida	Newspaper Articles	Traffic disruption
29th September 1993	Pluvial	Msida	Newspaper Articles	Traffic disruption and damage to private property
27th September 1995	Pluvial	Zebbug, Birkirkara, Msida, Burmarrad	Newspaper Articles	Traffic disruption, damage to the infrastructure, fatalities (2) and damage to private property
10th October 1995	Pluvial	Mosta, Qawra, Birkirkara, Msida and Marsa	Newspaper Articles	Traffic disruption
Flood Event Date	**Source of Flooding**	**Areas Affected**	**Source of Information**	**Consequences**
24th September 1997	Pluvial	Birkirkara, Msida, Birzebbugia, Hamrun, Santa Venera, Mqabba, Qormi and Gzira	Newspaper Articles	Traffic disruption and damage to private property
25th January 1998	Pluvial	Msida, Birkirkara, Qormi, Zebbug, Burmarrad and Mosta	Newspaper Articles	Traffic disruption, fatalities (1) and damage to private property
25th September 1998	Pluvial	Msida, Birkirkara, Mosta, Balzan and Sliema	Newspaper Articles	Traffic disruption and damage to private property
1st December 1999	Pluvial	Marsa, Birkirkara, Qormi and Siggiewi	Newspaper Articles	Traffic disruption and damage to the infrastructure
6th November 2002	Pluvial	Burmarrad, Marsa, Msida, Birkirkara, Bahar	Newspaper Articles	Traffic disruption and damage to private

		ic-Caghaq		property
21st February 2003	Pluvial	Birkirkara and Msida	Newspaper Articles	Traffic disruption
28th May 2003	Pluvial	Msida, Birkirkara and Gzira	Newspaper Articles	Traffic disruption and damage to private property
15th September 2003	Pluvial	Qormi, Msida, Birkirkara, Burmarrad, Siggiewi and Marsa	Newspaper Articles	Traffic disruption and damage to private property
17th September 2003	Pluvial	Burmarrad, Mgarr, Bahar ic-Caghaq, St Andrews, Birkirkara, Msida, Qormi and Marsa	Newspaper Articles	Traffic disruption and damage to private property
19th September 2004	Pluvial	Zabbar, Marsaskala, Rahal Gdid, Qormi and Marsa	Newspaper Articles	Traffic disruption
14th November 2004	Pluvial	Msida and Balzan	Newspaper Articles	Traffic disruption
4th October 2005	Pluvial	Birkirkara, Msida and Balzan	Newspaper Articles	Traffic disruption
9th January 2006	Pluvial	Birkirkara and Msida	Newspaper Articles	Traffic disruption
26th December 2006	Pluvial	Birkirkara	Newspaper Articles	Traffic disruption
9th March 2007	Pluvial	Birkirkara, Qormi and Imsida	Newspaper Articles	Traffic disruption
4th June 2007	Pluvial	Birkirkara, Balzan, Iklin and Bahar ic-Caghaq	Newspaper Articles	Traffic disruption and damage to private property
Flood Event Date	**Source of Flooding**	**Areas Affected**	**Source of Information**	**Consequences**
25th September	Pluvial	Birkirkara	Newspaper	Traffic disruption

2007			Articles	
25th October 2010	Pluvial	Msida, Birkirkara, Burmarrad, Balzan, Lija, Marsa and Qormi	Newspaper Articles	Traffic disruption and damage to private property
29th November 2011	Pluvial	Mosta, Xlendi, Marsalforn, Xaghra, Msida and Birkirkara	Newspaper Articles	Traffic disruption, damage to the infrastructure and damage to private property

Table 3: Past flood events

By analysing newspaper records it can be concluded that there are seven main areas that are susceptible to pluvial flooding during heavy and intense rainfall events. In Malta these areas are Birkirkara-Lija-Balzan-Attard-Msida, Gzira, Zebbug-Qormi-Marsa, Marsascala and Burmarrad whilst in Gozo, Xlendi and Marsalforn . These areas have repeatedly experienced problems with surface water runoff. In the subsequent paragraphs, the problems identified by the SWMP in each of these four catchments are discussed.

The Birkirkara-Lija-Balzan-Attard-Msida area has over the years experienced intense urban development. The urban area has spread across the valley and the arterial transport connection between Birkirkara and Msida (Valley Road) runs along the dormant valley bed, where all pluvial run-off of the catchment is naturally collected. A storm water system does not exist to control this flow however; any storm water pipes that do exist discharge excess water in the main road itself. As a result, the water converges at the lower section of the watershed in Msida creek, the main consequence of which is damage to properties and disruption of traffic.

The main flooding issue of Gzira is similar to that of Birkirkara. The water run-off is naturally collected along Wied Ghollieqa and flows in the natural valley until Triq Guze` Miceli in Gzira, where the bottom of the valley is blocked by the street and by building. At this point, the water flows over the streets toward the sea, causing problems, similar to those apparent in the Birkirkara-Msida area, downstream in the main road, parallel to the shore (Triq ix-Xatt).

In Marsa there are two main sub-catchments: one passing through Qormi and Marsa (Wied Incita and Wied is-Sewda) and one passing downstream of Zebbug (Wied Qirda and Wied il-Kbir). The water runoff collected by Wied Incita, downstream becoming Wied is-Sewda, reaches Qormi where the valley abruptly ends in the main urban road (Triq il-Wied). Further downstream the channel starts again its course and runs beyond Qormi toward Marsa and into the sea. In Qormi, flooding occurs because the main road, the channel and the bridges over the channel are not designed to convey and withstand the water that can potentially flow through the area. Similarly in Zebbug, due to the absence of a storm water system and the morphology of the land, water runoff accumulates in the central urban low lying area of Zebbug.

In the Marsascala catchment the main problem is due to the fact that during storms all the runoff of the basin flows over the main road between Zabbar and Marsascala which was constructed on the valley floor. The valley does not have a drainage system and so the water converges to Marsascala Creek leading to the formation of puddles at the downstream sections of the valley.

In Burmarrad, the water flows down from the Wied il-Ghasel Valley system, which up to the beginning of the 19th century the area was designated as a flood plain that drained into the sea. It is nowadays replaced by cultivated fields.

In Xlendi, the extremity of the watercourse coming down from Victoria and Fontana has been partially blocked by urban development, whilst in Marsalforn, although the valley bed and storm water channel leading to the sea has not been invaded by urban development, has become too small to cope with the increase in flow from the heavy urbanization of Victoria, Xaghra and Marsalforn itself.

Although there is incomplete information on past flood events, the following observations can be made:

- In all cases flooding occurred in urban areas as a result of uncontrolled street surface runoff following intense rainfall events

- Flooding occurs due to rainfall and thus tends to be most severe during the autumn and winter months
- Some of the adverse consequences associated with past flood events were the result of a very limited public perception of the flood risk resulting in people or vehicles being at the wrong place at the wrong time
- As the events begin and end within a few hours the impacts can very much depend on the time of day they occur.
- The lack of an adequate storm water infrastructure is one of the main problems leading to flooding – a combination of urbanised areas that don't incorporate storm water
- The most widespread consequence of past flood events is the disruption of traffic and economic activities as a result of the temporary reactivation of the valley channel. Some past flood events resulted in fatalities with people being carried away by the water or becoming trapped in their premises.
- In most cases a combination of rapid urbanisation and planning which did not integrate storm water control led to the led to the modification of the valley floor which is then flooded by street surface runoff with the onset of intense rainfall events

4.2 Flooding from the sea

Newspaper evidence indicates that seawater flooding sometimes occurs in Malta. Puddles of seawater occur in Sliema, along a small stretch of Triq ix-Xatt, in Msida, at Triq il-Marina and Triq ix-Xatt at Marsaskala and in the area of St George's Bay in Birzebbugia. In all cases puddles of seawater form along the road which is adjacent to the water's edge and these barely last a couple of hours, sometimes causing some inconvenience to traffic. This usually occurs once or twice a year along the roads mentioned above and in all cases the puddles that form are very shallow. The other parts of the coast of the Maltese islands do not experience such affects from seawater since a large proportion of the coast of the Maltese islands is made up of coastal cliffs.

5. Future Flooding

5.1 Future flood risk

A large volume of work has already been carried out to develop hydrological models of the Malta river basin district and to model future flood events. The first important study in this regard was the Storm Water Master Plan (SWMP) which developed a hydrological model of the present and foreseeable storm water events so as to identify the key problem areas. The SWMP also included a technical feasibility study to abate the flooding by suggesting a number of technical options. Due consideration was given to the effectiveness of existing structures in alleviating problems as well as explore potential benefits of future project options.

The SWMP adopted a comparison procedure for filtering and ranking the major flood relief projects in order to be able to prioritize the projects and to enable the Maltese decision maker to choose the order of the projects construction. Preference was given to projects within the following criteria:

- Urban areas rather than those draining agricultural areas
- Densely populated areas
- Commercial and tourist-oriented areas
- Flood relief in areas located in the vicinity of public services such as hospitals, first aid stations, police, fire stations and other public serving and essential institutions and premises.
- Projects that produce water were preferred

According to these considerations, the watersheds most severely hit were ranked by decreasing order of preference:

1. Birkirkara-Msida
2. Qormi-Zebbug-Marsa
3. Gzira
4. Marsascala

5. Birzebbugia
6. Cospicua
7. Kalkara
8. Zabbar
9. Burmarrad

The SWMP concluded that an integrated water management approach to flood relief was to be adopted in the first four priority catchments namely Birkirkara-Msida, Qormi-Zebbug-Marsa, Gzira and Marsascala.

The completion of the SWMP between 2006 and 2008 was the first step towards remedial measures for these specific areas. Further technical studies on the project design and evaluation led to the selection of a first series of project components as part of a national strategy to address these flash flood problems across the country. The project is known as the National Flood Relief Project (NFRP). The objectives of the NFRP are based on infrastructural interventions to mitigate the impacts of flash floods on the population and urban areas and to create scope for water conservation. Specifically the project will diminish risks to life and property, control damages caused by surface water runoff and reduce vulnerability to climate change by achieving the following objectives:

1. Design capability for 1 in 5 year storm events focusing on the areas prioritised according to the criteria mentioned above
2. Address problems that originate from beyond each locality by adopting a holistic catchments-based approach
3. Develop infrastructure that is suitable for future expansion
4. Develop a program for integrated valley management and maintenance Optimize scope for local and national water conservation
5. Optimise scope for local and national water conservation

Since the storm water systems in Malta that exist are very limited, these existing facilities were not included in the Feasibility Study of the NFRP. The hydraulics of the existing scenario was therefore limited to the calculation of discharges, levels and velocities of the runoff water naturally running and concentrating at the bottom of the valleys (i.e. over the main roads of the urbanized areas). Water discharges were first calculated by applying the rational method in order to become accustomed with the volumes of water related to each sub-catchment and define suitable technical options.

Each of the four catchment's studies as part of the NFRP was divided in a number of sub-catchments. The sub-catchments were obtained as the result of definition of the pour points, where the flow discharge is calculated. Pour points were defined at the locations that are strategic for the assessment of the technical proposals at Feasibility Study level. The sub-catchments' borders were identified by following the natural land contours and elevation, but taking also into account the urban network of the streets, where they represent a major obstacle to the runoff flow. The Birkirkara-Msida catchment was divided into 16 sub-catchments, the Gzira into 5 sub-catchments, the Qormi-Marsa into 8 sub-catchments and the Marsascala into 9 sub-catchments. In the Marsa catchment, the Zebbug area was also separately studied as a separate sub-catchment because of local flooding problems.

Flow discharges were calculated for several return periods. Table 4 summaries the flow discharge of the each whole catchment. Water discharges, level and velocities have been secondly calculated by applying a dynamic rainfall-runoff simulation model in order to obtain the necessary hydraulic inputs to calculate flood damages associated to different return periods and the flood risk and to optimize the design of the selected technical options.

The risk of flooding in the areas included in the NFRP has been calculated according to a widely accepted definition of flood risk. The flood risk, measured in €/yr of damages caused by a certain rainfall storm, is defined as the probability of failure of the hydraulic system, i.e. the storm water system, corresponding to the occurrence of the storm – overcoming probability (p_f), by the associated expected damages (E(D)):

$R= p_f.E(D)$

The probability of failure is a function of the occurrence of a certain rainfall storm (hazard) and of the performance of the storm water system (vulnerability). The calculation of the probability of failure included (i) rainfall analysis, (ii) determination of flow discharges, (iii) flood routing models, and (iv) hydraulic design of only storm water system. For the practical application of the flood risk assessment, the expected damages were evaluated for flood events of different probabilities. Based on these damage evaluations, a damage-probability curve was constructed.

In the risk calculation, all hydraulic processes are not deterministic. Moreover the expected damages were also associated with uncertainties since little information is available about the relation between damage causing factors and the resulting flood damage. Therefore, for the design rainfall event, there is a residual flood risk that assumes an acceptable value ($R \rightarrow 0$), defined according to International and/or National standards. The risk under the design scenario proposed in the NFRP was acceptable to the Government of Malta. In this respect, the water depth in the streets after the design never surpasses 0.10m.

The proposal put forward by the NFRP is designed to create an accepted vulnerability level of the system, namely to provide flood relief to the project areas vulnerable to impact from the rainfall storm with a return period of 1 in 5 years, as established statistically by the rainfall data captured by the SWMP study, that is up to 2005. The level of accepted vulnerability was derived after considering the specific assets at risk, the type of floods that occur in Malta, the type of storm water infrastructure required to provide flood relief in the Maltese valleys and cost-benefit considerations. Common return period of similar projects is between 10 to 20 years, but there are a number of arguments that support the value of 5 years as the optimal solution for the NFRP. A return period of 10 years would have increased the cost of the project implementation by approximately 40%, making the project economically unviable. Moreover, in terms of risk of occurrence of a storm of a certain return period (5,10, 20 years) within the expected life of the system (50 years) the benefit of adopting 10 instead of 5 years return period is limited.

The NFRP estimates the effect of flooding on the population. Table 5 describes the estimated numbers of people that are directly affected by flooding in the catchment areas covered by the project. The definition of ‘directly affected population’ refers to people whose home, business;

property etc is directly affected by flooding. This will normally involve suffering of damages or limitation to direct access.

Catchment	Directly Affected Population	Properties
Birkirkara-Msida	3,300	1,200
Attard-Qormi	5,400	1,740
Zebbug-Marsa	2,200	620
Gzira	2,000	530
Zabbar-Marsascala	3,800	430
TOTAL	**16,700**	**4,520**

Table 4: Estimated number of people and properties within the catchment areas covered by the NFRP

The first part of the NFRP has already started and this involves the construction of the necessary infrastructure to capture storm water from the streets and to discharge it into the sea through catchment grilles, culverts, tunnels and pipes. In all instances the infrastructural works being carried out through the NFRP does not involve any river bank improvements or other conventional flood defense works, simply because there is a lack of available land and due to the fact that the main cause of flooding as experienced in Malta is solely that arising out of an inadequate or inexistent urban rainwater drainage system.

In the past, flooding from seawater only affected a very small section of the Maltese coastline and puddles of sea water are very shallow. This however causes traffic disruption since the drivers of the vehicles try to avoid passing through streets containing puddles of saline water. Given the uncertainty in climate change models for predicting changes in sea level in the

Mediterranean and considering the very low tide of the Mediterranean Sea, future flooding from seawater is expected to be very similar to the current levels.

5.2 Future Flooding and Climate Change

In the design of future flood events, the NFRP sought to apart from reducing the risks to life and property also reduce the vulnerability to climate change. This is addressed through the development of infrastructure that is capable of withstanding the uncertainties associated with future flood events and also through the adoption of a holistic catchment based approach to surface runoff management. Moreover the National Climate Change Adaptation Strategy has put forward a number of recommendations to limit the effect of climate change on the occurrence of flood events such as the introduction of a one-off flood fine for properties not having cisterns and therefore contributing to uncontrolled street surface runoff.

5.3 Significant Flood Risk Areas

As stated earlier Malta does not have any rivers and in Malta the term floods and flooding are used to describe the presence of surface water runoff within the original valley channel. This is the general and commonly accepted interpretation of flooding locally since it is the only form of flooding ever experienced locally, or that can be recalled from institutional memory, media reports and archives.

Malta has long since acknowledged the importance of managing the local impacts arising from intense rainfall events. Economic disruption and other damages and risks caused by flash floods justify the construction of storm water drainage infrastructure in the specific problem areas to address these problems conclusively.

The production of the SWMP was driven by this specific problem which is being addressed by the NFRP. Through the NFRP Malta is currently working on a number of projects for the improved management of the surface water flowing within the valley channel. This will be reinforced through the development of the necessary infrastructure to manage the water flow in the urbanized valley channels with the scope of reducing the disruptions to the normal activities carried out in these areas. By the end of the project the problems arising from uncontrolled street surface runoff as a result of intense rainfall events will be contained due to appropriately designed infrastructure, for the given design storm, as characterized by the pre-2005 data. As previously stated the infrastructural works being carried out as part of the NFRP do not involve any river bank improvements or other conventional flood defence works, simply because land for such works is very scarce and the nature of 'flooding' as experienced in Malta is solely that arising out of inadequate or inexistent urban rainwater drainage systems.

Given that the occurrence of uncontrolled street surface water runoff has been limited to those areas where the valley bed has been incorporated in the urban texture, the main national priorities in the field of surface water runoff management are focused on projects that minimize the inconveniences and risks to people living in urban areas located within the valley bed.

Following the implementation of the NFRP, the residual flood risk will assume an acceptable value. Therefore it can be concluded that in the future any consequences arising from future flood events will be greatly curtailed, provided that the NFRP is implemented successfully.

Similarly although there will be areas that in the future might experience some degree of puddling as a result of seawater intrusion, the impacts to people, properties, the environment or the economy will be minimal with the implementation of new and adequate infrastructure.

6. Summary and Conclusions

This report has been prepared to comply with Article 4 and 5 of the Floods Directive, which require all member states to undertake a Preliminary Flood Risk Assessment (PFRA), based on readily or readily derivable information to assess potential significant risks. This report comprises the PFRA for the Malta Water Catchment District.

The information used in this report has been derived from the report on the Storm Water Master Plan for Malta, the documentation of the National Flood Relief Project together with newspaper articles. No modelling of current or future flood scenarios was carried out as part of the PFRA as this had already been done as part of the compilation of the Storm Water Master Plan and the National Flood Relief Project.

Flood events have occurred in the Maltese islands in recent history, predominantly as a result of the reactivation of dry valley systems following rainfall events. Following rainfall events, surface water runoff flows through the dry valleys systems but the water never overflows the valley channel to inundate the surrounding dry land. Urbanisation of the lower sections of the catchments has led to some of the dry valley channels being incorporated into the existing road network with the result that these roads act as the natural channel of water flow.

This phenomenon is locally considered as flooding since some of this surface water runoff flows along the roads constructed along the valley bed whereas in reality no flood waters inundate land that is normally dry. None the less Malta acknowledges that there are areas that experience some problems as a result of the uncontrolled street surface water runoff. The most frequently hit areas are Msida-Lija-Attard-Balzan-Birkirkara, Gzira, Qormi-Zebbug-Marsa, Marsaskala and Burmarrd in Malta and Xlendi and Marsalforn in Gozo.

The problems arising in these areas as a result of street surface runoff are being tackled through a number of infrastructural projects as part of the NFRP. Upon completion of this project the residual flood risk is designed to be acceptable therefore no significant flood risk areas have identified. The implementation of the NFRP together with the introduction of new legislation for the incorporation of rain water cisterns and the recommendations put forward as part of the National Climate Change Adaptation Strategy will also help reduce the vulnerability of the problem areas to flooding risk arising from climate change.

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