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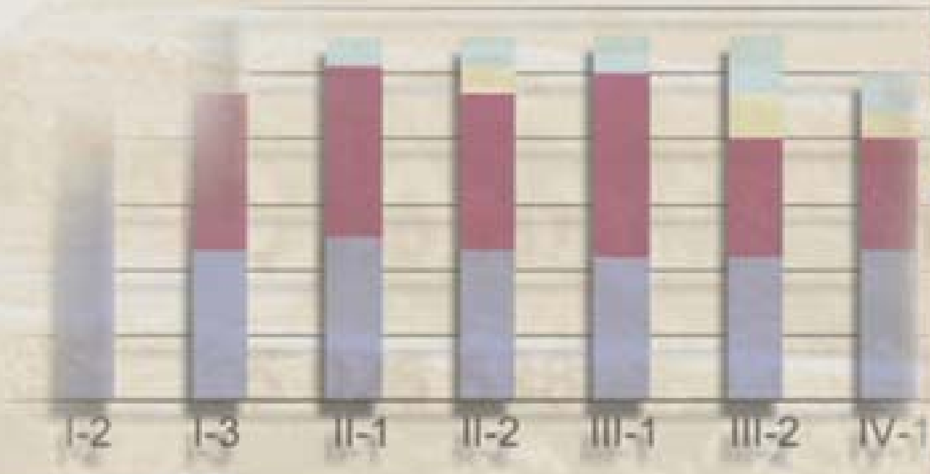

WATER RESOURCES REVIEW

Malta water resources review

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Acknowledgements

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Foreword

The Maltese Islands are densely populated but poorly endowed with freshwater resources. Since the 1980s, the drinking-water supply has been heavily dependent on saltwater desalination. The population and the tourist sector are served with good-quality drinking-water, but certain trends give rise to concern: groundwater depletion in terms of both quantity and quality; and a growing dependence on oil imports for water desalination. The public is poorly educated about national water issues and ill-prepared to assimilate information and contribute to shaping the required action. These and other associated trends have raised concerns about Malta's long-term water sustainability and security.

Sustainable water resources are vital to Malta's long-term prosperity. Water is necessary for drinking and it supports everyday life at work, at home and at leisure. Water is essential to agriculture and to the health of the natural environment that supports all human activities. Every sector of the economy depends on secure and sustainable access to water. Despite the very limited resources of the islands and the importance of water to a healthy future, water has not to date been valued as the precious resource that it is. There are no easy solutions to Malta's water shortage yet the nation requires water security for the future. Legal and administrative measures need to be taken according to a plan emerging from a strategy, which in turn is the expression of a national water policy.

A comprehensive review of Malta's water resources was carried out in 2003–04 by the Malta Resources Authority with the collaboration of the Food and Agriculture Organization of the United Nations. This review was presented and examined at a stakeholder workshop in March 2004, and was then open for consultation. Comments were received from stakeholders, and adjustments were made in order to address the issues raised.

The Malta Water Resource Review is intended to provide a strong and objective factual knowledge base on the status of the islands' water resources and trends in water use. It is hoped that it will serve as a platform for discussion among stakeholders and contribute to the development of both a national water policy and a groundwater management strategy for Malta.

List of acronyms

BC	Blue Clay
BRGM	Bureau de Recherche Géologique et Minière
NACE	Classification of Economic Activities in the European Community
EU	European Union
GBH	Gauging borehole
GDP	Gross domestic product
GL	Globigerina Limestone
GS	Greensand
ILI	Infrastructure Leakage Index
LCL	Lower Coralline Limestone
MEPA	Malta Environment and Planning Authority
MOU	Memorandum of understanding
MRA	Malta Resources Authority
NGO	Non-governmental organization
NSO	National Statistics Office
RO	Reverse osmosis
TSE	Treated sewage effluent
UCL	Upper Coralline Limestone
WFD	Water Framework Directive
WHO	World Health Organization
WSC	Water Services Corporation

Glossary

Adaptive management
Adaptive management is based on an acceptance that in complex situations there may never be sufficient information to come to an "optimum" decision. Therefore, it puts the emphasis on flexible planning backed by strong monitoring and information management systems that allow constant adaptation and upgrading of plans and activities.

Aquifer
An aquifer is subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater.

Closed basin
A closed basin is a river basin where utilizable outflows are fully committed.

Cost recovery
Cost recovery involves the use of fee or tariff structures that cover the cost of providing the service or investment.

Demand
In economic terms, demand is an expression of willingness to pay for goods or services by those who can afford to pay for them. However, non-economists often understand demand as being the same as needs or requirements. In the context of this report, the definition of demand is usually understood to be somewhere between these two concepts: an expression of need but based on an understanding and acceptance of a "fair price" (monetary and other) for a given level of service. This concept of a "fair price" is subjective, particularly in the case of water and sanitation services, where there is a social aspect to the services, and the traditional price is well below the full economic cost.

Demand management
Demand management involves the use of price, quantitative restrictions and other devices to limit the demand for water.

Externality
An externality is the unintended real (generally non-monetary) side-effect of one party's actions on another party that is ignored in decisions made by the party causing the effects.

Groundwater body
A groundwater body is a distinct volume of groundwater within an aquifer or aquifers.

Information base
The term information base is used rather than the more common "database" to underline the fact that what is being collected and stored is a wide range of physical and societal information (including data) that may require storage in different formats and locations.

Plan
A plan is a coherent set of decisions about the use of resources that, taken together, have the potential to achieve a vision. A plan includes an explicit statement of the methods, costs, responsibilities, schedule of activities, and agreed targets.

Runoff
Runoff (or surface runoff) is the portion of rainfall that flows over the land surface. It can concentrate in depressions or behind impounding structures or it can continue to flow over the land surface into watercourses.

Scenario
A scenario is an internally consistent pathway into the future; stories about the way the world might turn out tomorrow. Developing a set of narrative scenarios helps identify possible pathways into the future based on current trends and some knowledge of sources of greatest uncertainty. Narrative scenarios can and should be a mix of qualitative and quantitative information.

Stakeholder
A stakeholder is an agency, organization, group or individual that has a direct or indirect interest in a project/programme, or that affects or is affected positively or negatively by its implementation and outcome.

Stakeholder platform
A stakeholder platform is commonly defined as a "decision-making body (voluntary or statutory) comprising different stakeholders who perceive the same resource management problem, realize their interdependence for solving it, and come together to agree on action strategies for solving the problem."

Strategy
A strategy is a medium- to long-term planning framework within which plans are developed and funded. Over time, an effective strategy should lead to achievement of a vision. Strategies should be updated constantly in the light of new information. Strategies tend to be highly political and reflect the policies of a governing body or an organization.

Vision
A vision is a desired future state. Consensus on this vision is required before a strategy is developed.

Water governance
Water governance relates to the range of political, social and economic and administrative systems that are in place to develop and manage water resources and the delivery of water services at different levels of society. EMPOWERS focuses particularly on local water governance – governance at a level ranging from the community to the district/governorate.

Executive summary

The state of Malta's water resources is poor. With the support of FAO, the Malta Resources Authority has been undertaking studies and consultations to articulate a national water policy and formulate a set of workable regulations. The rationale behind this process is that involving stakeholders will lead to a policy that is socially and politically acceptable and geared to tackling the complex water-related challenges facing the country. In addition, it is intended that the water policy will ensure that Malta is in compliance with the European Union Water Framework Directive. This directive requires Malta to achieve the status of "good" by 2010.

As part of the policy formulation process, a water resources review was conducted to: (i) assess the current status of water resources; (ii) evaluate the demand trends of different sectors; (iii) provide information; and (iv) identify opportunities for improving the sustainability, efficiency and equity of water resource management.

This review shows that, although the demand for groundwater is outstripping supply, there is scope to reverse current trends through demand management, supply augmentation and strategic protection of groundwater resources. Groundwater quality can be protected and the mean sea-level aquifer stabilized. Policies and practices to do this need to be based on accurate information and acceptance that solutions must be applicable in the long-term. As such, political consensus and cross-party support is vital. This review provides the basis for that consensus.

Malta's core water challenge is one of water governance. Tough decisions will have to be made immediately if the environmental sustainability of Malta's aquifer systems is to be achieved. However, decision-making is currently fragmented, policies are poorly aligned, and awareness of the consequences of continued mismanagement of the sea-level aquifers is poor. Nonetheless, there is much scope for improving Malta's system of water governance. This reports lists 20 practical options and opportunities for improving the sustainable management of Malta's water resources.

Malta faces many infrastructural challenges both in terms of engineering hardware and the institutions that are responsible for service delivery. Considerable investment has been made in desalination plants and further investment has been committed for the construction of sewage treatment plants. However, additional investment will be required if a much higher proportion of Malta's freshwater needs are to be met with desalinated water and if the treated sewage effluent is to be treated further than the statutory requirements of European conventions and conveyed to potential users and/or to locations where it can be used safely to recharge groundwater (using the precautionary principle as a guide).

Considerable private investment has been made in water-related infrastructure (e.g. boreholes and small desalination plants). Private investors are likely to resist a water policy that makes it difficult for them to capitalize on their investments or that necessitates further private investment.

There is scope for augmenting water resources by improving the capture of runoff particularly in urban areas. A 25-m^3 cistern or equivalent in every household is estimated to create a storage capacity of about 4.5 hm^3 (about 25 percent of annual domestic demand). However, logistical constraints hamper the practicability of attaining such levels of storage and self-supply.

Studies undertaken as part of the water resources review indicate that an effective water policy will require:

- improved governance;

- improved awareness;
- staged and adaptive implementation;
- demand management;
- supply augmentation;
- the ensuring of equity and justice;
- targeted interventions.

It is suggested that a water policy should aim to achieve the following vision by 2015:

- levels of water use regulated according to sustainable abstraction levels;
- aquifers restored to a status that represents a strategic reserve;
- water quality of all aquifers restored to within permissible limits;
- widespread use of local and decentralized solutions (e.g. rainwater cisterns, grey-water recycling, and pollution control);
- high levels of collective responsibility for managing and protecting Malta's water resources.

The report describes four demand scenarios (based on current levels of demand and the subsequent projections that have emerged from discussions with various stakeholders). It also discusses different strategies for meeting future demand and achieving the vision.

The report also identifies a set of risks and assumptions that will apply if a proposed water policy is implemented. These are:

- Reversibility of aquifer degradation: It is assumed that a reduction in groundwater abstraction will lead to an improvement in water quality to acceptable levels. The risk is that in some areas this may take many years.
- Climate change: Climate change may become a serious issue in the future.
- Equity: Implementation of the water policy will almost certainly lead to changes in patterns of water availability and use that may result in distinct winners and losers and reduced equity. Provision should be made for compensation schemes that would ensure socially acceptable outcomes.
- Impact on livelihoods: To be effective, the water policy must have an impact on water demand of the water-using sectors and individual water users. There is a risk of negative impacts on some commercial operations and the livelihoods of some users. Attempts should be made to minimize impacts on poorer social groups.
- Non-compliance: There is a history of poor compliance with water-related regulations. Enforcing the water policy effectively will require both resources and political will.

Chapter 1
Introduction

THE MAIN CHALLENGES IN MANAGING MALTA'S WATER RESOURCES

Meeting the demand for water

Malta is densely populated but poorly endowed with freshwater resources. Meeting a high and rapidly increasing demand for water while protecting and conserving the resource base and the environment is a major challenge.

Annual rainfall is about 550 mm and highly variable. There are no surface waters that can be exploited economically, and groundwater resources are subject to increasing competition. Historically, the Maltese people have coped with water scarcity through a limited allocation of water per person. However, in recent decades, urban water users have not experienced prolonged periods of water shortages. One reason for the good supply-reliability record is that, since the early 1970s, a large proportion of the urban water demand has been sourced from desalination plants. While the desalination plants have ensured reliability of supply, a less positive aspect is that they have encouraged a "water" culture that takes only limited interest in conservation or efficient use of water resources. The main control on urban water demand, whether it be for the domestic, industrial or tourist sectors, has been the tariff charged by the Water Services Corporation (WSC). Tariffs have had the desired effect of encouraging some larger hotels to install their own mini-desalination plants and some industries to recycle water. However, they have not been sufficient to encourage widespread rainwater harvesting and reuse at a local/domestic level.

In contrast, agricultural water users continue to be more dependent on the vagaries of the climate and access to water resources for irrigation. Water shortages have resulted in farmers shifting towards cultivation practices and irrigation systems that make efficient use of water resources. The main source of water is groundwater pumped from private boreholes and conveyed to fields via pipe networks and water tankers. Although farmers are relatively more conscious of the importance of water conservation than urban water users, increased agricultural water use and excessive groundwater abstraction in recent years has affected the sustainability and viability of aquifer systems. Severe degradation has taken place in some areas, and the prognosis for other areas is not encouraging. Groundwater degradation linked to agriculture takes two distinct forms. First, there is increasing salinity of the Lower Coralline sea-level aquifer systems as a result of vertical and horizontal seawater intrusion. Second, there is nitrate contamination of practically all the aquifer systems as a result of intensive livestock production, high levels of fertilizer use, and leakages in the sewage collection system (particularly in heavily urbanized areas).

Other users of water include tourism, industry and government organizations (e.g. hospitals and schools). Although there are specific challenges that relate to each of these sectors, their overall water demands are considerably lower than either the domestic or agriculture sectors.

Protecting the resource base

If Malta's water resources are to be protected, some difficult decisions will have to be made in the very near future. To be successful, these decisions must affect the patterns of groundwater abstraction and commercial practices that are currently degrading the water resources. Political imperatives for such actions include:

- the large increase in domestic water bills that will result from sourcing potable water entirely from desalination plants;
- the gradual collapse and/or major reduction in the profitability of irrigated agriculture that will result from further degradation of the sea-level aquifers;
- the penalties that might result from non-compliance with relevant European Union (EU) directives concerning water and the environment.

About 80 percent of Malta's groundwater resources are abstracted from sea-level fractured-limestone aquifers. These support a groundwater body that takes the form of a lens of freshwater floating on the underlying denser saltwater. Such groundwater bodies are inherently fragile and extremely vulnerable to poor management. Continued unregulated overabstraction of groundwater from these aquifers carries the severe risk of, in practical terms, destroying their capacity to store freshwater. Overabstraction is slowly reducing the volume of freshwater in the lenses. Deep boreholes and high-levels of localized abstraction carry the risk of disrupting and broadening the interface between freshwater and seawater and, thereby, further reducing the capacity of the lenses to store freshwater.

The perched limestone aquifer systems sit on impervious clay strata above sea level. Most of these aquifers are overexploited to the extent that groundwater levels have fallen and the flow from natural springs has dwindled. The freshwater flow from a number of these springs also supports important endemic species and ecosystems, which are protected under relevant national and European legislation. As a result of intensive farming practices, high-levels of nitrate pollution have made these bodies of groundwater unusable as sources of water for domestic use.

Improving water governance

Malta's main water management challenge is to ensure that priority demands for water are met while maintaining the viability of the aquifer systems. The challenge facing Malta is a complex one. Moreover, it is not solely linked to the selection of water management strategies that reduce the pressure on the aquifers while maintaining reliable and adequate water supplies to users. The fundamental challenge is to establish systems of water governance that take account of societal, economic and environmental conditions that are characterized by uncertainty, variability and change. It is not possible to make water management decisions and/or plans that will solve all water management problems now and well into the future. Instead, Malta requires the water governance capacity (i.e. information systems, stakeholder platforms, legal and regulatory mechanisms, executive capabilities, and conflict resolution systems) to enable society to respond to uncertainty, variability and change that could be localized or islandwide, short or long term, political, economic or environmental. This includes approaches to water management planning that are flexible and able to adapt or respond to uncertain future challenges.

The effective management of water resources is only possible where good-quality information exists on the status of resources and current and future demands. It is also extremely important that decision-makers at all levels have a good understanding of the characteristics of the water resource systems that they are managing and of the potential consequences of different courses of action. Although a lot of water-related information exists in Malta, this information is fragmented and difficult to access. Furthermore, much of the statistical information is misleading, inaccurate and/or out of date.

There is much scope for an improved alignment of policies that have the potential to affect the resource base or stimulate increased demand for water. There is also scope for better sharing of information and for planning processes that take better account of the fragile nature of Malta's water-resource systems. Water-resource planning and management is not integrated across the relevant line departments, agencies and private-sector organizations. This is leading to situations where certain departments are pursuing policies that encourage increased water demand and use while others are attempting to regulate demand. Planning processes do not exist that maximize the allocation of water to the most beneficial use nor do they consider potential negative trade-offs associated with different courses of action.

Misconceptions have had a major impact on decision-making and behaviour at all levels. In the main, they have led to a mistaken belief that Malta's groundwater resources are unlimited. Although it may be a slow process, carefully structured and well-targeted awareness campaigns are needed urgently to overcome this problem.

Finally, water governance will only improve substantively if there is wide acceptance of the need for a water policy that includes regulations. For this to happen, the regulations must be seen to be equitable and just. Furthermore, there has to be the political will to enforce such regulations. There has been a history in Malta of non-compliance with water-related regulations, including the illicit construction of boreholes. A new water policy must take account of lessons learned from earlier attempts to introduce regulations.

Supplying water at an acceptable cost

In Malta, the pricing of water supplied by the WSC is a political issue. Although nominally the responsibility of the Malta Resources Authority (MRA), the Government sets the tariffs that can be charged for water by the WSC. The Government also sets the price of energy for running the desalination plants. Private groundwater abstractors do not pay a charge for the water they abstract. For farmers, the cost of water is represented by the costs incurred in the drilling of boreholes, installing pumping equipment, and the running and maintenance of such capital. The Government considers the revenue foregone a "social contribution" to the sector. The net result of the active role that the government takes in setting the price of water means that prices rise, the electorate tends to blame the Government.

EU member states are to ensure that by 2010 water-pricing policies provide adequate incentives for users to make efficient use of water resources. An adequate contribution by the respective water users will reflect the utility of this commodity in industry, domestic consumption and agriculture. The costs of water services have to be recovered, and accounted for under the "polluter pays" principle. In structuring this pricing policy, member states should consider the social and economic effects of the recovery mechanism as well as the geographical and climate conditions of the region.

If tariffs are to be used to regulate demand, they will have to be set at a level that changes the behaviour of users to the point that they encourage: improvements in efficiency and productivity; consideration of alternative sources of supply to groundwater; and a shift away from using water for "low-value" activities.

The economic argument for using tariffs to regulate groundwater use is strong. If groundwater quality continues to deteriorate, at some point domestic water supplies will have to be sourced almost entirely from desalinated water. In terms of production costs, the cost of substituting groundwater with desalinated water will be about LM4 million/year (about US$1.333 million/year, at an exchange rate of LM1 = US$0.3332) based on current energy costs. If this increased cost is passed on to the consumers, this will lead to a doubling of household water bills. If groundwater quality deteriorates to the point that it is unusable for agricultural purposes, farmers may have to switch to desalinated ("polished") groundwater or treated and "polished" sewage effluent. Based on current energy costs, this would result in increased per-hectare irrigation costs of about LM1 000 and LM3 000 for crops irrigated with treated sewage effluent (TSE) and desalinated water, respectively. These estimates are based on a crop requiring 500 mm of irrigation per year and estimated TSE and desalinated water charges of LM0.2 and LM0.6 per cubic metre, respectively.

Improving the infrastructure

The main infrastructural challenges include:

- Development of additional desalination capacity. Excess capacity exists to meet Malta's current demand for producing desalinated seawater. However, additional capacity will have to be created if all of Malta's freshwater resources have to be sourced from desalination plants.
- Development of TSE supply and storage systems. It is anticipated that there will be sufficient capacity for treating all of Malta's sewage effluent by 2008. However, challenges exist if all this water is to be used for agriculture. These include infrastructure to convey water to where it is needed and extra-treatment of the effluent if the saline content of the sewage is not controlled. Given the seasonal nature of demand for irrigation water, storage capacity will also be needed to ensure that water is available when needed.
- Leakage reduction. Real losses (i.e. leaks, illegal connections, etc.) from the urban water supply network continue to be about 30 percent. Reducing losses to more acceptable levels is an ongoing challenge facing the WSC.
- Increased water harvesting. Water resources could be augmented by increasing local-level rainwater harvesting, particularly in urban areas. However, sufficient space and adequate fiscal incentives may prove to be a challenge.
- Recognizing the aims and aspirations of private investors. In recent years, considerable private investment has been made in the drilling of boreholes for a range of uses from land clearance to irrigation systems. In the case of agricultural users, the need to pay off debts is likely to be an important factor in whether or not farmers are willing to reduce their water demand or switch to alternative and more costly (to the individual) water sources. Connecting to these sources may require additional investment in infrastructure.

Increasing supply and limiting demand

Although the water resource situation in Malta is extremely serious, there is much that can be done. However, there are no "quick fixes" that might result from a single political initiative such as formulating a new set of groundwater regulations. However, a single policy initiative that is well formulated, equitable and just and that takes a long-term view could prompt the crucial changes in attitude and behaviour needed at all levels if safeguarding the water-resource base is to become a component of political decision-making.

Details of opportunities for augmenting water supplies for different uses and for regulating the demand of different users are discussed in other sections of this report.

COLLABORATION WITH FAO

Malta has no national water law per se. While the Civil Code includes a clause dealing with entitlements to water from springs, it is the Malta Resource Authority Act that sets out the regulatory arrangements for the groundwater resources.

In July 2002, FAO entered into an agreement to assist the Government of Malta in the review and drafting of new or amended legislation for the sustainable management of groundwater. A strictly related objective was to anticipate the implementation and administration requirements of the proposed legislation. A complementary objective was to assist the Government of Malta in the review and analysis of policies resulting from its review work in support of the preparation of a new groundwater allocation policy and new groundwater legislation. The objective of building national capacity in the conceptualization and drafting of groundwater-resources management legislation, in anticipating and meeting the implementation and administration requirements of the proposed legislation and in water resources policy analysis and formulation was also considered to be a necessary component of the project.

Among other activities, the project undertook a large number of studies. The reports from these studies are available from the Web site of the MRA.

Public announcements of a policy approach have to date been limited to the release in March 2004 of the consultation document "A water policy for the future" prepared by the MRA with the assistance of FAO. Seventeen responses to the document were made by government departments, the Malta Chamber of Commerce and Enterprise, academics, consultants and the Farmers' Central Cooperative. There was general support for the need for a holistic water policy. Subsequently, the MRA compiled a document outlining and commenting on the responses received, which is available on its Web site.

AIMS OF THE REPORT

The overall aims of this report are:

- to provide a comprehensive review of the current status of Malta's water resources and an assessment of demand trends for the different sectors;
- to assess the relative factors that may affect water supply and demand;
- to identify specific opportunities for improving the status of Malta's water resources and meeting future demands;
- to consolidate information that can inform discussions on Malta's water policy. In particular, the report has been written in support of the preparation of a national water policy document that will serve as the basis for the establishment of new water regulations, enhanced institutions and governance, and water-demand management programmes.

The preparation of the report involved a review of information on water resources status, use and demand from the studies carried out by the project and others. Particular attention was given to identifying and removing discrepancies and inconsistencies, and to presenting information that has been verified by the relevant stakeholders.

Chapter 2
Basic facts about Malta

PHYSIOGRAPHY AND DEMOGRAPHY

The Maltese archipelago consists of three inhabited islands: Malta, Gozo and Comino, and a number of uninhabited islets scattered around the shoreline of the major islands (Figure 1). 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 the island of Malta is 136 km while that of Gozo is 43 km.

The Maltese Islands have a population of about 398 000, increasing at a rate of about 2 400 inhabitants/year. Official statistics show that the Maltese population is expected to continue growing for the next 20–year period to a total of 425 000 inhabitants. This increase will 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 of 1 250 inhabitants/km^2, Malta is among the most densely populated countries of the world. Consequently, Malta is highly urbanized and more than 23 percent of the surface area is built-up.

It is expected that the total number of households will increase, a change that will be accompanied by a decrease in household size – mainly as a result of changing family perceptions. A steady decrease in household size has been evident in recent years. The average household size of 3.1 persons registered in the 1995 census is projected

FIGURE 1
The Maltese Islands

to fall to 2.7 persons by 2020. As a consequence, the total number of households is expected to increase from the 119 479 households recorded in the 1995 census to about 160 000 households by 2020. Population statistics also indicate an internal migratory flow from the Southern Harbour to the Northern Harbour and other districts, which will also be reflected in a redistribution of the housing stock in the country.

The Maltese economy is becoming increasingly service oriented. In 2002, the manufacturing sector contributed to about 35 percent of gross domestic product (GDP), while the market/services sector accounted for slightly more than 48 percent of GDP. Sectorally, the percentage employment shares in 2004 for the agriculture, industrial, services and public sectors were 1.6, 24.2, 37.4 and 36.8 percent, respectively.

Tourism plays an important role in the country's development. Through the multiplier effect, it contributes towards an employment complement of about 40 000. About 1.1 million tourists visit the islands, for an average total of 10.5 million days per year. The average daily tourist population is 32 000. Tourist arrivals peak in July and August, placing additional strains on the country's water resources.

Urban development in Malta has increased dramatically in the last 50 years and development has altered the physical characteristics of the landscape drastically, increasing the quantity of impermeable surfaces and, thereby, reducing infiltration processes. The result has been a decrease in natural groundwater recharge.

HISTORICAL DEVELOPMENTS

Historically, Malta has had a lack of natural resources in relation to demand, and water resources have always been considered of strategic importance. Thus, for example, near the world heritage site of Hagar Qim and Mnajdra, there is a group of rock-cut cisterns known as the Misqa Tanks (Plate 1). The antiquity of these tanks is uncertain although they are generally presumed to be contemporary to the megalithic temples.

In 1512, when King Charles V offered the Maltese Islands to the Knights of St John, a fact-finding mission reported that: "The water is salty and putrid but there are good springs which are probably due to rain fallen in winter time. The origin of these springs in not very deep, they often disappear in summer but they always diminish in volume. One generally drinks rainwater collected in tanks or in ditches." (Knight Quintinus Haedus, 1536).

Until 1610, Valletta was supplied solely through stored rainwater. In that year, work began on an aqueduct (Plate 2) to carry water from the springs in the Rabat Plateau to Valletta.

Plate 1
The Misqa tanks.

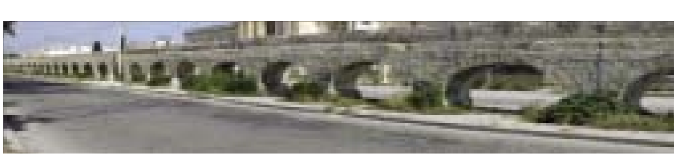


Plate 2
The Wignacourt Aqueduct.

Under British rule, various major infrastructural works were undertaken including the digging of a deep well close to Valletta and the installing of a motorized pump in 1851. In 1866, galleries were constructed to abstract water from the perched aquifers, while in 1881 a boiling-type distillation plant was built at Tigne (Plate 3).

Other important works undertaken over the years included: the construction of the Sta Marija Reservoir in 1886; the construction of galleries and a pumping station at Wied il-Kbir, and the installation of a pipeline water system supplying Valletta, Floriana, Sliema, Birkirkara, Zebbug, Siggiewi, Rabat and Mdina in 1887; the construction of galleries and pumping stations, the Fiddien Reservoir (91 000 m^3), the Qrendi Reservoir (54 500 m^3) and major pipelaying works between 1955 and 1961.

Plate 3
The building that housed the 1881 distillation plant at Tigne.

Between 1965 and 1968, four multiflash seawater distillation units (with a maximum production of 20 500 m^3) were installed. In the 1970s, it was decided to boost groundwater production from the mean sea-level aquifer through an intensive borehole-drilling campaign. Overall groundwater production figures increased, but with a deleterious effect on the qualitative status of the aquifers. By 1980, the average annual salinity of the mean sea-level aquifer had risen to 1 600 mg/litre, exactly twice what it had been in 1969. By this time, it had become evident that the heavily depleted aquifers could no longer meet the growing demand.

Therefore, reverse osmosis (RO) technology was chosen as the strategic alternative water-supply source for the islands. The first seawater RO plant started production in 1982 at Ghar Lapsi on the west coast of Malta, at that time producing 20 000 m^3/day. Since then, other plants at Marsa (brackish-water), Tigne, Cirkewwa and Pembroke have been constructed. Today, desalinated water accounts for about 55 percent of the total potable water production. Malta has one of the longest track records of RO plant operation in the Mediterranean region, with high output levels and reliability.

Chapter 3
National economic and political setting

NATIONAL ECONOMIC, SOCIAL AND ENVIRONMENTAL OBJECTIVES

In 2002, the Government of Malta submitted a report to the World Summit on Sustainable Development (Government of Malta, 2002). The report analyses the major environmental issues facing the Maltese Islands, reviews the progress achieved on these issues and outlines what remains to be done in order to meet the objectives set.

The report highlights the achievements in the five-year period preceding the its publication. It provides specific information on the leakage-reduction and energy-saving programmes initiated by the WSC.

The report presents the main threats relating to the integrity of groundwater as:

- overpumping of the mean sea-level aquifers and a consequent rise in salinity levels;
- point and diffuse pollution from anthropogenic activities namely agriculture (fertilizer and pesticides), industry and waste disposal;
- the effects of land development, including road development on natural aquifer recharge.

The report also notes that "freshwater resources support particular habitats and that their contamination poses an ecological threat. Furthermore, freshwater habitats have been steadily decreasing due to competition with other land-uses."

The main objectives set by the Government in this report with regard to sustainable development in the water sector are:

- attainment of internationally acceptable standards in drinking-water quality through the undertaking of the necessary improvements in the water production and distribution infrastructure;
- protection of high-status sites in line with the EU Water Framework Directive (WFD);
- the designation of the entire Maltese Islands as a nitrate-vulnerable zone in order to protect the quality of groundwater;
- the need to encourage further water conservation measures (with specific reference to the use of cisterns);
- the need to optimize the use of second-class water;
- integrated water resources management coupled with further enforcement of regulatory measures (in particular with regard to illegal abstraction).

NATIONAL LEGISLATION

A review of the history of Maltese legislation (FAO/MRA, 2004d), indicates that groundwater has only recently been recognized as a resource and regulated as such. In fact, in 1886, when the Civil Code was being drafted, water was considered "a natural resource which falls from heaven", but now it is being recognized as an economic good.

The Civil Code and the Code of Police Laws are the earliest legal instruments regulating water resources. The Civil Code regulates the collection of natural water resources and identifies who has the right to collect water flowing naturally on the land. The Code of Police Laws tries to protect "public waters". Furthermore, it was under the Code of Police Laws that the regulation of pollution was first introduced.

Although the legal status of the codes is hierarchically superior to primary and subsidiary legislation, this hierarchic superiority is waived when more recent and more specific primary and subsidiary legislation comes into force. In 1991, the Water Services Act was promulgated, which regulated the management of water resources. This law repealed two ordinances that regulated the abstraction of groundwater as well as the use of groundwater for irrigation, namely the 1939 Irrigation Ordinance and the Groundwater Ordinance.

Under this act, the roles of regulator and operator were attributed to the WSC. The act empowers the WSC to acquire, transform, manufacture, distribute and sell potable and non-potable water. The WSC is also entrusted with the treatment, disposal and reuse of sewage water and wastewater and the reuse of stormwater runoff. Although this act does not define underground water, there is an operative part that lists the duties of the WSC with respect to the supply of groundwater. In fact, it is the duty task of the WSC "to survey, inspect or cause the sinking of bores…for the purpose of ascertaining…the presence, quality or quantity of underground water…" This section is the first legal provision that provides for the quality of groundwater.

In 2000, the Malta Resources Act was enacted. This act defines the functions of the WSC and the MRA as the operator and the regulator, respectively. This new act deleted all the provisions under the Water Services Corporation Act that empowered the WSC to issue licences for the supply, sale or any other functions concerning water, water pumps and other apparatus related to the supply of water.

The functions of the MRA, which has a directorate for the regulation of water resources, have been fashioned upon the functions laid down in the Water Services Corporation Act. The only difference is that the MRA safeguards and manages water resources through the adoption of regulations and granting of licences, whereas the WSC performs its duties and implements these functions as a water-supply utility.

Another pertinent act is the Environment Protection Act of 2001. Under this act, the wide definition of the term "environment" includes "water". The competent authority under this act is the Malta Environment and Planning Authority (MEPA). The MEPA is entrusted with the implementation of the Government's duties under this act. Furthermore, the MEPA has to cooperate and make arrangements with other entities in order to better monitor the implementation of and compliance with the provisions of this act. This can be done through the adoption of memoranda of understanding between the MEPA and other authorities, such as the MRA. Such coordination is needed between the MEPA and the MRA in order to establish which will be the competent authority for licensing operations relating to the abstraction, use or other forms of management of groundwater. However, this act also provides that the minister responsible for the environment may issue regulations under the Environment Protection Act, and may establish that another person or body besides the MEPA shall be responsible for the performance of those regulations.

Finally, the Constitution of Malta states: "Nothing (in this article) shall be construed as affecting the making or operation of any law so far as it provides for vesting in the Government of Malta the ownership of any underground minerals, water or antiquities". Thus, the constitution can be considered to formally vest in the Government of Malta the sole ownership of all groundwater resources in the islands.

EUROPEAN WATER DIRECTIVES

The acceptance of the application submitted by Malta to become a member state of the EU triggered the process of harmonization. This has led to a major re-evaluation of Malta's legislative system, particularly in the field of environmental management. As an EU member state, Malta is obliged to take a more sustainable and integrated approach to groundwater management than was previously the case. The regulation of groundwater management in Malta has also needed to be harmonized with the relative sources of the *acquis communautaire*, which are comprehensive and holistic in their approach.

The Malta Resources Authority Act and the Environment Protection Act paved the way for the adoption of subsidiary legislation that has transposed into Maltese legislation two EU directives regulating groundwater, namely: the WFD; and the Groundwater Directive. These two directives provide for specific measures for the protection of groundwater.

The legal instrument that adopted the EU Groundwater Directive into Maltese legislation is "The Regulations for the Protection of Groundwater against Pollution caused by Dangerous Substances 2002". This is the first regulation completely adopted for the protection and management of groundwater. This legislation defines groundwater as: "all water, which is below the surface of the ground in the saturation zone and in direct contact with the ground or sub soil". These regulations are particularly aimed at protecting the quality of groundwater against pollution caused by dangerous substances. The term pollution has been given a wide definition, and pollution in groundwater occurs whenever there are "anthropogenic direct and indirect discharges of substances,...... which might endanger human health or water supplies, harm living resources and the aquatic ecosystem or interfere with other legitimate uses of water."

The MRA is the competent authority to take preventive measures, grant authorization and the required licences, conduct investigations, and monitor and implement the provisions of these regulations. However, certain provisions lay down general obligations, and in some of them there are no set thresholds for determining when quantities and concentrations are likely to cause deterioration in the quality of groundwater. Hence, the MRA has to set its own policies on these matters.

These regulations also provide for the "polluter pays" principle. Any person found guilty of polluting the groundwater shall be guilty of an offence that entails a pecuniary punishment, imprisonment or both. Hence, the "polluter pays" principle has been introduced to serve as a deterrent and enhance better protection of groundwater from pollution.

The WFD has been adopted into Maltese legislation by "The Water Policy Framework Regulations 2004". These establish a framework of action for the protection of "inland surface waters", "transitional waters", "coastal waters" and "groundwater".

These regulations designate the MRA as the competent authority for "inland water". Hence, it is the task of the MRA to take all necessary measures to ensure that the environmental objectives established under these regulations are met and to coordinate "all programs of measures for the whole of the catchment district". The MRA has a number of obligations to implement under these regulations in order to ensure good management, as well as protect groundwater from pollutants. This exercise of implementation entails a lot of work and numerous studies to identify water catchment districts, and to see which areas within these districts require special protection under specific legislation for the protection of groundwater. The regulations lay down timeframes for the competent authority to achieve and start adopting the required implementation measures (Table 1). This framework has to be worked out together with the public. In fact, the competent authority must ensure that the public is consulted and informed. Furthermore, the regulations also oblige the competent authority to encourage the active involvement of interested parties in the implementation of these regulations, particularly in relation to the formulation, review and updating of water-catchment plans.

These regulations provide new obligations and new implementation measures that the competent authority has to follow in order to protect both the quality and the quantity of groundwater in line with European standards.

Other directives that also have an impact on the regulation of groundwater (e.g. the Nitrates Directive, the Habitats Directive, the Landfilling of Waste Directive, the Plant

TABLE 1
Timetable for implementation of the Water Framework Directive

Year	Requirement
2003	Directive transposed into national legislation.
	Identification of river-basin districts and of the competent authorities that will be empowered to implement the directive.
2004	Completion of the first characterization process and the first assessment of impacts on the river-basin districts.
	Completion of the first economic analysis of water use.
	Establishment of a register of protected areas for the river-basin districts.
2006	Environmental monitoring programmes established and operational.
	Work programme for the production of the first River Basin Management Plan established.
2007	Public consultation process on significant water management issues in the river-basin districts initiated.
2008	Publication of the first River Basin Management Plans for public consultation.
2009	First River Basin Management Plan finalized and published.
	Programme of measures required in order to meet the environmental objectives of the directive finalized.
2012	Programme of measures to be fully operational.
	Work programme for the production of the second River Basin Management Plan published.
2013	Review of the characterization and impact assessment of the river-basin districts.
	Review of the economic analysis of water use.
	Interim overview of significant water management issues published.
2014	Publication of the second River Basin Management Plan for public consultation.
2015	Achievement of the environmental objectives specified in the first River Basin Management Plan.
	Second River Basin Management Plan finalized and published with revised programme of measures.
2021	Achievement of the environmental objectives specified in the second River Basin Management Plan.
	Third River Basin Management Plan to be published.
2027	Achievement of the environmental objectives specified in the third River Basin Management Plan.
	Fourth River Basin Management Plan to be published.

Protection Products Directive, and the Environment Impact Assessment Directive) have also been transposed into national legislation. This process has resulted in a comprehensive legal framework addressing groundwater management for the very first time in Malta's legal history. Although not yet published, the Strategic Environment Assessment Directive and the Biocides Directive should soon be transposed into Maltese legislation and put into effect.

Implementation of EU directives

The process for the implementation of the WFD is guided jointly by the MEPA and the MRA through a memorandum of understanding (MOU) agreed upon by the two authorities. Under this MOU, the MRA is the competent authority in Malta for "inland waters" with the exception of inland surface waters protected under the Development Planning Act or the Environment Protection Act. For such inland surface waters, the MEPA is the competent authority.

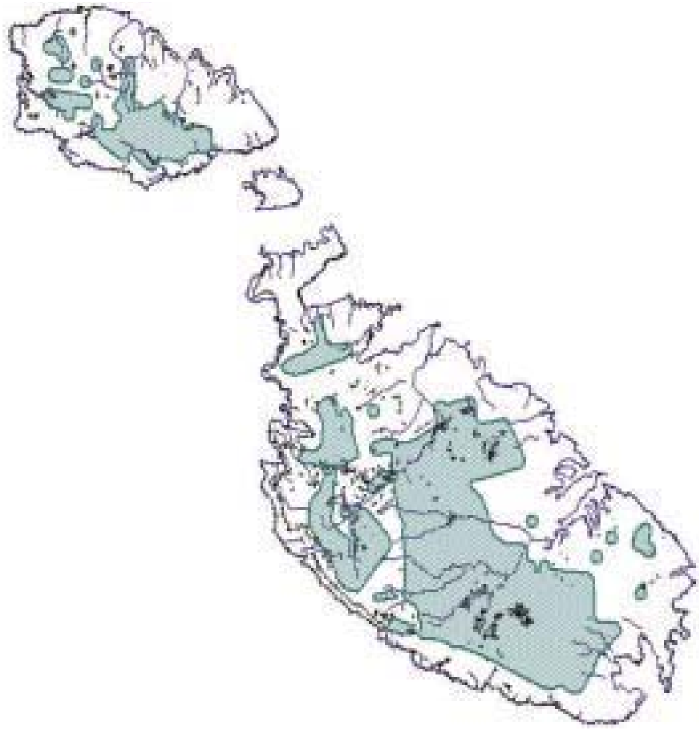
Thus, the MRA is currently carrying out the characterization of the groundwater bodies in the Maltese Water Catchment District and publishing the results of this analysis on its Web site. The MRA has also defined Groundwater Protected Areas (Figure 2) for the protection of groundwater utilized or intended to be utilized for human consumption and it has initiated the economic analysis of water use in the water catchment district. Initial results are also available on its Web site.

In addition, the groundwater monitoring strategies are being re-formulated in order to align them with the requirements of the WFD. The MRA aims to conclude this process by mid-2005 in order to have the monitoring networks operational in hydrological year 2005–06.

The overall objective of the WFD is to harmonize water environmental policy and regulation across Europe. As regards groundwater, the main aims of the legislation can be outlined as follows:

- prevention of deterioration in the status of groundwater bodies;
- protection, enhancement and restoration of all groundwater bodies;
- achievement of good groundwater qualitative and quantitative status by 2015;
- prevention and limiting of the input of pollutants in groundwater;
- reversing any significant upward trend in pollutants in groundwater;
- achieving the standards and objectives set for protected areas in other national and Community legislation.

FIGURE 2
Groundwater Protected Areas in the Maltese Islands



These objectives will be achieved through the setting up of "programmes of measures" within the Water Catchment District Management Plans. The directive requires these programmes to be based on the results of the characterization analysis in order to achieve maximum impact.

Furthermore, the MRA is also involved in the negotiations on drawing up the new Groundwater Directive. This directive is a requirement of the WFD, which states under Article 17 that "on the basis of a proposal from the Commission, the European Parliament and the Council shall adopt specific measures to prevent and control groundwater pollution by defining some common criteria on good chemical status and quality trends".

The current proposal sets out specific measures as per Article 17(1) and (2) of the WFD in order to prevent and control groundwater pollution. These measures include:

- criteria for the assessment of good groundwater chemical status;
- criteria for the identification and reversal of significant and sustained upward trends and for the definition of starting points for trend reversals.

The proposal also establishes a requirement to prevent or limit indirect discharges of pollutants into groundwater. Once adopted, this directive will be transposed into Maltese legislation.

Chapter 4
Water governance

REGULATION AND ACCOUNTABILITY

Malta has no national water law per se. While the Civil Code includes a clause dealing with entitlements to water from springs, it is the Malta Resource Authority Act that sets out the regulatory arrangements for groundwater resources.

The MRA is a public corporate body with regulatory responsibilities relating to water, energy and mineral resources in the Maltese Islands. It was set up by the Maltese Parliament through the Malta Resources Authority Act of 2000. The MRA has wide-ranging responsibilities essentially involving regulation of: water and energy utilities; quarry operators and private abstractors of groundwater; and retailers, operators and tradesmen in the regulated sectors. The Directorate for Water Resources Regulation has the duty to ensure the proper and sustainable use of all water resources in the Maltese Islands while respecting hydroenvironmental and socio-economic constraints. As the body responsible for the formulation of water regulations and policies, the Directorate for Water Resources Regulation is currently reviewing existing legislation and working on the implementation of EU directives recently transposed into Maltese law.

The MRA is mandated under Article 2(b) (i) of the founding legislation, the Malta Resources Authority Act XXV Chap. 423 of 2000, to secure and regulate the acquisition, production, storage, distribution or other disposal of water for domestic, commercial, industrial or other purposes. The MRA is also the designated competent authority for the Groundwater Directive. This directive requires the protection of groundwater regardless of its current use and aims to control pollution by a detailed list of substances. Where there is a risk of contamination, prior investigation is required before an authorization of discharge is released. The WFD is "results-oriented" in that it aims to achieve "good status" of surface water and groundwater by 2015. It requires a holistic management at water-catchment scale aiming at the achievement of specific environmental objectives.

Regarding groundwater, the WFD requires:

- the classification of well-defined groundwater bodies into good or poor status by way of quantity and quality;
- an assurance of no further deterioration;
- the restoration of groundwater bodies in poor status.

Further and more precise requirements are spelled out in the EU Directive on the Protection of Groundwater Against Pollution. Some aspects of the policy are covered by the statutory powers of the MRA. However, additional subsidiary legislation will be needed to achieve all the policy objectives.

WATER SERVICES

The WSC is a public utility body responsible for the supply, production and distribution of water in the Maltese Islands. It was set up by the Maltese Parliament in the Water Services Act XXIII 1991. The WSC operates four RO desalination plants with a total nominal capacity of 100 000 m^3/day. It also manages the municipal water-distribution network. This network consists of about 2 000 km of pipework of varying materials and sizes and a further 1 700 km of service pipework connecting more than 200 000 premises to the network. Extensive effort and investment have been devoted to leakage control, improved management practices and water conservation programmes.

Since October 2003, the WSC has also been responsible for the collection and proper disposal of wastewater.

In its strategic plan for the period 2004–08, the WSC spells out its national vision: "The Water Services Corporation is nationally recognized and respected as a top organization. It has a reputation for excellence in providing an essential service to the community, in meeting its social responsibilities, in sharing its expertise to industry and commerce and for not taking advantage of its monopolistic situation. The Corporation considers the customer as its driving force. It ensures the provision of water when and where it is required, and efficient, effective and safe wastewater management, at the lowest possible cost. The Corporation seeks to minimise the negative effects its activities can have on the environment, internationally, nationally and locally, and uses all its resources to champion the cause of environmental protection and enhancement. In that regard, the WSC has a reputation for excellence in its water conservation programme and activities to make optimum use of all water resources."

The WSC acknowledges in its strategic plan that by being the single largest abstractor/producer of water in the islands, it must play a leading rode in the management of the nation's water resources. The key goals of the WSC in the area of water governance, as outlined in the strategic plan, are:

- make water governance central to its efforts for maintaining sustainable development and effective management of Malta's water resources;
- identify and implement on a consistent basis water governance policies and practices through the widespread use of the tools of integrated water resources management;
- lead the way in the allocation and management of water resources in ways that meet current national, social and economic needs, and yet secure the future by ensuring the long-term sustainability of the available water resources;
- analyse all water problems or crises through established policies and practices of water governance to prevent future recurrences;
- seek to create accountable but active and positive relationships between the different and sometimes competing players and stakeholders, to explore common ground and to find equitable regulatory procedures that satisfy all water interests and needs.

The mission statement of the WSC is: "We supply water reliably, and dispose of waste water safely, to recognised standards of quality, aiming to satisfy the expectations, of all sectors of the community, using resources effectively and economically, while safeguarding health and the environment."

SECTORAL RESPONSIBILITIES

The Health Department is currently responsible for regulating drinking-water quality. Subsidiary legislation under the Public Health Act transposing Directive 98/83/EEC is being adopted. A transitional period of three years has been granted for the full implementation of the provisions of the directive with regard to the application of Annex 1 Part B on nitrate and fluoride and Part C on conductivity, chloride, sodium, sulphate and iron. This will allow time for the necessary infrastructural improvements to bring these substances in line with the limits imposed by the directive. The Health Department is also responsible for the quality of bathing waters.

The Department of Agriculture within the Ministry of Rural Affairs is responsible for the implementation of the Nitrates Directive transposed under the Environment Protection Act as Legal Notice 343 of 2001. A code of good agricultural practice has been drawn up to guide farmers on measures to reduce nitrate pollution from agricultural activity.

The MEPA and the MRA are both responsible for the implementation of the WFD (Chapter 3). An MOU has been signed by the two competent authorities for the purpose of clarifying the roles and defining their responsibilities in support of water-catchment management and the achievement of the objectives of the WFD. The agreement also seeks to foster cooperative working relationships between the two authorities by coordinating and simplifying the implementation procedures articulated in the regulations.

The Malta Standards Authority is responsible for setting the provisions for and certification of services in quality management systems (MSA ISO 9001: 2000) and environmental management (against ISO 14000), so guiding institutions and organizations towards improved performance and improved environmental conservation.

CIVIL SOCIETY

The non-governmental sector is considered an important stakeholder for the scope of this policy exercise. There are about 20 non-governmental organizations (NGOs) in Malta, most of which have been and will continue to be consulted on the more important issues of the policy.

Chapter 5
Water resources

CLIMATE
Rainfall

The climate of the Maltese Islands is typically semi-arid Mediterranean, characterized by hot, dry summers and mild, wet winters. During the summer season, the islands are dominated by high-pressure conditions. The mean annual rainfall was about 550 mm for the period 1900–2000 but with high seasonal and interannual variability (variation coefficient: 27 percent), with some years being excessively wet and other years being extremely dry. The highest precipitation rates generally occur between October and February (Table 2). Rainfall is characterized by storms of high intensity but of relatively short duration.

TABLE 2
Mean monthly values of main climate parameters, Malta

Month	Rainfall (mm)	Max. temp. (°C)	Min. temp. (°C)
January	86.4	14.9	10.0
February	57.7	15.2	10.0
March	41.8	16.6	10.7
April	23.2	18.5	12.5
May	10.4	22.7	15.6
June	2.0	27.0	19.2
July	1.8	29.9	21.9
August	4.8	30.1	22.5
September	29.5	27.7	20.9
October	87.8	23.9	17.7
November	91.4	20.0	14.4
December	104.3	16.7	11.4

FIGURE 3
Annual rainfall for Luqa meteorological station, 1947–2004

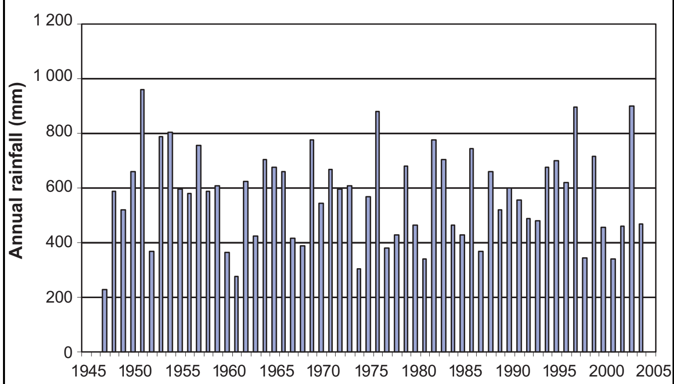


Figure 3 presents the annual rainfall for the Luqa meteorological station for the period 1947–2004. The average rainfall for this site for this period was 569 mm. In order to give a better impression of interannual variability, Figure 4 presents the deviation of annual rainfall from the long-term average for the same meteorological station. This figure shows that annual rainfall of 300 mm more or 250 mm less than the average is common. Although there is no indication of systematic variability, consecutive years of above- or below-average annual rainfall are common.

In Malta and Gozo, the WSC operates 14 rain gauges, 3 weather stations, 3 wind-monitoring stations and 4 runoff recorders. From the data gathered by the WSC from its weather stations (Plate 4 and Figure 5), the highest maximum rainfall intensity was registered in 1994/95 with 56 mm/h; while the lowest maximum intensity was 16.8 mm/h in 2000/01.

During the hydrological year 2001/02, the WSC registered 108 days of rain with the maximum rainfall intensity being 20.4 mm/h. The maximum wind speed was recorded as 24.5 m/s. The highest maximum and minimum temperatures were recorded as 37.1 and 3.2 °C, respectively, with the average maximum temperature of 20.6 °C being the lowest registered in the most recent seven-year period. The average evaporation, wind speed and mean rainfall were 5.4 mm/day, 3.2 m/s and 24 mm/month, respectively.

FIGURE 4
Deviation from mean annual rainfall for Luqa meteorological station, 1947–2004

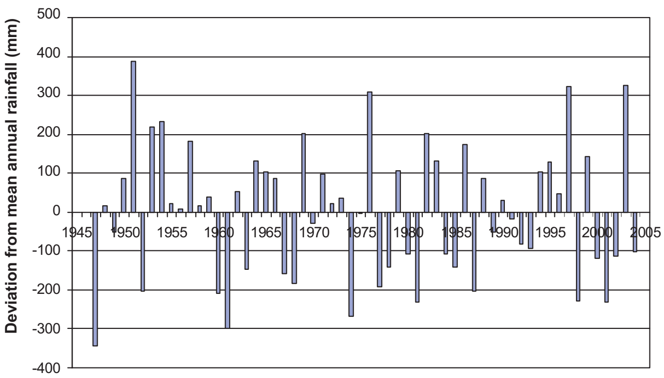


Plate 4
WSC weather station.

Consequences of the semi-arid Mediterranean climate that are of particular relevance to water management include:

- variability in interannual and intra-annual rainfall;
- high-intensity, short-duration rainfall events;
- seasonal scarcity of precipitation when the water requirements of the agriculture and tourism sectors are highest (normally from June to August);
- frequent occurrence of low rainfall years when groundwater recharge is likely to be low;
- frequent occurrence of high rainfall years when runoff is likely to be high.

Evapotranspiration

The potential evapotranspiration calculated by the Penman formula using 1947–1989 climatological data for the Maltese Islands is 1 390 mm (albedo = 0.2) with an interannual variability of 3 percent. Table 3 summarizes various figures for annual average rainfall, actual evapotranspiration, runoff and effective rainfall rates as calculated in different studies.

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

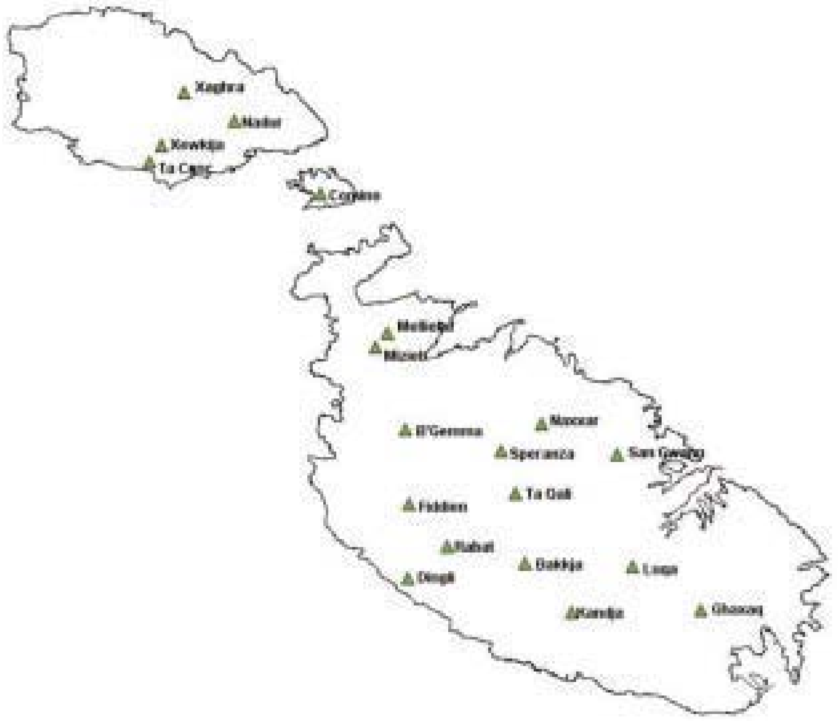
RUNOFF

Most runoff occurs after heavy torrential rain. This is the only time when surface water flows (for a few days at most) along the beds of the major valleys. To retain this storm discharge, 31 small dams have been constructed across the drainage lines (Plate 5). They

TABLE 3
Rainfall, evapotranspiration and effective rainfall

	Rainfall	Evapotranspiration	Runoff	Effective rainfall
Author		(mm)		
Morris (1952)/Edelmann (1968)	522	392		130
ATIGA (Martin)	587	475		95
ATIGA (Verhoeven/Gessel)	536	439		97
ATIGA (WWD Data)	551	431		120
FAO	587	437		150
Spiteri Staines (1987)	508	356	30	122
BRGM (1991)	551	348		203

FIGURE 5
WSC meteorological and rain-gauge stations



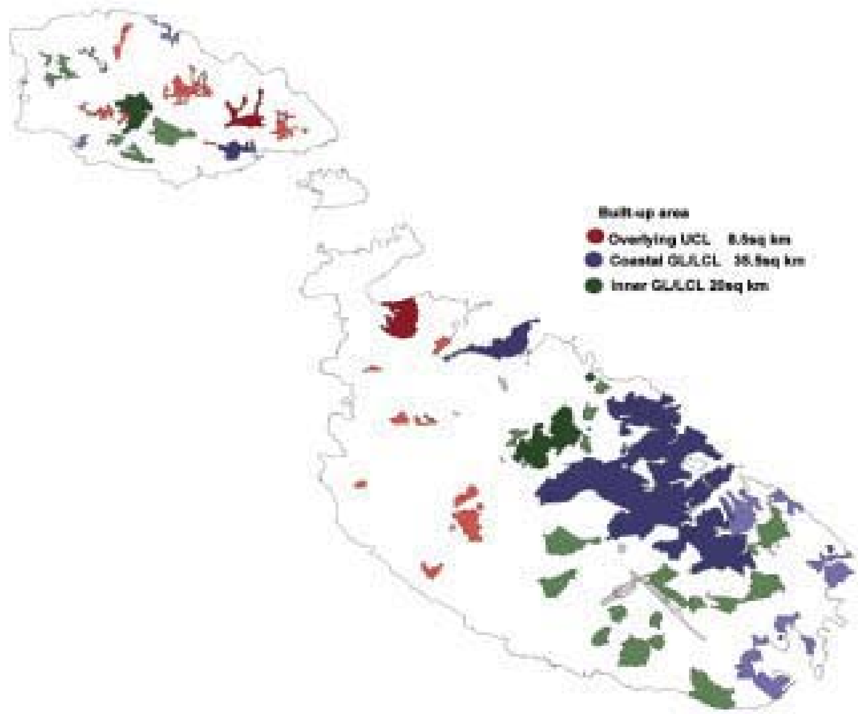
also serve the purpose of reducing the rate of soil erosion. Total dam capacity is estimated at 154 000 m³. A number of open reservoirs have been constructed along roads to catch flowing runoff water; their total volume is estimated at 250 000 m³.

Plate 5
Dam at Wied is-Sewda.

The Rural Development Plan (Ministry for Rural Affairs and the Environment, 2004) reports that in 1993 there were a total of 18 dam systems with a total capacity of 37 000 m³ that were no longer in use and notes that "this number is likely to have increased since then". However, the cleaning and rehabilitation of dam systems has recently been recognized as an important aspect of water management. Major rehabilitation works were undertaken in 1997 on the Wied il-Qlejjgha Dam systems, while rehabilitation and upgrading works have been carried out in the last two years on major dams in Malta including those of the Wied il-Ghasel and Wied il-Kbir valley systems.

According to Edelmann (1968), the eight-year average of surface runoff at the Marsa gauge, which controls a large part of the area, ranged between 2 and 3 percent of the annual precipitation. The same study reports that at the Mannarino gauge, only 1 percent of the rainfall was registered. ATIGA (1972) assumed an average surface runoff of 3 percent of rainfall to take into consideration the distribution between

FIGURE 6
Map showing the extent of urbanization, 2000



inland rural and built-up urban areas. Runoff records for 1961/62 in the Burmarrad Valley basin, which lies north of the Victoria Fault, gauged runoff at about 0.5 percent of the total rainfall.

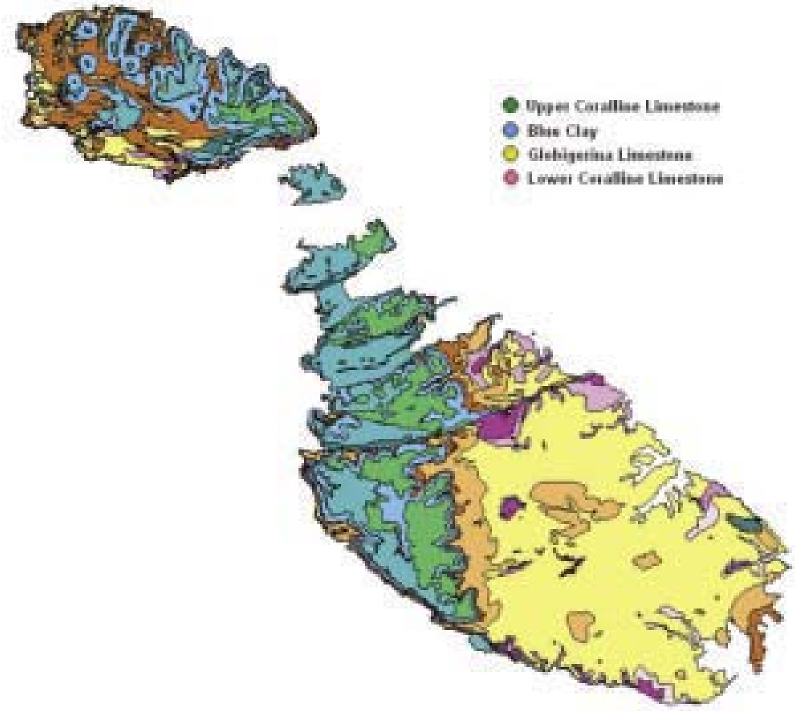
In view of the lack of observational data to support these assumptions, the runoff from rural areas that is lost to the sea is considered to be in the range of 2–5 percent of annual rainfall for the purposes of this study. In urban areas, localized runoff is considered to be as high as 80 percent of annual rainfall with the amount lost to the sea being highly dependent on geographical location. Hence, land use and urbanization have a considerable impact on the hydrology and water balances of different parts of the islands. Figure 6 shows the extent of urban areas.

GEOLOGICAL STRUCTURE

The geological formations exposed in the Maltese Islands are of the Tertiary and Quaternary Ages, having been deposited in the last 35 million years (Figure 7). The Lower Coralline Limestone (LCL) is of the Oligocene Age (23–35 million years old); with the other overlying formations being of the Miocene Age (5–23 million years old). The very top of the Upper Coralline Limestone (UCL) could be of the Upper Messinian Age possibly extending into the early Pliocene Age (1.6–5 million years old).

The UCL is a porous massive formation, which outcrops over the western and northern zones of the island and forms the highest parts of the topography. In view of its lithographic nature and its response to karstic erosion, this formation should be considered as a porous and fissured formation that could contain a generalized aquifer. The UCL formation varies considerably in thickness due to erosion. The existing thickness in the ridges and plateaus averages 30 m, while the range in the valleys

FIGURE 7
Simplified geological map of the Maltese Islands



(structurally low blocks) is 60–90 m with a 100-m maximum at Bingemma, south of the village of Mgarr. The rather small thickness of this formation on the plateaus has historically made possible the direct exploitation of water resources by shallow wells. The outcrops of the UCL act as a generalized recharge area for the underlying groundwater body.

The "Greensand" (GS) occurs as green glauconitic marl and rusty-coloured, sandy-textured limestone. The thickness of this formation varies from 0.25 to 1.5 m, locally increasing up to 12 m.

The "Blue Clay" (BC) formation is considered as an aquitard that supports the groundwater body in the UCL. The karstic evolution that affected the Maltese Islands should have locally but significantly modified this aquitard property, allowing groundwater stored in the UCL to "leak" down to the underlying sea-level aquifer. The average thickness is about 30 m, with the formation generally being thicker in western Malta than in the east.

The "Globigerina Limestone" (GL) is generally a massive and porous formation, which is rather homogeneous all over the Maltese islands. Short regressive periods during its deposition have created hardground and phosphoritic beds. Formations and also sedimentation conditions have changed locally and resulted in thin clayey or marly layers interbedded in the GL. These less-porous layers act as horizontal aquitards in the porous body of the GL, giving rise to small local water tables in a perched position above the main water body. The total thickness of the formation ranges from 30 to 210 m.

The total thickness of the LCL formation is estimated at more than 450 m according to reconnaissance oil-well results. In the LCL, many coral-reef formations have developed under shallow water and shoal conditions. The material of these reefal formations is generally more porous than in the main part of this geological unit. This observation is important from a hydrogeological point of view as these reefs could be considered as higher permeability zones in the porous matrix of the LCL. On the other hand, the vertical and horizontal extensions of these reefs are not known nor are their volumes and their possible interconnections. As such, the heterogeneity they create in the main aquifer body is important when assessing the general hydrodynamic behaviour of the aquifer.

In conclusion, the Maltese Islands are mainly composed of two porous and fissured limestones (the UCL and the Globigerina/LCL), separated by a relatively thin layer of clayey and marly material (the BC formation), sometimes overlain by the GS. The lithologically different natures of these formations together with their geological position give rise to two broad aquifer types: the upper (perched) aquifers in the UCL, and the lower (mean sea-level and coastal) aquifers in the lower limestone units (porous and fissured Globigerina and/or LCL) and, due to the general structure of the islands, in the UCL in the north of Malta.

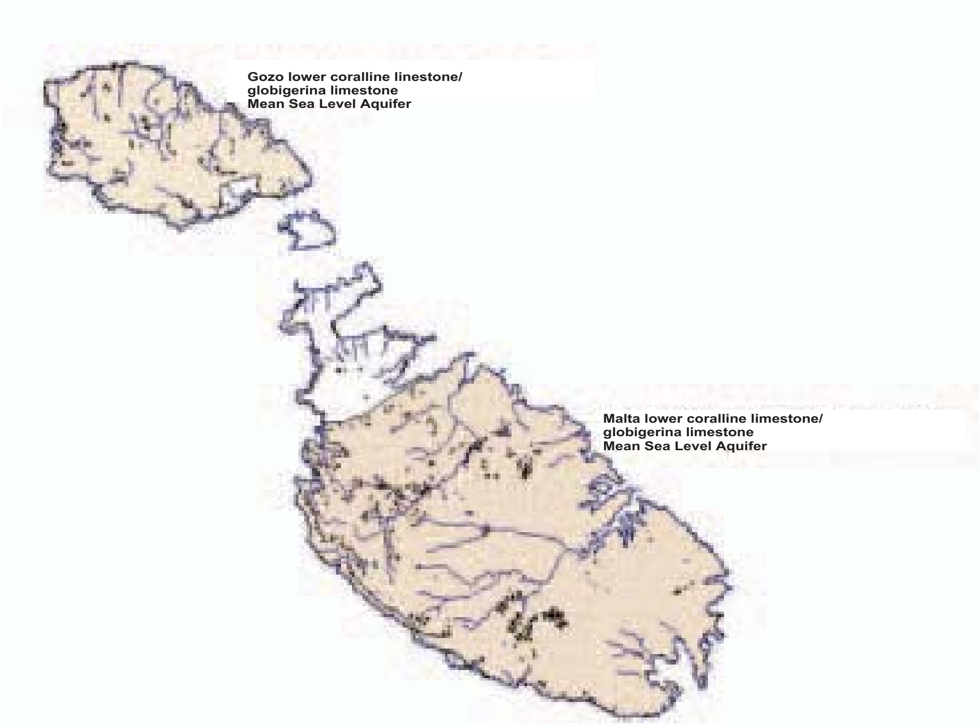
HYDROGEOLOGICAL CONSIDERATIONS

The UCL and LCL formations are considered to function as aquifer rocks. The GL functions locally as an aquifer only where fractured and/or located at sea level, and normally it is expected to transmit water from the surface into the main groundwater bodies along fractures. The BC and the GS are normally impermeable and underlie the perched aquifer. However, faulting, sinkholes and patch reefs partially penetrate these impermeable layers. Although the soils have a high water storage capacity, they are generally present as thin layers.

From a structural point of view, the island of Malta can be subdivided into two parts: the northwest, and the central-southeast; the limit being marked by the major fault line usually called the Victoria Fault (Figure 8). Fault systems in the island are not

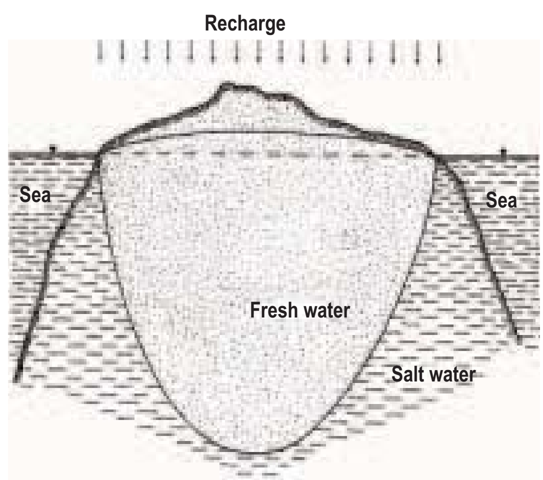
FIGURE 8
Structural map of the Maltese Islands showing the major fault lines

FIGURE 9
Extent of the Globigerina/Lower Coralline Limestone aquifers in the Maltese Islands



consistent in their hydraulic function. There are fault seals, especially where the aquifer is displaced against an impermeable formation. The Ghar Lapsi Fault appears to work as a seal owing to a dragged clay and marl fill along the fault plane. Other faults encourage communication, especially vertically. The Victoria Fault allows communication along and across the fault due to intense fracturing.

FIGURE 10
Scheme showing a Ghyben-Herzberg (floating) groundwater body in an island



In a significant part of the island, south of the Victoria Fault, the UCL and the Globigerina/LCL aquifers are stacked vertically (Figure 9). The LCL aquifer is in lateral and vertical contact with seawater. Because of the density contrast between freshwater and saltwater, a Ghyben-Herzberg system has developed (Figure 10). This consists of a freshwater lens floating on saltwater with a thickness about 36 times more below sea level than the height of the freshwater surface above sea level. In the central regions of the island of Malta, hydraulic heads of about 4–5 m were recorded in the 1940s when the aquifer was still relatively unexploited. Today, the potentiometric surface in these regions has receded to levels of about 1 m above mean sea level, mainly as a result of unsustainable groundwater overabstraction.

The effect of the pumping-station gallery network must also be taken consideration. This is because the galleries skim the surface of the groundwater lens, thereby fixing the piezometric head at the skimming level.

The porosity and permeability of the rock depend to a large extent on fissures and microfractures. Infiltration into the sea-level aquifer is predominantly through fissures in the overlying GL. From this aquifer, extraction takes place through a gallery system near the centre axis of the island and by boreholes further away from the centre. Because of brackish water upconing, the water pumped from the LCL has a chloride level that exceeds 1 000 mg/litre in a number of major sources, with peaks exceeding 2 000 mg/litre.

The UCL aquifer in this zone is perched above a BC seal (aquiclude) on the Rabat-Dingli Plateau. The aquifer outcrops partly below a thin soil cover, and infiltration of surface water is direct. No saltwater intrusion is possible. Large-scale private extraction from shafts and springs takes place.

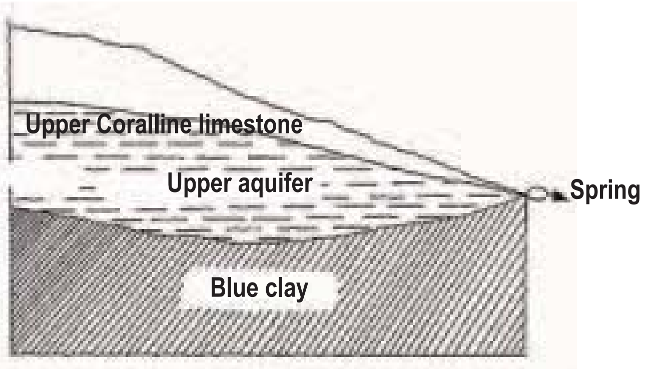
The northern part of the island is divided by a northeast–southwest fault system into a succession of horst and graben like structures; the graben being occupied by rather flat valleys separated by ridges. This structure, with parallel compartments separated by faults, leads to the view that the resulting aquifer blocks should be considered as independent from one another from a hydrogeological standpoint. The fault bounding the south of the Pwales Valley between Ghajn Tuffieha Bay and St Paul's Bay separates the main aquifer of the island from the northern, smaller graben and horst units. Thus, perched aquifers are developed in the UCL of Mellieha Ridge, Mgarr/Wardija Plateau and Mizieb Valley while coastal aquifers are present at Mellieha Bay, Pwales Valley and Marfa Ridge (Figure 11). The aquifers in the northern part of Malta have only a small potential for water abstraction. The aquifers at Mgarr and Mizieb have a limited vertical contact with saltwater, thus further limiting their potential groundwater yield.

FIGURE 11
Extent of the Upper Coralline Limestone aquifers in the Maltese Islands

The groundwater is used mainly for public water supply and irrigation. The small broken-up blocks allow little room for economic, large-scale water production development.

In Gozo, the LCL sustains a mean sea-level aquifer displaced over the whole of the island except for a small region around the harbour of Mgarr where the BC formation occurs at sea level due to faulting. The UCL outcrops in the island, namely at Ghajnsielem, Nadur, Xaghra, Zebbug and Victora/Kercem, sustain small perched aquifers which are exclusively used for irrigation (Figure 12). A number of minor perched aquifers are sustained by small outcrops of the UCL, such as those at Ghar Ilma and il-Gordan.

FIGURE 12
Perched aquifer scheme



Source: IGN (1990).

GROUNDWATER BALANCE

Replenishment of the aquifers is by rainfall and leaks from the water-supply system. Surface runoff into the sea is comparatively small because of the morphology, good water absorption by the soil and infiltration into the rock, and runoff interception by numerous dams, walls and terraces built over the centuries. The major surface water loss is by evapotranspiration. Aquifer recharge varies according to the rainfall. The amount of water in storage in the Ghyben-Herzberg lens of the main aquifer is of the order of 1 500 hm^3. Before the impacts of groundwater overextraction, this could be considered quite large compared with yearly recharge, whereas the recharge forms a very large percentage of the water in storage in the perched and coastal aquifers. In the sea-level aquifers, the yearly recharge replaces abstraction and storage water after dry years. In relative terms, a considerable amount of water flows into the sea from coastal and submarine springs or is lost by diffusion into the sea. For a long-term average, the total recharged water that is not abstracted flows into the sea. As the existence of the freshwater lens also implies an outflow gradient, even in years of subnormal rainfall, freshwater is lost in this way and adds to the water deficiency in the sea level aquifers. The occurrence of this outflow is a prerequisite for the existence of the freshwater lens.

Table 4 presents a holistic groundwater balance for the aquifers in the Maltese Islands. However, all conclusions drawn from the water balances presented here are based on figures that are no more than estimates. A major assumption in this water balance is that groundwater outflow was in the same region as the inflow during the base year. This assumption is based on the fact that the piezometric levels in gauging boreholes in the sea-level aquifers during the last five-year period indicate only mild decreases. This fact led to the choice of the ATIGA coefficient of 0.5 for natural groundwater outflow to the sea as opposed to 0.6 for the BRGM coefficient (which would significantly increase the deficit in the sea-level aquifers).

The groundwater balance is based on an average hydrological year with a precipitation of 550 mm. The evapotranspiration coefficient is taken as 63 percent while the runoff coefficient varies from 2 to 5 percent according to the geomorphological conditions of each aquifer catchment area. The WSC official abstraction figures for the period 2001/02 are used; while the private extraction is based on estimates of the irrigation demand of the agriculture sector activities and of the various industrial and commercial concerns.

TABLE 4
Holistic groundwater balance for the aquifers in the Maltese Islands, base year 2002

Inflow		hm^3/year	Comments
A	Precipitation	174	Based on an average annual rainfall of 550 mm
B	Surface runoff to the sea	24	Based on a variable catchment area runoff coefficient (excluding coastal built up areas)
C	Actual evapotranspiration	105	Assumed as 68% of the total surface water
D	Natural aquifer recharge	45	B and C deducted from A
E	Artificial recharge from leaks	12	Estimated inflow from potable water and sewage network leakages
F	Total groundwater inflow	57	Sum of variables D and E
Outflow			
G	WSC groundwater abstraction	16	Official WSC extraction for hydrological year 2002/03
H	Private groundwater abstraction	15	Estimate based on water demand of various sectors (industry and agriculture)
I	Subsurface discharge to the sea	23	Estimate based on groundwater modelling
J	Total groundwater outflow	54	Sum of variables G, H and I
Balance			
K	Total groundwater inflow	57	Equal to variable F
L	Total groundwater outflow	54	Equal to variable J
M	Balance	3	Inflow (K) less outflow (L)

Source: Malta Resources Authority (2003).

TABLE 5
Water balances of the individual groundwater bodies in the Maltese Islands, base year 2003

Groundwater body code	Groundwater body name	Size (km^2)	Inflow	Outflow (hm^3)	Balance	Major extraction
MT001	Malta Main Mean Sea Level	216.6	34.27	36.65	-2.38	Abstraction for potable and agricultural purposes
MT002	Rabat-Dingli Perched	22.6	4.64	4.62	0.02	Abstraction for agricultural purposes
MT003	Mgarr-Wardija Perched	13.7	2.86	3.46	-0.59	Abstraction for potable and agricultural purposes
MT005	Pwales Coastal	2.8	0.69	0.69	0.00	Abstraction for agricultural purposes;
MT006	Mizieb Mean Sea Level	5.2	1.11	0.96	0.15	Abstraction for potable and agricultural purposes
MT008	Mellieha Perched	4.5	0.75	0.53	0.22	Abstraction for agricultural purposes
MT009	Mellieha Coastal	2.9	0.69	0.38	0.31	Abstraction for agricultural purposes
MT010	Marfa Coastal	5.5	0.89	0.62	0.27	Abstraction for agricultural purposes
MT011	Mqabba-Zurrieq Perched	3.4	0.50	n/a	n/a	Abstraction for agricultural purposes
MT012	Comino Mean Sea Level	2.7	0.52	0.30	0.22	Abstraction for agricultural purposes
MT013	Gozo Mean Sea Level	65.8	8.66	9.78	-1.12	Abstraction for potable and agricultural purposes
MT014	Ghajnsielem Perched	2.7	0.73	0.34	0.39	Abstraction for agricultural purposes
MT015	Nadur Perched	5.0	1.15	0.58	0.57	Abstraction for agricultural purposes
MT016	Xaghra Perched	3.0	0.71	0.33	0.38	Abstraction for agricultural purposes;
MT017	Zebbug Perched	0.4	0.10	0.03	0.07	Abstraction for domestic purposes
MT018	Victoria-Kercem Perched	1.5	0.39	0.14	0.25	Abstraction for domestic purposes

This holistic groundwater balance masks the fact that individual, important aquifers are in imbalance. Therefore, Table 5 presents a breakdown of the calculations on an aquifer-by-aquifer basis. The table shows that the sea-level aquifers are in gross imbalance when compared with the perched aquifers and that the overall positive balance in the holistic representation is being achieved through the combined contribution of the smaller perched aquifers.

Large increases in unconventional water resources are planned. In particular, the WSC is planning to treat all sewage effluent by 2008. If this is achieved and if the effluent is desalinated to the level that it can be used for artificial recharge and a wide range of industrial and agricultural purposes, total annual production of TSE should be about 14 hm^3. Although it is too early to estimate the impacts on the groundwater balance, the TSE may be used to reduce groundwater abstraction or to increase artificial recharge to some aquifers. Figure 13 shows aquifer zones that have already been identified for irrigation using TSE (further details in Chapter 6).

FIGURE 13
Aquifers identified for irrigation with TSE

OUTFLOW OF GROUNDWATER TO THE SEA

A number of groundwater bodies are in lateral and/or vertical contact with seawater. The groundwater in the relevant aquifers is not at rest but flows away more or less horizontally. Part of this lateral flow is recovered by public and private abstractions using galleries and boreholes, while the remaining part continues its outward journey towards the coast to be discharged into the surrounding sea. For a long-term average, the total recharged water that is not extracted is flowing out to the sea. Methods to reduce this loss of groundwater but that do not increase intrusion of seawater should be investigated.

This outflow has been estimated by ATIGA (1972) to account for about 50 percent of the recharge of the sea-level aquifers. Aquifer modelling of the main mean sea-level aquifer by the BRGM has quantified outflow from this aquifer at 30 million m^3/year, or about 60 percent of the recharge. The results of the ATIGA report have been preferred in the water-balance calculations, basically to reflect the mildly decreasing trends in the piezometric head registered in the last ten years. Adopting the BRGM estimates would have led to large imbalances in the sea-level aquifers that would not have mirrored the field results obtained by the WSC monitoring network. However, this issue should be tackled through the construction of a mathematical model of the aquifer. In fact, this is one of the projects being currently undertaken in the implementation process of the WFD.

GROUNDWATER QUALITY

The quality of groundwater in Malta is highly variable with contamination of groundwater by nitrates (Figure 14) and chlorides (Figure 15) being the main quality issues of concern.

FIGURE 14
Nitrate content of groundwater abstracted from the LCL and UCL aquifers

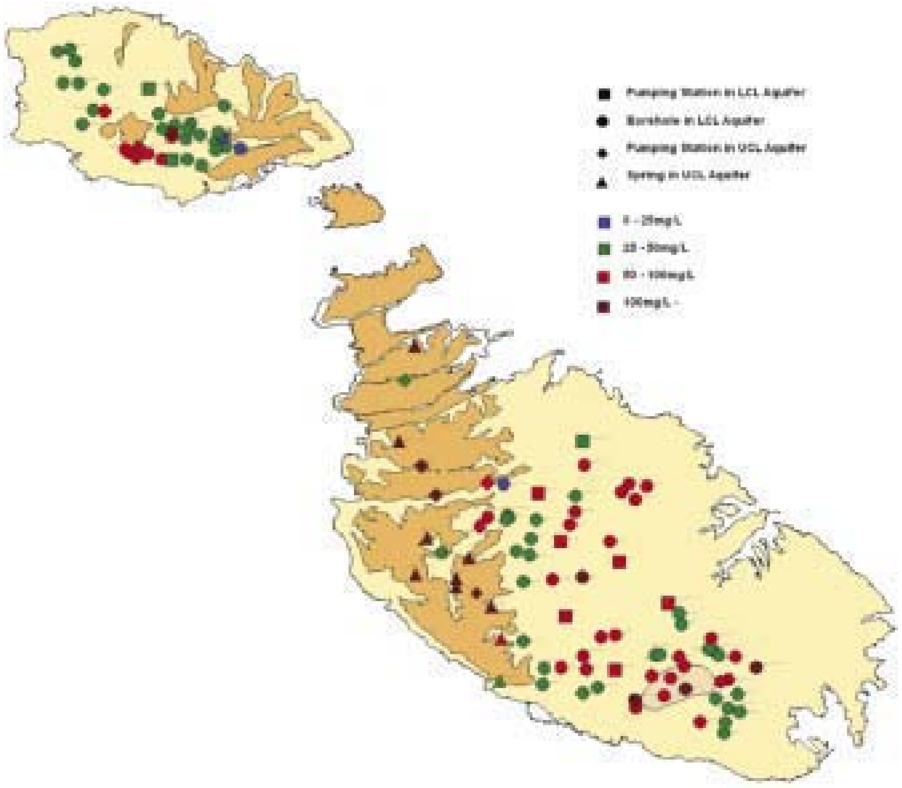
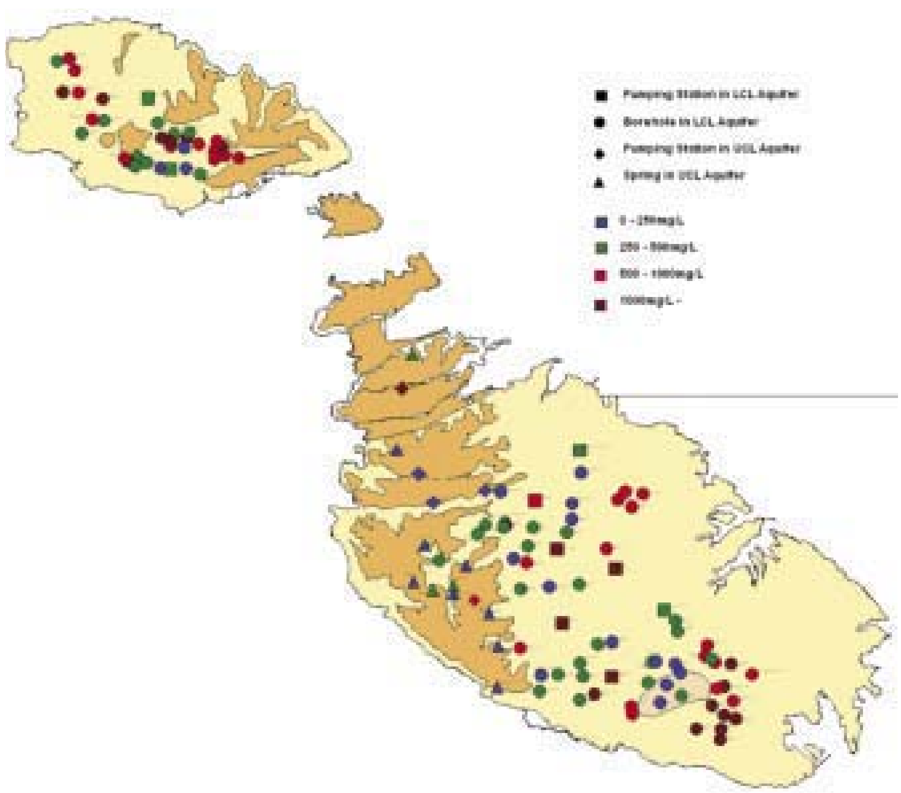


FIGURE 15
Chloride content of groundwater abstracted from the LCL and UCL aquifers



Nitrates occur naturally in the environment and are produced from the decaying of vegetable material in the soil. The natural nitrate level in the mean sea-level aquifer is generally expected to be low. Soil cover in Malta is relatively thin and poor in organic content. Furthermore, there are no naturally occurring formations that contribute towards nitrate content in groundwater. Thus, nitrate contamination in groundwater is largely attributed to anthropogenic activities, e.g.: agricultural practices through the application of nitrogenous fertilizers on arable land; and contamination from human or animal wastes and refuse dump runoff. The movement of these pollutants below the surface is affected by the properties of the underlying strata. Nitrate concentration varies seasonally and by location, with maximum concentrations corresponding to the rainy season (October–March) as a result of the leaching of nitrates in the unsaturated zone. Responses are more direct in the perched aquifers because of the karstic nature of the UCL than in the sea-level aquifers where changes are more subdued.

Groundwater in Malta has generally high levels of chloride concentrations as a result of overextraction of groundwater and seawater intrusion. The situation is further influenced by the large perimeter in comparison to the area of the islands and the karstic nature of the aquifer. Generally, chloride levels in the perched aquifer are significantly lower than the mean sea-level aquifer, and these lower values result from the topographical nature where the aquifer is largely protected from seawater intrusion. However, relatively higher chloride concentrations at the Bingemma and Mizieb pumping stations have occasionally been registered. These are attributed to periods of increased abstraction and they are influenced by seawater intrusion as the top of the confining clay layer lies below the mean sea level.

POTENTIAL IMPACTS OF CLIMATE CHANGE

The sea level of the Mediterranean Sea is expected to rise by up to 96 cm by 2100. This will cause a consequential rise in the freshwater lens. This rise will have a negative effect on the abstraction stations in the sea-level aquifers. This is because these will be more vulnerable to salinization as the degree of saltwater upconing is directly dependent on the distance between the bottom of the well and the freshwater–saltwater interface.

Recent results have shown that in the central regions of the islands, particularly around major pumping stations, the freshwater–seawater interface has reached levels close to the mean sea level. Thus, any relative change in the mean sea level will have more pronounced effects in these regions. In fact, the conductivity logs for the Ta Kandja and Mriehel gauging boreholes (GBHs) show the interface standing at -10 m for the Ta Kandja GBH, located near the Ta' Kandja pumping station and at -80 m for the Mriehel GBH, which is not located particularly close to any pumping station (Figure 16). The state of the aquifer in the Ta Kandja region makes it more prone to adverse effects from sea-level changes.

Annual rainfall is expected to fall by 10–40 percent by 2100 over much of Africa and southeast Spain with smaller but significant changes in other places. The rainfall pattern is also expected to change, resulting in a shorter rainy season with shorter but higher-intensity storms. These two factors are most likely to cause a decrease in the amount of water infiltrating. This situation would affect both aquifer types but would be expected to have a drastic and immediate effect on the perched aquifers where the annual recharge forms a large percentage of the aquifer storage.

In the case of the mean sea-level aquifer, a reduction in precipitation coupled with a sea-level rise would not only cause a diminution of the volume of freshwater available but would also be expected to reduce the groundwater storage capability of the freshwater lens. This is basically because the height of the piezometric head at any point in the island is proportionally dependent on the amount of infiltrating recharge; and the storage capability of the groundwater body for a given set of geological conditions depends exclusively on the hydraulic head.

FIGURE 16
Conductivity logs and relative locations of WSC gauging boreholes

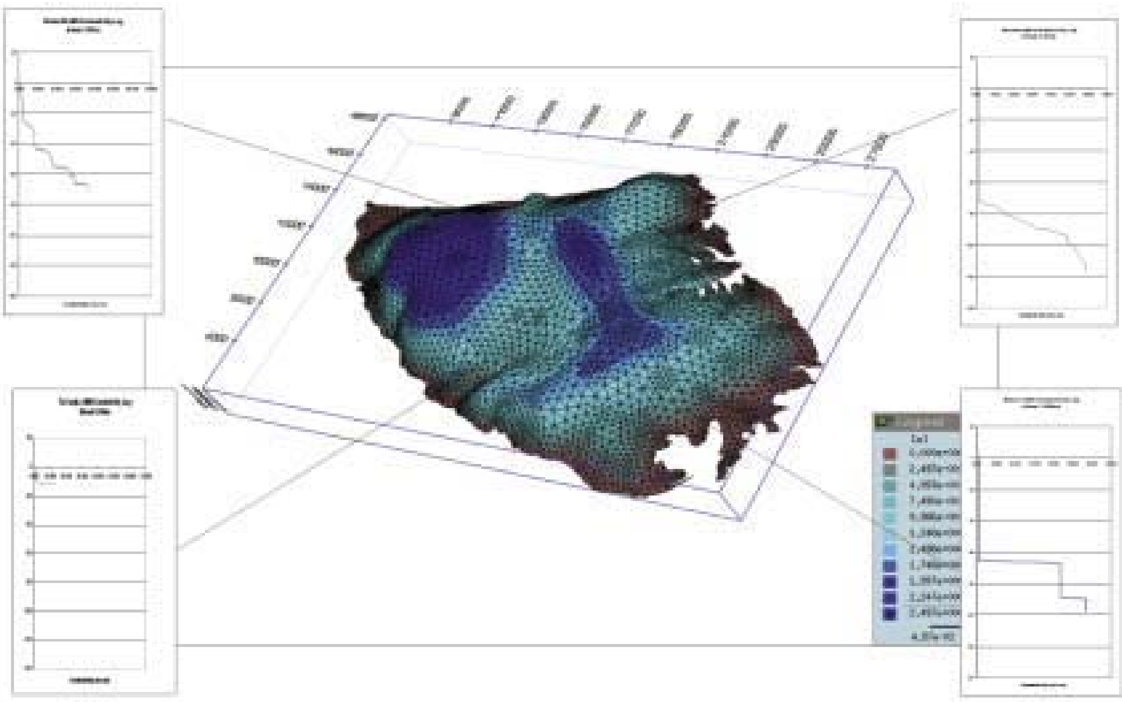
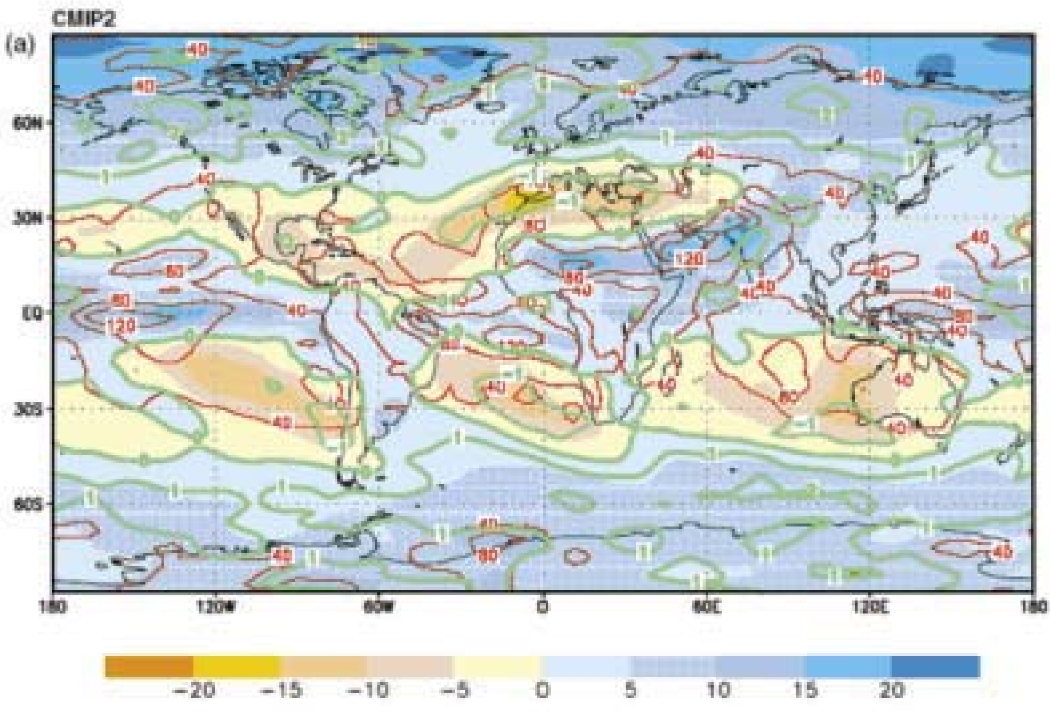


FIGURE 17
Multimodel ensemble: annual mean change in precipitation



Note: Change in precipitation (colour shading); unit percent for the CMIP2 scenarios.

Chapter 6
Water-related infrastructure

WATER PRODUCTION

Figure 18 presents the estimated percentage of water produced in 2003 using various methods. The total volume of water produced in 2003 was an estimated 59 hm^3. The WSC was the single main producer of water in 2003, while the agriculture sector was the main producer of water (or in this case primarily abstractor) in the private sector. The WSC produced slightly more desalinated seawater than groundwater.

URBAN WATER SUPPLY

The two main sources of urban water supply are groundwater and desalinated seawater. The WSC currently does not make use of the perched aquifer springs within the Rabat-Dingli and Mgarr-Wardija groundwater bodies or the Dingli Road pumping station. A number of production sources in the sea-level aquifers have also been discontinued particularly in the northern and southeastern regions of Malta because of high chloride concentrations. Figure 19 shows the location of the public groundwater sources. These include boreholes and pumping stations. The latter consist of horizontal radiating galleries dug in the rock slightly above sea level in order to skim freshwater from the top of the freshwater lenses that constitute the sea-level aquifers.

Private desalination plants are also used primarily as a source of water supply, particularly by users that are charged high tariffs by the WSC (e.g. hotels). In 2003, total private desalination production was estimated to be in excess of 1 hm^3. Rainwater harvesting using cisterns is also a source of urban water supply. In 2003, this was estimated to have a potential capacity of about 2 hm^3.

Figure 19 also shows the location of WSC RO plants that are used to produce desalinated seawater, much of which is blended with groundwater of higher salinity. Care is taken to ensure that the resulting blend has a salinity that is within permissible drinking-water limits. In 2003, the production of desalinated seawater was about 18.9 hm^3 (Table 6). This represents a major reduction in production compared with the mid-1990s. Excess capacity currently exists for the production of desalinated seawater. However, there is insufficient working capacity should all urban water supplies have to be sourced from RO plants.

In 2003/04, desalination contributed about 55 percent of the water supplied to the public distribution system. Currently, the WSC operates three seawater RO plants at Lapsi, Cirkewwa and Pembroke through its subsidiary company Malta Desalination Services Ltd. The RO plant at Marsa, which treats brackish water, is currently not being utilized. Malta has one of the longest and best track records of RO plant operation in the Mediterranean region with high output levels and reliability.

FIGURE 18
Breakdown of estimated water production, 2003

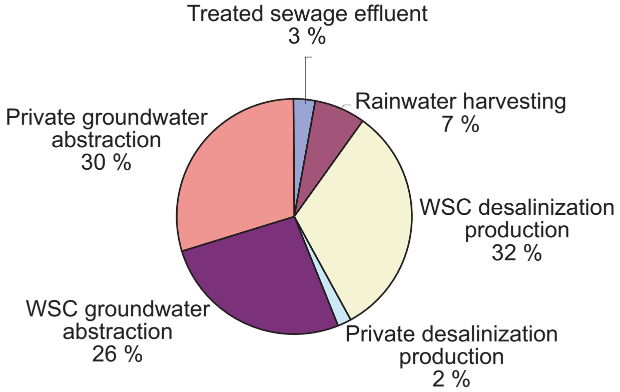
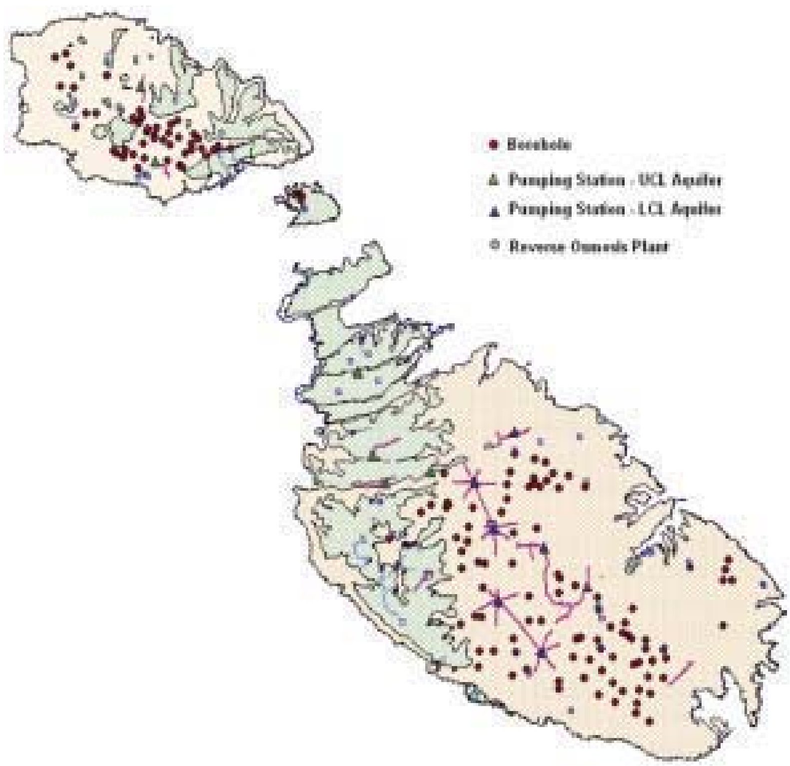


FIGURE 19
Public groundwater production sources in the Maltese Islands



There has been a significant decrease in RO-water production since 1994/95 (Table 6). RO production reached a minimum in 2001/02 largely as a result of water-demand management actions adopted by the WSC. These actions included intensive leakage control, improved management practices and water conservation programmes. This downward trend in production has been reversed with slight increases in RO production in the last three hydrological years. However, this figure must seen in relations to the reduction registered in groundwater abstraction by the same WSC and the stabilization of total annual production at about 33 hm³ in the last four years (Figure 20).

TABLE 6
Desalination production trends

	Lapsi	Cirkewwa	Pembroke	Tigne	Marsa	Total
			(hm³)			
1994/95	7 474 547	5 330 357	14 313 367	4 471 061	1 135 732	32 725 064
1995/96	7 230 901	5 025 538	12 545 201	2 767 145	1 198 332	28 767 117
1996/97	6 184 113	3 744 213	13 348 596	29 431	1 196 526	24 502 879
1997/98	5 717 995	3 777 559	11 753 338	-	1 201 697	22 450 589
1998/99	3 933 032	3 787 597	10 566 473	-	1 113 979	19 401 081
1999/00	3 511 275	3 669 047	10 079 919	-	81 533	17 341 774
2000/01	3 085 585	3 702 376	9 786 928	-	35 185	16 610 074
2001/02	3 482 973	5 981 059	10 360 825	-	-	17 924 857
2002/03	3 829 721	4 046 030	10 352 358	-	-	18 228 109
2003/04	4 250 263	3 706 696	10 945 033	-	-	18 901 992

AGRICULTURAL WATER SUPPLY

The amount of irrigated land amounts to just more than 9 percent of all agricultural land in the Maltese Islands. Most of the irrigated land is found in the UCL regions in the north and west of Malta. Historically, the shallow depth of the perched aquifers and the occurrence of natural springs made water resources for agriculture more easily accessible. However, in the last decade, a large number of "illegal" boreholes have been dug, particularly in the main LCL aquifers. New and more accurate data regarding the extent of irrigated lands are expected to be available with the completion of the agricultural land registration currently being conducted by the Agricultural Department.

Figure 21 shows the location of registered boreholes and springs as registered in the 1997 water-source registration process.

FIGURE 20
Trends in WSC water production

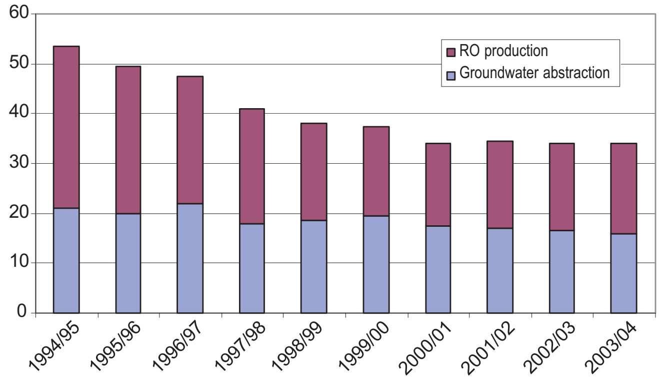
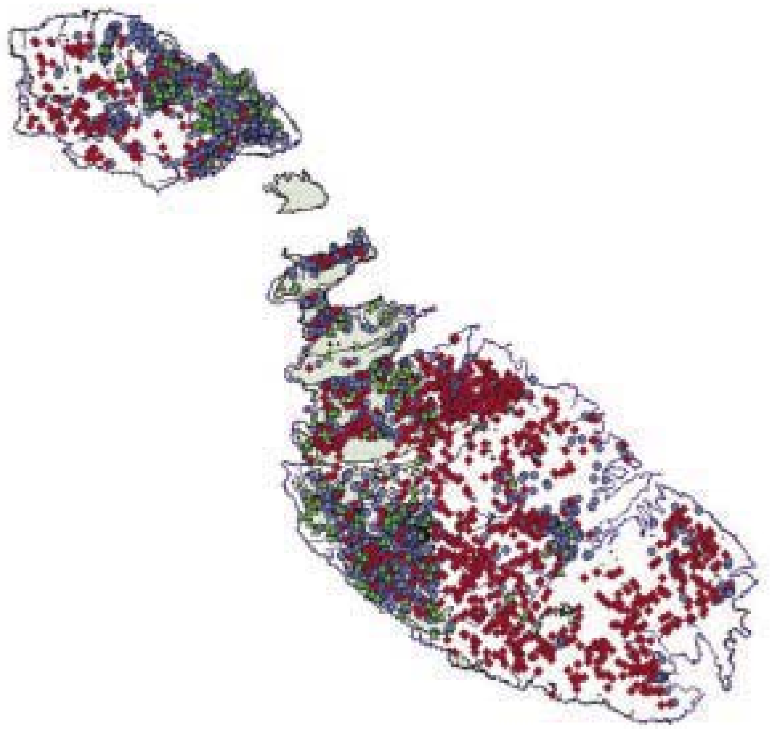


FIGURE 21
Location of registered private water sources in the Maltese Islands



Note: Blue dots – old private boreholes; red dots – new boreholes registered for the first time in 1997; green dots – springs.

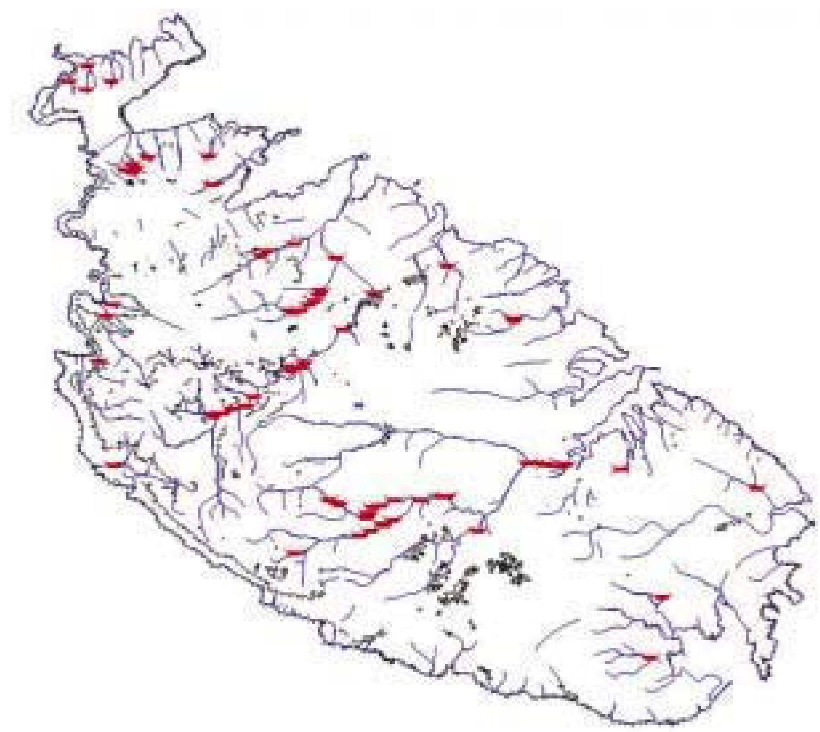
RUNOFF COLLECTION

Historically, responsibility for storm-water management has been shared among a number of government departments/agencies. This arrangement has traditionally led to a fragmentary approach to stormwater management. A stormwater master plan is being prepared by the WSC, which aims to transform existing threats into opportunities by optimizing stormwater use. Most runoff occurs after heavy torrential rain. To retain this storm discharge, 31 small dams have been constructed across the drainage lines (see Figure 22 and Chapter 5). The water collected is mainly used for agriculture and recharging the sea-level aquifers.

Runoff generated from urban areas should also be reduced with the enforcement of legislation concerning the construction of rainwater cisterns. In "old" villages, a large number of private cisterns have a certain influence on the surface runoff. This helps reduce the amount of floodwater currently occurring after heavy rainfalls in built-up areas, particularly in Msida and Marsa. The cisterns also provide a source of second-class water for household use, thereby reducing the load on the public distribution system. It is planned that all major housing projects should also have common runoff-water storage facilities. A 25-m^3 cistern or equivalent in every household would result in the collection of about 4.5 hm^3 of stormwater runoff, which amounts to more than 40 percent of the official billed domestic water consumption. However, this potential figure may be constrained by factors related to creating storage as part of high-density apartment developments.

The total potential surface runoff generated in an average year has been estimated at 30 hm^3 in Malta alone, of which more than 80 percent occurs in the built-up areas. The main drawback facing the harnessing of this resource is the fact that it occurs as large volumes in a comparatively short period.

FIGURE 22
Location of dams in the main watercourses in Malta



In addition to groundwater resources, agriculture also makes use of harvested rainwater. The agricultural census of 2001 registered about 9 000 agricultural cisterns. Preliminary figures place the total rainwater harvesting potential of the agriculture sector at 2 hm^3.

USE OF TREATED SEWAGE EFFLUENT

Currently, 13 percent of the total sewage generated in the Maltese islands is being treated and made available for subsequent reuse by the agriculture and industrial sectors. The situation will change by 2007 as the planned construction of three new sewage treatment plants will result in the production of about a further 38 000 m^3/day. Thus, the total amount of TSE available will be an estimated 14 hm^3/year.

Four agricultural areas were earmarked in a preliminary study carried out by the WSC in 1998 as test sites where TSE can be safely applied for irrigation and the gradual re-instatement of severely depleted aquifers. Land in these localities is considered to be suitable for irrigation with TSE as the aquifers are heavily overpumped, polluted and not used for the abstraction of water intended for drinking purposes. These are the catchment areas of the aquifers at Cirkewwa (310 ha), Qammiegh (184 ha), Pwales (141 ha) and Burmarrad/Maghtab (728 ha), all of which are detached from one another and from the mean sea-level groundwater body south of the Victoria Fault.

Currently, there is only one wastewater treatment plant, located at Sant' Antnin, l/o Zabbar, which was constructed in 1983 (Plate 6). In 1996, this plant was upgraded to a treatment capacity of 17 000 m^3/day of raw sewage. At present, the plant treats an average of 3 500 m^3/day in winter and 10 500 m^3/day in summer; which annually results in more than 3 hm^3 of raw sewage being directed to the plant. Thus, the plant normally operates at 50–65 percent of its capacity. The treatment includes preliminary, primary, secondary and tertiary treatment facilities supplemented with disinfection. The treated waters are used for agriculture (with requirements fluctuating seasonally) and for industry.

The quality of the treated effluent from the plant is as follows: five-day biochemical oxygen demand (BOD_5) ≈ 10 mg/litre; chemical oxygen demand (COD) ≤ 70 mg/litre; ammonia (NH_3^+) ≤ 30 mg/litre; $P–PO_4^{2-}$ < 30 mg/litre; faecal coliforms (FC) ≤ 5 counts/ 100 millilitres; and electrical conductivity (EC) ranges from 7.00 to 15.00 dS/m. The major problem encountered with reusing the effluent produced is its high electrical conductivity. Measurements taken in 1992 indicated that these high values are caused by a number of factors, the most important of which is seawater infiltration through confined parts of the sewerage system, whose occurrence was identified for the Malta North, Marsa Sea and the Zejtun-Zabbar sewers. In addition, the same study concluded that the dumping of brine reject from inland private RO plants into the sewers and the use of seawater for flushing purposes in hotels also contributes significantly to the high salinity of the sewage in the Malta North sewerage system.

The second-class water produced by the plant amounts to an average 2 hm^3/ year. The treated effluent is distributed to agricultural concerns in the Zabbar-Marsascala area and to the Bulebel Industrial Estate. Current estimates indicate agriculture consuming 1.5 hm^3/year of treated effluent with the remaining 0.5 hm^3 being used by

Plate 6
Aerial view of the Sant' Antnin wastewater treatment plant.

industry. Losses in the treated effluent distribution network are very high, reaching peaks of about 90 percent, with theft of water being a major concern in the area.

The current plans for future sewage and wastewater treatment envisage a centralized approach, with one new treatment plant planned for the southern region of Malta. This plant will be operational by mid-2007 and will have a capacity to treat up to 58 000 m^3 of effluent per day (based on 2020 projections and assuming the decommissioning of the Sant' Antnin plant). It is likely that this wastewater treatment plant will not be sufficiently advanced to produce effluent for reuse for agricultural purposes and/or artificial recharge of groundwater in aquifer zones utilized for the abstraction of groundwater for potable purposes. Other treatment plants are planned by the end of 2006 for ic-Cumnija (capacity: 6 700 m^3/day) and Ras il-Hobz, Gozo (capacity: 6 000 m^3/day). These two relatively small plants are intended to produce water mainly for agricultural use.

PRIVATE AND COMMERCIAL BOREHOLES AND RO PLANTS

In recent years, there has been a large increase in the construction of private boreholes for commercial use or for leisure-related activities such as filling swimming pools. In some cases, small RO plants have been purchased and are being used to desalinate the pumped groundwater. However, accurate information on this infrastructure does not exist.

PIPE NETWORK

The water distribution network operated by the WSC consists of more than 2 500 km of pipework of varying material and sizes. The network includes transfer mains linking sources to reservoirs, intrareservoir connections and distribution mains with trunk mains and reticulation mains. There are also a further 1 700 km of service pipework serving about 220 000 accounts. Extensive development has been carried out by the WSC on the distribution system in recent years, mainly as part of the drive to curb water leakages. However, in 2002 the network still comprised more than 1 000 km of cast-iron or galvanized pipes with no internal lining. These pipes are contributing to an increase in the concentration of corrosion products, resulting in water discoloration. Also contributing to the same problem are the old galvanized iron service connections.

Currently there is no network infrastructure for the distribution of second-class water, apart from the limited network in the southeastern regions of Malta used for the distribution of treated effluent produced in the Sant' Antnin treatment plant (Figure 23).

DELIVERY SYSTEM LOSSES

The control of water losses in the national water distribution system plays a vital role in the operations of the WSC, particularly as these represent a substantial loss of revenue in real terms. Real losses consist of all forms of leakage within the network, such as service-pipe leakage, leakage on fittings, reservoirs, trunk/transfer/street mains, etc. Any leakage downstream of a production source and upstream of the consumer revenue meter is termed a real loss (Rizzo, 2000). The management of water losses includes both real water losses, more commonly known as water leakages, and apparent water losses, which represent any water consumed but not paid for, such as water theft, metering errors and billing anomalies (Figure 24).

Leakage control (comprising active leakage localization, leakage repair, pressure control and network infrastructure management) is considered to be a major contributor towards a reduced national system demand. The WSC distribution network has been segmented and rationalized into hydraulic zones. Water balances have been developed, and studies of flows and minimum night flows in areas, system rationalization and establishment of more than 300 hydraulic zones have been carried

FIGURE 23
WSC infrastructure

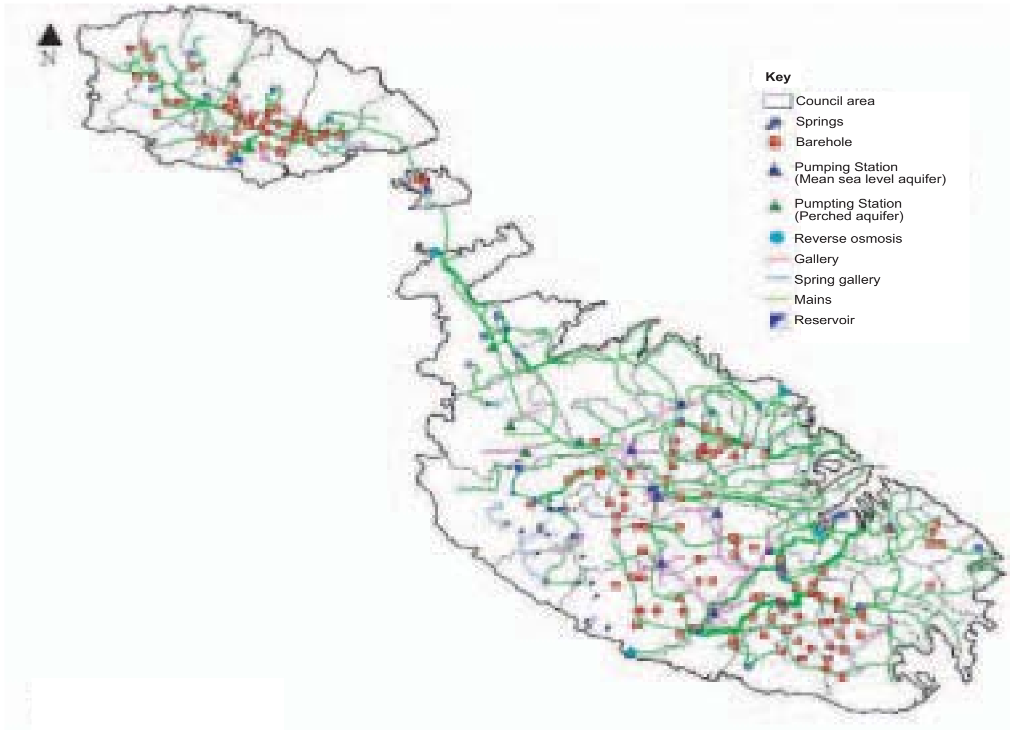
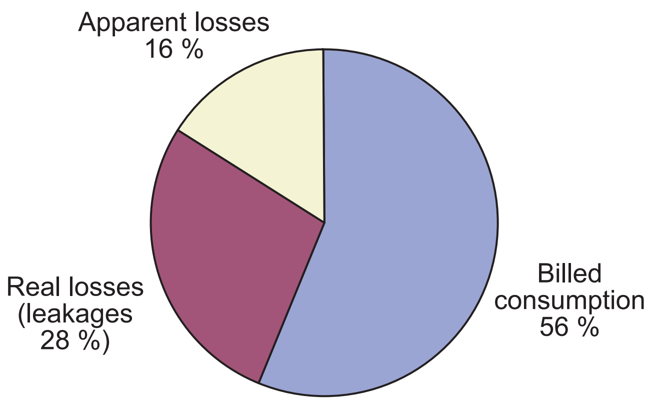


FIGURE 24
Billed water consumption and losses in the public distribution system, 2003

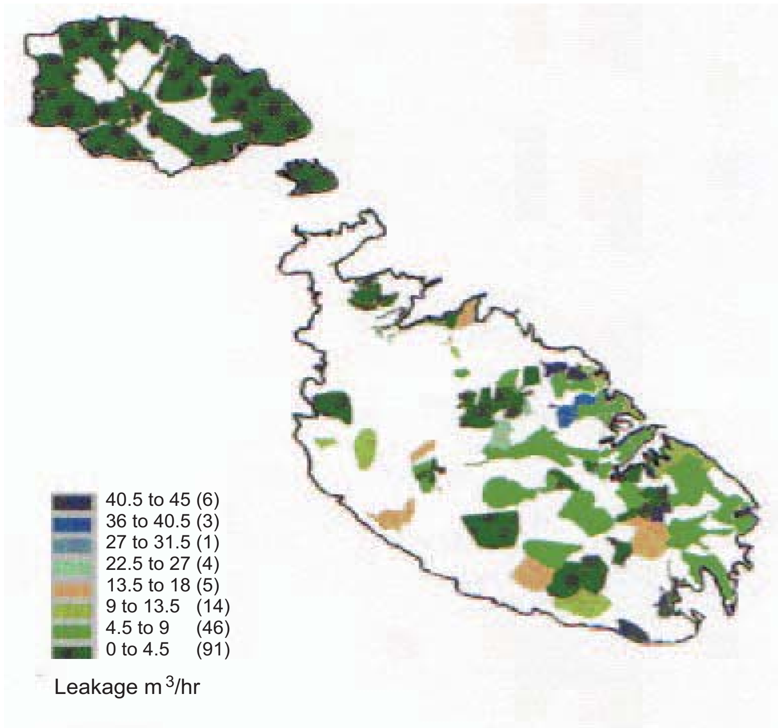


out. Furthermore, high-leakage zones have been further subdivided into step-testable areas, and data logging of zone inlets permits computation of accurate leakage figures. Comprehensive and pilot leakage studies and trials carried out successfully by the WSC in Gozo achieved an infrastructure leakage index (ILI) of 1.5. High-pressure zones in the distribution system caused by improper system design and network conditions are being eliminated through automated pressure control. Existing methodologies for estimating and operating within economic leakage levels are also being refined by the WSC.

It has been estimated that leakage has been reduced over the whole distribution system from 2 692 m^3/hour (19.0 m^3/km/day) in 1995 to about 900 m^3/hour by July 2004. The unavoidable annual loss of the distribution system is estimated to be 300 m^3/hour, and the WSC plans to reach this target by 2010.

The ILI levels for the distribution networks in Malta and Gozo, reported in the WSC annual report as at July 2004 are 3.6 and 1.5 respectively (Figure 25). These ILI levels represent a total leakage loss of 9.6 hm^3 (1 100 m^3/hour), which represents about 28 percent of the total WSC water production.

FIGURE 25
Map of the leakage zone clusters in the Maltese Islands indicating relative leakage levels



Source: WSC (1999).

The term apparent losses refers to the three principal sources of unaccounted-for water that is consumed but not billed successfully (Rizzo, 2000). For this reason, these components are not considered as a “real loss” (as is leakage) but an “apparent loss”. These components are:

- Metering errors: This component can be further subdivided into two categories: (i) revenue-meter underregistration resulting in a lower than actual computation of consumer water usage; and (ii) production-meter overregistration, resulting in a higher than actual computation of system demand.
- Water theft: This consists of the illegal or unauthorized usage of water taken from the system.
- Billing anomalies: These include a multitude of factors that contribute to a distorted picture of legitimate consumer usage stemming from the ineffectiveness of the water utility’s billing system.

Over the years, the WSC has sought to reduce the apparent losses through a number of measures. An ongoing programme by the WSC aims to replace old Class C meters with Class D meters. By 2001, more than 115 000 Class D meters had been installed. Results showed (WSC, 1997) that, for 1996, consumption through Class C meters was an average of 18 percent less than Class D meters. The WSC is also in the process of upgrading its meter-reading section with the extension of an on-site meter reading system, which was launched in 2003.

One of the problems facing the WSC regards the estimation of consumption made whenever meter readings are not available. Reasons for the unavailability of readings include closed premises and non-functioning meters. Estimates accounted for about 15 percent of billed volume in 2000/01. Meter accessibility varies from a low of 64 percent in domestic garages to a high of 88 percent in “social assistance” households.

Table 7 gives details regarding the levels of meter accessibility as at 2000/01.

TABLE 7
Ratio of meters read to total, Cycle 1, 2001/02

Consumer type		Number of invoices	Meters read "OK" or not in use	Percentage read
Domestic	Residential	158 561	132 849	84
	Social assistance	11 939	10 516	88
	Other	14 843	9 520	64
Industrial		1 046	875	84
Farms		1 817	1 430	79
Tourist		1 975	1 509	76
Government		1 909	1 585	83
Commercial	Bars and restaurants	1 577	1 214	77
	Others	16 073	11 831	74
Other		541	405	75

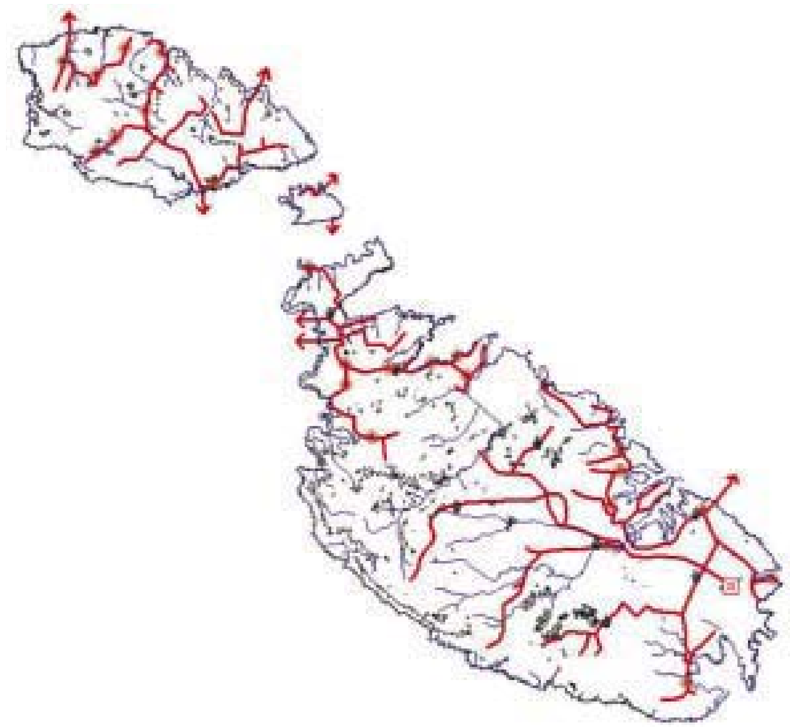
SEWAGE AND SEWERAGE

The sewerage system in Malta collects domestic and industrial wastes as well as a certain unquantified amount of stormwater runoff. The system is made up of about 1 050 km of gravity mains and includes 125 km of galleries, 45 km of pressure mains and 82 pumping stations. Basically, it comprises two main networks, commonly called Marsa Land and Marsa Sea, and three subsidiary networks: Malta North, Malta South, and Gozo (Figure 26). The two main networks service the southeastern and central parts of the island and converge at the Marsa sewage pumping station, from where sewage is pumped to the submarine outfall at Wied Ghammieq, and the sewage treatment plant at Sant' Antnin.

There are currently two main outfalls in Malta (Wied Ghammieq and Cumnija) and one in Gozo (Ras il-Hobz). Other minor outfalls are present but their discharge rates are much less. They include Anchor Bay (Malta) and Wied Mielah and San Blas (Gozo). No direct measurements are kept for the discharge rates from these outfalls. However, discharge rates are generally estimated on the basis of water consumption.

The Wied Ghammieq outfall is located on the southeast coast of Malta and discharges raw sewage at an average rate of 33 000 m^3/day (about 12 million m^3/year). This flow

FIGURE 26
Main sewer network and outfalls



is made up of the contributions of Marsa Land, Marsa Sea and Malta South, less the flow which is conveyed to the Sant' Antnin sewage treatment plant. Wastewater from the northern region of Malta is conveyed mainly to the outfall at ic-Cumnija, with a small fraction conveyed also to the Anchor Bay outfall. Both stations are located on the west coast of Malta, in the Mellieha region. The estimated average discharge rates at ic-Cumnija for 2000 were about 4 000 m^3/day. Therefore, on an annual basis, the Cumnija outfall discharges about 1.5 hm^3 of sewage.

In Gozo, almost 85 percent of all wastewater is discharged through a submarine outfall at Ras il-Hobz. Another two outfalls are located on the north coast of Gozo at Wied Mielah and San Blas. These outfalls discharge minor quantities of wastewater. The total wastewater generated in Gozo is estimated at 5 500 m^3/day, or an annual total slightly exceeding 2 hm^3.

Estimates for the total amount of wastewater discharged into the marine environment for 2000 indicate an annual volume of about 19 hm^3 (52 000 m^3/day). These figures indicate a substantial reduction in the discharge of sewage from the estimated 23 hm^3 produced in the early 1990s. This reduction is mainly attributed to the reduction in water consumption.

Although the sewerage network covers most of the Maltese Islands, there are still about 1 000 households that are not connected to the main network. Instead, they are linked to cesspits that are emptied weekly at authorized discharge points. To these, small villages (such as Bahrija and Bidnija) served by communal cesspits must be added. It is estimated that about 98 percent of all the wastewater is collected. Cesspits are also found on animal-rearing facilities. These are regularly emptied into the public network.

The sewerage collection and treatment system is being upgraded to meet the requirements of EU Directive 271/91. By 2007, it is expected that all domestic and industrial wastewater will be treated to a secondary level, and the treated effluent will be either discharged to the marine environment through submarine outfalls or reclaimed and reused. However, the subsequent use of treated effluent depends on: the real and perceived health considerations; the cost of production, storage and distribution; and the quality of the water produced.

ASSETS AND ASSET MANAGEMENT PLANS

The WSC currently operates 131 groundwater abstraction boreholes, 13 pumping stations and 3 RO plants, which are supplied through 76 sea-wells. The WSC also operates a groundwater polishing plant at Ta Cenc, Gozo, with the capacity to treat 4 000 m^3/day. Apart from these, the WSC also administers a number of water sources that are currently not being used for production purposes. These include 4 pumping stations (Via Dingli, Wied Dalam, Mgarr and Wied is-Sewda), 26 springs, 256 boreholes and a brackish water RO plant at Marsa together with 10 associated sea-wells. To these, one must add the water distribution network with all the associated reservoirs. These facilities are regularly maintained by the Groundwater Operations Unit of the WSC.

As from October 2003, the WSC also assumed ownership of wastewater collection, disposal and treatment facilities, which include the wastewater collection/disposal network and relevant pumping station as well as the wastewater treatment plant at Sant' Antnin.

However, the WSC does not possess a comprehensive asset management plan; although regular maintenance/upgrading of facilities are undertaken. It is planned to develop such a management plan under the licence proposed by the MRA.

SERVICE-LEVEL AGREEMENTS

The WSC currently possesses no formal service-level agreements, but the licence proposed by the MRA to the WSC envisages the development of such standards. The

WSC is also in the process of preparing its customer service charter. The charter will eventually contain a list of corporation and client responsibilities as well as the basic level of service customers should expect from the WSC.

The building blocks of this charter can be established from the vision of the WSC as outlined in its latest Annual Report:

"A number of customer-first measures have been introduced, which are regularly reviewed to ensure long-term improvement. The established code of the WSC sets out precise service-delivery standards. The areas covered in the code are:

- customer friendly, customer care set-up;
- response time and style to written enquiries;
- arranging appointments;
- meter reading and billing organization;
- response time to flooding from the water/wastewater service and other leaks;
- response time to requests for new services;
- planned and unplanned interruptions to the water supply and wastewater disposal;
- level of service – water pressure;
- commitment to improve the quality of water;
- commitment to an ambitious leakage control programme."

This vision is further defined in the current strategic plan of the WSC, where the customer service objectives are outlined. The strategic plan indicates a number of initiatives that are being implemented with the aim of improving the efficiency and effectiveness of the WSC. Among these initiatives are the following actions:

- bringing the quality of water up to the highest standards required by the EU directives;
- continual monitoring;
- implementing works to improve the system to ensure quality potable water to all parts of the Maltese Islands (Figure 27);
- implementing works to improve the system to ensure the safe disposal of wastewater in all parts of the Maltese Islands, with minimum impact on the environment;
- keeping the customer informed about intended projects and problems that might affect the supply of quality water.

An analysis of the service levels of the WSC was last performed in 2001. From this study, two main indicators were identified for monitoring service-level trends: (i) access to safe drinking-water; and (ii) share of distributed water not conforming to quality standards.

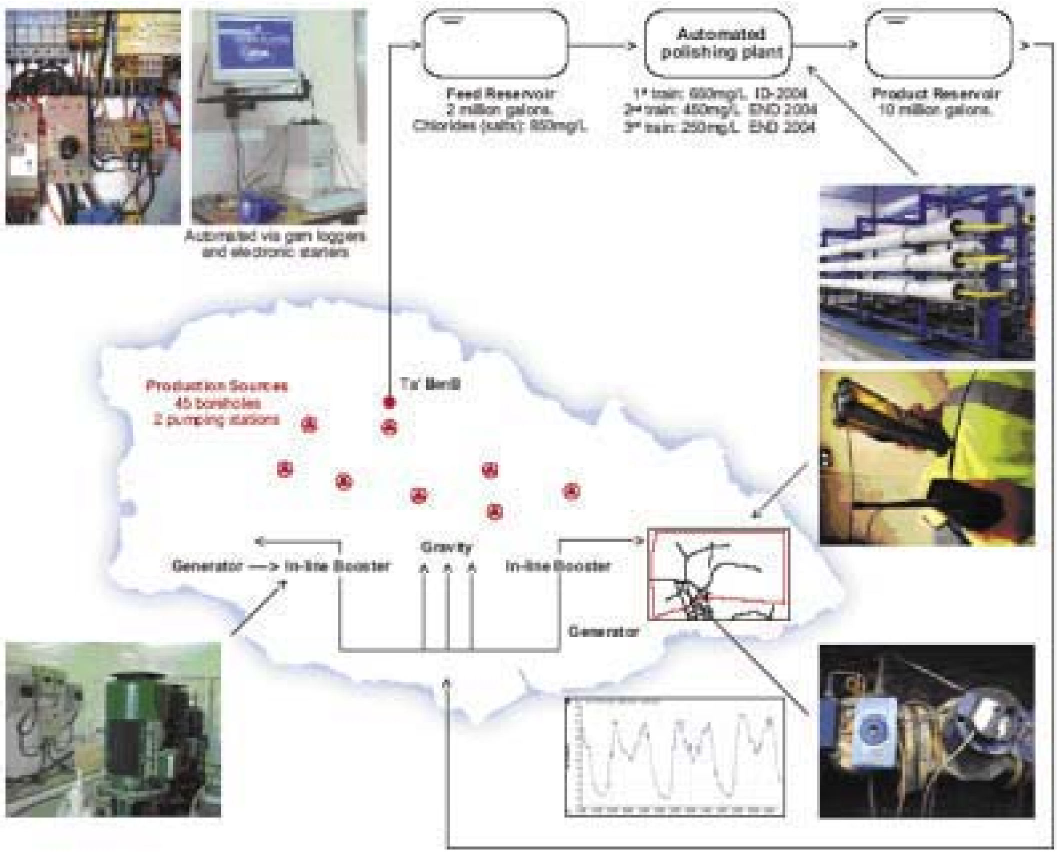
The first indicator represents the proportion of the population with access to safe drinking-water (more than 20 litres/day/person), and it is expressed as a percentage: access to safe drinking-water (2000/02) = 100 percent.

The second indicator represents the quality of drinking-water supplied at the consumer's tap in accordance with the EU drinking-water quality directive 98/83/EC. It is further subdivided into three components to account for the different categories defined by the same directive, i.e. microbiological parameters, mandatory chemical parameters, and indicator chemical parameters. The percentage of water supplied at consumer's tap in 2000/01 not in accordance with drinking-water quality standards was as follows:

- microbiological parameters: 6.2 percent;
- mandatory chemical parameters (EU Directive 98/83/EC Part B): 1.3 percent;
- indicator chemical parameters (EU Directive 98/83/EC Part C): 23.8 percent.

The WSC has also recently invested heavily in order to achieve a better quality for the water supplied through its network. These investments include the construction of a water-collection system and a "polishing" plant in Gozo in order to decrease saline

FIGURE 27
Measures to improve potable water quality in Gozo



Source: WSC (2004).

content in potable water as well as the implementation of a nitrate reduction programme in Malta. These programmes are intended to align potable water production with the EU Drinking Water Directive by the end of 2005, as negotiated in the EU accession agreement, as well as attain the indicative concentrations for chlorides by the end of 2007.

EMERGENCY PLANNING

A contingency plan is envisaged under the WSC licence. At present:

- On average, 250 000 m^3 and 48 000 m^3 of water are stored in first-class storage reservoirs in Malta and Gozo, respectively. This approximates to a reserve supply for an estimated 2.7 days for the Maltese Islands.
- The RO plants are all operating well below full capacity.