Malta Tourism Authority

Ix-Xaghra l-Hamra Golf Course, Mellieha Malta

Technical Appendix 6: Geo-environmental Baseline Studies

Supporting Document for
Environmental Impact Statement

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On behalf of
Adi Associates

September 2005

Geo-environmental Baseline Studies

Proposed Golf Course and Supporting Facilities

Ix-Xaghra l-Hamra and Tal-Qortin, l/o Mellieha

Report for:

Malta Tourism Authority
Auberge D'Italie
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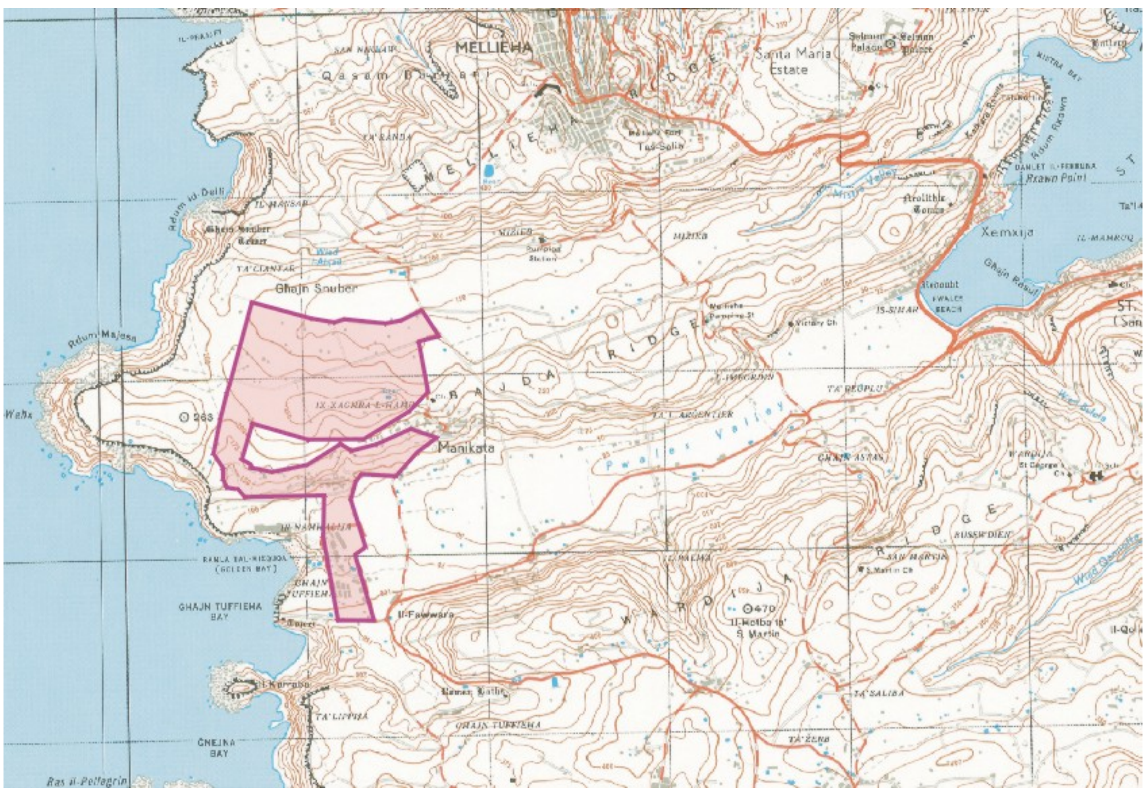
1. INTRODUCTION

BACKGROUND

1.1. The Government of Malta intends to seek planning permission for the development of a golf course in the vicinity of Golden Bay and Manikata, in an area known as Ix-Xaghra l-Hamra and Tal-Qortin in the limits of Mellieha. The project has been proposed by the Malta Tourism Authority (MTA) on behalf of the Government of Malta, which has been requested by the Malta Environment and Planning Authority (MEPA) to prepare an Environmental Impact Statement (EIS) as required by Legal Notice 204 of 2001.

Figure 1: Site Location



1.2. The scope of the EIS is to determine the current state of the environment in the area affected by the development and the likely effects thereon of the construction and operation of an eighteen-hole championship golf course and ancillary uses.

1.3. This report represents the geo-environmental baseline input to the EIS.

TERMS OF REFERENCE

2.0 DESCRIPTION OF THE SITE AND ITS SURROUNDINGS

This description is identified by the area of influence for each relevant parameter. The area of influence for each parameter shall be determined by the consultant who shall also justify the extent of the chosen sphere of influence. This must be approved by the Malta Environment and Planning Authority prior to commencement of the EIA. This description should include:

2.4 Geology, geomorphology, palaeontology, hydrogeology, and hydrology (With an emphasis on any special features or protected areas).

This should include a survey and characterisation of the sites' geology, geomorphology and soils, palaeontology and the site's hydrogeological conditions including fracture density and mapping of major discontinuities. Details, baseline surveys, and characterisation of sites' hydrological conditions should also be provided. Baseline surveys on characteristics of aquifers including aquifer properties, thickness of the unsaturated zone, depth to the permanent water table, sources of recharge of groundwater, pumping and abstraction, groundwater quality modelling of ground water flow identifying gradients within at least 500m radius of the site's boundaries, hydraulic conductivity of the lithological beds underlying the areas within at least 500m radius of the site's boundaries in the unsaturated and saturated zones; characteristics of watercourses (within at least 500m radius of the site's boundaries) including sediment and sedimentation, flood patterns, other discharges and withdrawals, water quality; catchment areas and drainage patterns, run-off including volume and route taken by run-off, dilution capacity, dispersion characteristics and established groundwater protection zones including proximity to water catchment areas particularly those used for drinking water and irrigation and proximity to groundwater abstraction sources, wells, springs etc. (all abstraction sources within at least 500m of the site shall be identified); estimates over the past 5 year period of groundwater quantities abstracted and use of abstracted water from sources identified should be carried out. Seasonal variations must be identified. Background quality levels of natural water resources are to be recorded as described in EU Directive 80/68/EEC (Ground water Directive) and as guided by the Water Directorate within the Malta Resources Authority and the Water Services Corporation. Details of hydroclimatological conditions of the site including prevailing conditions relating to rainfall and actual evapotranspiration rates. Water balance models for the site and its surroundings

5.4 Effects on soil, geological features and hydrology

This should assess palaeontological, geomorphologic, and physiographic aspects. The assessment of significance of impacts (positive and negative) should also include soil and coastal erosion, slope stability / instability, impacts on aquifers and water resources with particular reference to fracture characteristics, permanent and/or temporary changes to the hydrologic regime of watercourses which may traverse the site, permanent and/or temporary changes to the underlying groundwater bodies and their recharge; pollution of run-off and watercourses, permanent and/or temporary alterations to the morphology of the site and its surroundings. If the impact assessment predicts potential hazards like slope instability or subsidence a risk assessment should be carried out.

A water resource vulnerability study of the area is required (area of influence to be agreed with the MEPA) This should include a risk assessment identifying and quantifying short, medium and long-term risks on hydrological resources. Impacts on the aquifer/s, springs, drainage patterns (which are to be linked to possible modification of the morphology of the site), wells, channels, run-off and valley hydrology should be assessed. The impact of surface water runoff on downstream areas should also be assessed.

Assessment and detailed contaminant transport modelling of pollutants in groundwater resulting from the irrigation and fertilisation of the golf course is required.

An assessment of impacts on the water supply infrastructure by this proposal shall be provided

The risk assessment should help to identify and describe engineering and management controls for management/reduction of the risks and outline any limitations in these control measures. The assessment should also address the long-term viability of pollution control measures during the operation of the proposed golf course.

Should treated effluent be used for irrigation the short and long term impacts that such use would have on the quality of water resources should be assessed.

In terms of water pollution, the:

- *Type, concentration and frequency of any discharge; and*
- *The effects the above will have on the aquatic ecology, other flora and fauna and huans, visual amenity, landscape, recreation, etc., should be included.*

Pollution levels may be assessed by measuring the following parameters:

- *BOD and COD'*
- *Suspended solids,*
- *Salinity,*
- *Trace pollutants including heavy metals etc.*

Effects on soil should not be limited to the top and subsoil, but should include underlying drift deposits and, in some circumstances, solid geology. A description of the physical and chemical effects on the soil should be included.

Note on ToR

1.4. It is noted that the ToR require the Geo-environmental Studies address matters such as a) fracture density and mapping of major discontinuities, b) modelling of ground water flow identifying gradients within at least 500m radius of the site's boundaries, c) dilution capacity, dispersion characteristics and established groundwater protection zones including proximity to water catchment areas particularly those used for drinking water and irrigation and proximity to groundwater abstraction sources, wells, springs etc. (all abstraction sources within at least 500m of the site shall be identified); d) estimates over the past 5 year period of groundwater quantities abstracted and use of abstracted water from sources identified should be carried out. e) Seasonal variations must be identified. f)A water resource vulnerability study of the area is required (area of influence to be agreed with the MEPA) This should include a risk assessment identifying and quantifying short, medium and long-term risks on hydrological resources. g) Assessment and detailed contaminant transport modelling of pollutants in groundwater resulting from the irrigation and fertilisation of the golf course is required.

1.5. Since the data required to address for such matters are not available, and cannot be acquired within the requisite timeframe of at a reasonable cost, it has been agreed with MRA and MRAE[1] that it would be appropriate to assume a 'worst case scenario' whereby the beds underlying the proposed site for the golf course are totally permeable, such that what ever leachate passes through the turfgrass sward will find its way to the aquifer beneath. In order to ascertain the effects of the potential of nitrates, the Consultants developed a mathematical model to determine the mass balance nitrate Impact of the golf course.

[1] Meeting November 2005: re Working Paper No 2: Proposed Drainage System and Geotextile Membrane (McMillan Shiels, Hawtree Ltd and Adi Associates Environmental Consultants Ltd)

Competence of Surveyor

1.6. The Geo-environmental study was carried out by Dr Saviour Scerri, as approved by MEPA.

SCOPE OF THE REPORT

Baseline Surveys and Studies

1.7. The scope of this report is outlined in the Terms of Reference provided by MEPA. They require the following baseline surveys and studies:

- Literature search to identify past studies undertaken within or in the region of the site, particularly those concerning the hydrology and hydrogeology of the Mizieb Basin, Bajda Ridge, Pwales Valley, and Wardija Ridge;
- A baseline geological survey to identify and describe geological, palaeontological, and geomorphological features, including soils, on or close to the site, and an assessment of their scientific importance. The Area of Survey for the geo-environmental study extended out of the site to cover the catchment basins of the watercourses crossing the site.
- A baseline hydrological/hydrogeological survey to identify and describe the following features: aquifers, watercourses, springs, wells, water channels, cisterns, catchment areas, surface run-off, recharge, evapo-transpiration, and any other features apparent on or close to the site to cover the catchment basins of the watercourses crossing it;
- A baseline survey of the drainage potential of the site. This comprises the delineation of the full catchment upstream of the site and the estimation of its run-off characteristics. The study of the drainage potential covered the site as well as the entire watershed upstream;
- An assessment of the seasonal variations in run-off based on available data on monthly rainfall percentage, run-off percentage percolation, and percentage evapo-transpiration;
- Field study and literature search on available well data to identify aquifers present on site, including aquifer properties, thickness of the unsaturated zone, depth to permanent water table, sources of recharge of groundwater, pumping abstraction, and groundwater quality;
- Collection of background quality levels of natural water resources according to EU Directive 80/68/EEC (groundwater directive) available at the Water Directorate of the Malta Resources Authority, and at the Water Services Corporation;

- An assessment of the impact of the project on the geology, palaeontology, geomorphology, hydrology, and hydrogeology, and in particular on the widespread limestone pavements (Xaghra) that cover most of the site; and

- Description of mitigation measures to be designed to minimise any adverse impacts and enhance the geology, palaeontology, geomorphology, and hydrology/hydrogeology of the site, including water quality.

PREVIOUS WORK

1.8. The site of the proposed golf course forms part of an extensive study of the Upper Coralline Limestone and underlying perched aquifer undertaken by Costain, 1958. The work included the drilling of stratigraphic wells down to the perched aquifer to identify the depth to the perched aquifer, its height above the Blue Clay and the quantity of water it contained.

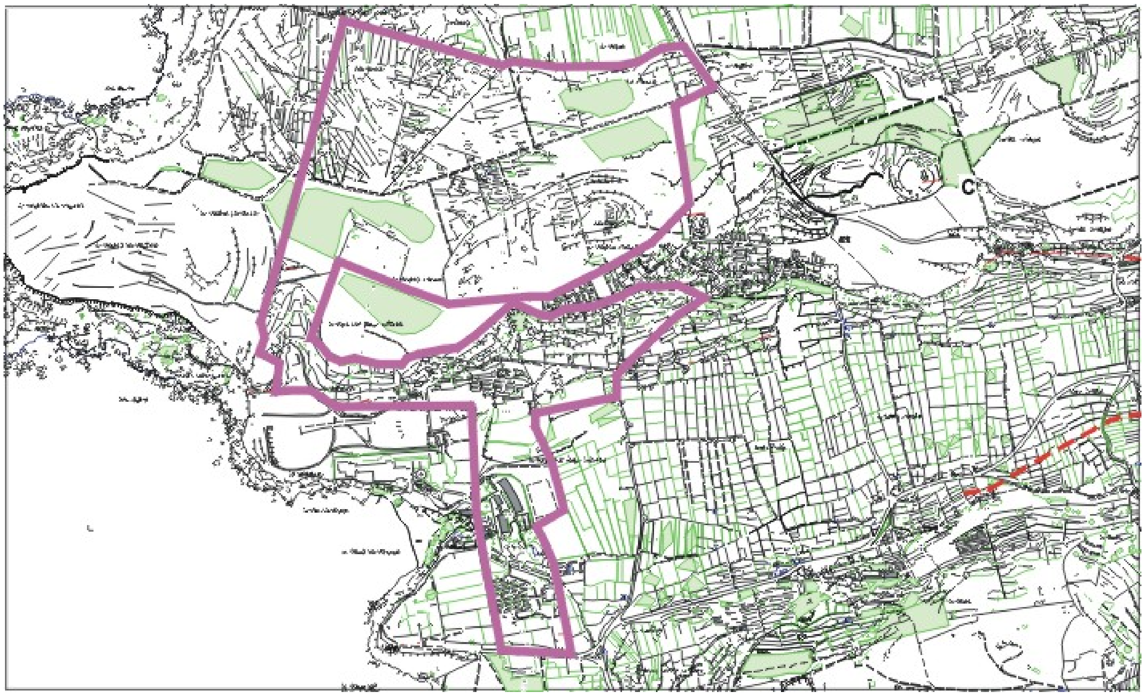
1.9. In 1997, Malta University Services Ltd was commissioned by the GAIA Foundation to undertake a geo-environmental study of the Ghajn Tuffieha coastal area extending from Il-Qarraba to Ras il-Wahx.

1.10. In 2001, the writer carried out a survey of the Golden Sands Bay area in connection with the Environmental Impact Assessment for the Golden Sands Hotel Redevelopment Project. This report focused on the geology, hydrogeology and the impact of the new development on the stability of the cliff line that bounded the hotel footprint to the south. The geo-environmental baseline survey work included a subsurface geological investigation, which consisted of the drilling of five holes with continuous core sample recovery and a fracture survey of the cliff face.

1.11 The Project was primarily a redevelopment of the previous hotel with a slight increase in the built footprint. It lies very close to the cliff and had a limited hydrological catchment outside the boundary wall of the site. For this reason impacts on the geo-environment were mostly confined to the site. There were no apparent impacts on the stability of the cliff face or on the stability of the foundations of the new development.

DESCRIPTION OF THE SITE

Figure 2: Site plan



1.12. The major part of the site is a trapezium- shaped plot of land measuring approximately 100m by 700m, having an area of 105.8Ha, located at Ix-Xaghra l-Hamra and Tal-Qortin on the western extension of Bajda Ridge. It ranges in altitude from 45m to 85m above sea level. The site extends marginally into the Mizieb Basin in the north and a 200m-wide corridor in the westernmost segment of the Pwales valley in the south extends from Ghajn Tuffieha Camp to Ta' Lippija.

1.13. As the toponym '*Xaghra*', common within and around the site suggests, the proposed golf course lies prominently on bare Tal-Pitkal Member of the Upper Coralline Limestone Formation. This rock unit weathers mainly by solution, yielding a residue of terra rossa, thus explaining the barren nature of the terrain of mainly limestone pavement dissected by rock pools (kamenitzas), karren, and other small-scale limestone features, which at times change into a stony pavement, depending on the lithological nature of the underlying substrate. The rock is intensely karstified and is highly permeable. Drainage is mostly subsurface.

1.14. The main hydrologic feature in the area is the Mizieb perched aquifer lying within the upper coralline rock overlying the on Blue Clay bed.

1.15. The main geomorphological features in the locality are the western extensions of the Mizieb Basin, Bajda ridge, and Pwales valley. To the west and east they are dominated by the Wardija and Mellieha ridge respectively. Sheer cliffs run parallel to the eastern and southern margins of the site at a distance of 200 to 330m.

Users

1.16. The terrain at the site, particularly that forming part of the western extension of Bajda Ridge, is predominantly bare limestone with soil developed only in scattered tiny pockets. The main use of the site is for bird trapping as can be noted from the frequent bird traps and bird hides. Some terracing can be noted on the eastern slopes of Bajda ridge but the fields lie outside the proposed site. The narrow corridor extending into Pwales Valley was originally a British Services Military Camp; it is now partly occupied by the newly redeveloped Golden Sands Hotel, the new Scouts Camping Site, agricultural land uses, and the former Ghajn Tuffieha Holiday Complex (Hal Ferh).

Downstream Users

1.17. Away from Bajda Ridge, a soil layer has developed at Wied tal-Mistra further downstream (in the Mizieb basin), and Wied tal-Pwales on the east, thus permitting agricultural practices to develop. Groundwater in the Mizieb syncline is mainly harvested by the Water Services Corporation for distribution in the freshwater supply network. It is illegal for farmers to abstract such water. There are 8 private registered boreholes in the Mizieb basin. The annual groundwater extraction is 690,000m^3. (www.mra.org .mt)

1.18. Groundwater in Wied Tal-Pwales is readily available to farmers and agriculture and intensive horticulture activities are very well developed. In the early fifties Morris, 1952, reports that there were 70 private shafts. There are 74 private registered boreholes in the Pwales Valley and 2 springs. The annual groundwater extraction is 960,000m^3. (www.mra.org .mt). From observation, there are likely to be more than double this number of extraction points.

1.19. This valley hosts the nature reserve of is-Simar lying close to the greatly eroded sandy beach at Xemxija. A sewer pumping station lies close by; it pumps sewage to the main northern discharge outlet. The sewer runs along Bajda Ridge traverses the Mizieb Basin and Mellieha Ridge, and runs past Anchor Bay on its way to the discharge point at Ic-Cumnija.

METHODOLOGY

Desk Study

1.20. Prior to the field survey, the writer undertook a desk study on the geo-environmental characteristics of the site and its environs. This involved reviewing existing literature sources, including the Geological Map of the Maltese Islands (Oil Exploration Directorate, 1993) and previous work undertaken in relation to the geology of the region (e.g. Richard Costain Ltd, 1958, GAIA Foundation, 1997).

Surface Geology

1.21. Previous work on the subject is mostly related to the geology of Ghajn Tuffieha Bay and its surroundings, in relation to the management of this scheduled site.

Subsurface Investigation

1.22. The only subsurface investigation known to the author was undertaken by Richard Costain Ltd in 1958 to study the groundwater water resources with a view to developing them to the full by cutting subsurface galleries outside the A of I as shown in **Figure 4**.

Field Study

Field Mapping & Analysis

1.23. The field surveys were undertaken in August 2005; they focused on the geology, palaeontology, geomorphology, hydrology, and hydrogeology of the Site and its environs. The output from the field surveys included the following:

- A Geological Map;
- A Geomorphological Map;
- A Hydrological map; and
- Geological cross-sections across the site.

Geology / palaeontology

1.24. This part of the study consisted of a field survey to identify and map rock formations and to identify the quality of the terrain at the Site. Features of particular geological/palaeontological importance were identified.

1.25. Cross sections of the rock layers on site were plotted in order to estimate the thickness of the various formations and the location of the perched / mean sea level aquifer (see **Figures 4, 5** and **6**).

Geomorphology / Soils

1.26. This part of the study was carried out simultaneously with the geological field survey. Geomorphological units were identified and mapped (see **Figure 9**) and features of geomorphological importance and soils identified for further assessment.

1.27. The baseline survey will be compared to the remodelled site to identify the extent of the changes on the morphology of the site.

Hydrology & Hydrogeology

1.28. The scope of the field survey was to identify hydrological features such as watercourses, wells, reservoirs, canals, and water channels. Surface geological mapping identified aquifers and determined the positions of watersheds and hydrogeological basins, distinct or otherwise from the watersheds of the watercourses, in relation to the proposed golf course.

1.29. The survey included measurement of catchment areas to estimate a water balance for the site and run-off potential for each catchment area. These measurements, together with the amounts of rainfall expected, were used to calculate maximum run-off, evapo-transpiration rates, and infiltration and hence potential aquifer recharge.

Water quality

1.30. Water quality was assessed on the basis of analytical data available at the Water Directorate at MRA and at the Water Services Corporation.

1.31. The findings of the various surveys indicated the extent of vulnerability of the geo-environmental resources in the Area of Influence.

AREA OF INFLUENCE

Geology and Palaeontology

The area of influence for the geological and palaeontological field suf 1:2500 was taken as the boundary of the proposed site. Beyond the site the geological study extended to the entire catchments of Mizieb-Mistra Valley and Pwales Valley utilising the geological Map of the Maltese Islands on a scale of 1:25000.

Geomorphology

The geomorphological study extended to include the catchments of the Mizieb Basin and the Pwales Valley, bounded by Wardija Ridge on the south and by Mellieha Ridge on the north. The soil study extended only to the boundary of the proposed site

Hydrology and Hydrogeology

The hydrogeological and hydrological study extended to the catchments of the Mizieb Basin and Pwales Valley bounded on the south by Wardija Ridge and by Mellieha Ridge on the north.

POLICY CONTEXT

17. The principal sources of policy and legislative guidance for the Geo-environmental Study are the Structure Plan for the Maltese Islands[2], the draft North West Local Plan[3], and the policies relating to development sites. Reference was also made to legislation concerning the pollution of groundwater resources.

General Overview

1.32. The conservation importance of the geo-environmental features was established by reference to local legislation, the *Structure Plan for the Maltese Islands* (1990) and the guidance of the Nature Conservancy Council (UK) on Earth Conservation.

1.33. The extent of the vulnerability of the water resources was evaluated in the light of the above conservation policies and in accordance with the Water Policy Framework Regulations, 2004 (LN 194 of 2004).

1.34. The potential excavation of the Site, and hence the exploitation and conservation of mineral resources, as well as their vulnerability are assessed in the light of Structure Plan policies as well as the *Minerals Subject Plan*[4].

1.35. The disposal of the excavated material is regulated by LN 337 of 2001[5], and the reuse of the soil is governed by the Fertile Soil (Preservation) Act 1973, as amended in 1980.

Relevant local legislation affecting the geo-environmental resources

The Malta Resources Authority Act (Act XXV of 2000)

1.36. This provides for the establishment of an Authority and for the regulation of water, energy, and mineral resources. The Authority is charged with regulating, monitoring, and reviewing all practices, operations, and activities related to these resources and to grant the relevant licences or permits for their exploitation. Amongst other functions, the Authority regulates the conservation, augmentation, and operation of water resources and the sources of water supply, and ensures the optimum

[2] Planning Services Division, 1990a. *Structure Plan for the Maltese Islands: Written statement and key diagram*. Ministry for Development of Infrastructure, Government of Malta; xiii + 125pp + map.

[3] Planning Authority, 2001a. The North West Local Plan. Draft for Public Consultation. Floriana, June 2001.

[4] Planning Authority, 2001b. *Minerals Subject Plan for the Maltese Islands*. Draft for Public Consultation, August 2001.

[5] Waste Management (Permit and Control) Regulations, 2001.

utilisation of mineral resources and regulates the quality and quantity of minerals extracted.

The Water Services Corporation Act (Act XXIII of 1991)

1.37. This established the Water Services Corporation (WSC). Among other functions, the WSC was charged with conservation of water resources and with the promotion of safe disposal of wastewaters and reasonable use of water.

L.N. 194 of 2004 - Water Policy Framework Regulations, 2004.

1.38. The Water Policy Framework establishes a framework for the protection of inland surface waters, transitional waters, coastal waters, and groundwater. They also transpose the provisions of European Directive 2000/60/EC. The relevance of these Regulations to the Scheme lies in the presence of groundwater beneath the site, such that any operations (whether excavation of rock, or construction activities must be undertaken within the provisions and constraints set out in these Regulations. The Regulations aim to prevent the deterioration of the status of all bodies of surface water and groundwater, to protect, enhance, and restore all bodies of surface water and groundwater, and to implement the necessary measures aimed at progressively reducing pollution, including measures to prevent or limit the input of pollutants into groundwater. In the case of bodies of water affected by human activity, the Regulations seek to achieve the highest possible ecological and chemical status for surface waters, and the least possible changes to groundwater status. The Regulations also require the designation of areas requiring special protection (for the protection of their surface waters and groundwater or for the conservation of habitats and species directly depending on the water) by the end of November 2004[6].

L.N. 203 of 2002 - Regulations for the Protection of Groundwater against Pollution caused by Certain Dangerous Substances, 2002

1.39. These Regulations aim to prevent pollution of groundwater from pollutants listed in the Schedules to the Regulations. The Regulations do not apply to: (i) discharges of domestic effluent from isolated dwellings not connected to the sewerage system and situated outside the groundwater protection areas, (ii) discharges containing amounts of the substances in Lists I or II of the Regulations, that are so small as to obviate any present or future danger of deterioration in groundwater quality, and (iii) discharges of radioactive substances. The direct discharge of all List I substances is prohibited by the Regulations, and activities that may lead to indirect discharges of these substances must undergo prior investigation. Prior investigation is also required for the direct discharge of List II substances or for activities that may lead to their indirect discharge. These investigations include examination of the hydrogeological conditions of the area concerned, the possible purifying powers of the soil and subsoil, and the risk of pollution and alteration of the quality of the groundwater from the discharge,

[6] At the time of writing (September 2005), no such protected areas had been designated.

and they are to establish whether the discharge of substances into groundwater is environmentally satisfactory.

L.N. 337 of 2001 - Waste Management (Permit and Control) Regulations, 2001

1.40. These regulate the production and management of wastes, and promote sound waste management practices to safeguard human health and the environment. The potential excavation of the Site will need to be undertaken in accordance to a Waste Management Permit issued by the Director of Environment Protection as required by this Legal Notice.

Fertile Soil (Preservation) Act (Act XXIX of 1973)

1.41. This Act provides for the protection of fertile soil by prohibiting its transportation, burying, covering, deposition, or mixing with other materials as to render it unfertile, except with the written permission of the Director of the Agriculture Department. Further provisions under this Act are provided in the *Preservation of Fertile Soils Regulations (LN 104 of 1973)*.

Relevant Structure Plan Policies

1.42. The study area consists of a rural area characterised mainly by Limestone pavements with a few agricultural holdings, mainly on the low lying terrain. In this context, the most relevant Structure Plan policies, vis-à-vis the geo-environmental resources of the area, are those dealing with Rural Conservation, including the policies on the conservation of the water resources, soil, and landscape conservation.

Rural conservation policies of relevance to the geo-environmental resource

<u>Protective Designations</u>

1.43. The Structure Plan's strategy on the rural environment is based on the designation of Rural Conservation Areas and conserving sub-areas within these. Various policies focus on specific rural conservation issues, such as landscape, ecology, etc. The relevant geo-environmental policies include:

- **SP Policy RCO 1**: Designates Rural Conservation Areas (as identified in the SP Key Diagram) and provides for the designation of sub-areas on the basis of World Conservation Union criteria. The relevant designations include – Sites of Scientific Importance (SSI) that include important geological features and Areas of High Landscape Value (AHLV).

- **SP Policy RCO 4**: Provides for the protection and enhancement of areas of scenic value.

- **SP Policy RCO 11**: Lists the features that must be present for a Site to be designated an SSI.

The geo-environmental features that must be present include:

- A locality of special palaeontological interest;
- A lithostratigraphic type section;
- A locality of geomorphological interest; and
- Some other specific feature of scientific importance not listed above.

- **SP Policy RCO 12**: Establishes a classification (Level 1 to Level 4) for the designation of Sites of Scientific Importance. The policy provides a description of the characteristics of the different levels. These are further elaborated upon in the Explanatory Memorandum to the Structure Plan, in particular Clauses 15.34 to 15.40.

Erosion control

- **SP Policy RCO 21**: Includes a general presumption against development in areas prone to erosion.
- **SP Policy RCO 22**: Protects areas prone to erosion, such as sandy beaches, sand dunes, coastal clay slopes, soil and cliff edges, and calls for positive action aimed at their preservation.
- **SP Policy RCO 27**: Prohibits development involving the excavation of significant quantities of Blue Clay.

Valleys, Soil Conservation and Water Resources Management

- **SP Policy RCO 28**: Protects all valleys in view of their important role as water catchment areas.
- **SP Policy RCO 29**: Seeks to prevent soil erosion and encourage the conservation and management of water resources. No new physical development will normally be allowed on sides of valleys and especially on valley watercourses except for constructions aimed at preventing soil erosion and the conservation and management of water resources.

Soil Conservation Policies

- **SP Policy AHF 4**: Builds upon existing legislation (the Fertile Soils (Preservation) Act, 1973) and maintains the mandatory conservation of soil and other soil saving measures. The policy also provides for the adoption of soil replenishment measures where suitable opportunities arise.

Mineral Resources Policies

- **SP Policy MIN 1**: Safeguards mineral resources from sterilisation through development. The terrain at the site exposes Tal-Pitkal Member of the Upper Coralline Limestone Formation a source of good concrete aggregate. The Xaghra l-Hamra / Tal-Qortin area is on the western edge of a Level II Mineral Exploitation Target Area[7] as identified in the Mineral Resource Assessment undertaken by the Planning Authority in 1996. It must be noted that although such areas were identified as potential Mineral exploitation Areas, other land uses or environmental constraints may present over-riding considerations for the preservation of the site.

- **SP Policy MIN 4**: Introduces the concept of a minerals land bank by ensuring that land released for mineral extraction takes into consideration the overall rates of production and the levels of exploitable reserves. It introduces a presumption against the granting of permissions that would result in the release of significantly higher levels of permitted reserves.

- **SP Policy MIN 5**: Includes a presumption against surface mineral working in or near areas of acknowledged interest for ecology, archaeology, and in areas of high quality agricultural land. The policy also echoes SP Policy RCO 27 in prohibiting the extraction of significant amounts of Blue Clay, in order to protect groundwater resources and hillside landscapes.

- **SP Policy MIN 6**: Hints at sustainability issues with an emphasis on extensions of existing mineral workings in preference to the development of mineral workings in new areas. The exhaustion of mineral resources from committed areas is also an important aspect of this policy, encouraging the deepening of the existing extraction areas.

1.44. Various other policies related to mineral extraction as an activity are included in the Structure Plan, but these are not relevant to the project at hand. Other minerals-related planning policies are those contained in the Minerals Subject Plan, published by MEPA in 2001.

Relevant Minerals Subject Plan Policies

1.45. The Minerals Subject Plan deals with the activities of the minerals industry as a whole and provides planning guidance for the next 10 years. The Subject Plan's policies of relevance to the geological resources are:

- HS 3, HS 4, HS 5, HS 6, HS 7 and HS 8 dealing with the safeguarding and extraction of mineral resources;

[7] A Level II Target Area is one that requires further investigation to confirm or otherwise the quality of the resource. The Resource Assessment recommends safeguarding if these areas until further investigations are carried out.

- DC 1 to DC 22 dealing with the impacts of such practices;
- RES 1 to RES 12 dealing with the restoration of extraction sites; and
- BC 1 dealing with the extraction of Blue Clay.

Guidance

1.46. Conservation profiles are intended to prevent future potential damage to sites. Since no earth conservation model exists for the Maltese Islands, it has been suggested in past studies (e.g. Debono & Scerri, 1996[8], Mallia et al., 1999[9]) that until such a model is formulated, models used in other countries could be adopted for local use. The conservation model proposed is that adopted by the Earth Conservation Strategy of the Nature Conservancy Council (UK). In this model, sites of geological importance are classified into two groups: Exposure Sites and Integrity Sites. The conservation of the two groups is treated differently.

1.47. **Exposure Sites** are those whose scientific or educational importance lies in providing exposures of a deposit that is extensive or plentiful underground but that is otherwise accessible only by remote sampling. Exposure Sites include outcrops, stream and foreshore sections, and exposures in quarries, pits, cuttings, ditches, mines, and tunnels.

1.48. **Integrity Sites** are those whose scientific or educational value lies in the fact that they contain finite and limited deposits or landforms that are irreplaceable if destroyed. These deposits or landforms are usually of limited lateral extent. Examples include caves, karst, glacial and fluvial deposits, and unique mineral, fossil, stratigraphic, structural, or other geological deposits and features (NCC, 1991[10]).

European Union Directives

1.49. The European Union does not have any directive that protects the geo-environment or that regulates mineral extraction *per se*. Of relevance to the proposed development, however, are the directives on the protection of groundwater resources against pollution events:

[8] Debono, G. and Scerri, S., 1996. North Harbours Local Plan Geology Survey Report. Prepared by Malta University Services for the Planning Authority, Floriana, Malta; 72pp + 210 data cards + 15 figures + 20 plates.
[9] Mallia, A., Briguglio, M., Ellul, A.E. and Formosa, S. 1999, Population, Tourism, Land-Use and Non-Renewable Resources in the "State of the Environment Report for Malta 1998" commissioned by the Environment Protection Department, Government of Malta, Malta Council for Science and Technology, Malta.
[10] Nature Conservancy Council, 1991. "Earth Conservation Strategy", Peterborough, UK; 1991.

- **Directive 80/68/EEC:** On the protection of groundwater against pollution caused by certain dangerous substances;
- **Directive 98/83/EC:** On the quality of water for human consumption;
- **Directive 80/778/EEC:** Relating to the quality of water for human consumption; and
- **Directive 2000/60/EC:** The Water Framework Directive.

2. GEOLOGY

STRATIGRAPHY

2.1. The five Late Tertiary rock formations exposed on the Maltese Islands are, from base to top (see **Figure 3**):

(a) Lower Coralline Limestone (oldest);

(b) Globigerina Limestone;

(c) Blue Clay;

(d) Greensand; and

(e) Upper Coralline Limestone (youngest)

2.2. In addition to these formations, Quaternary continental deposits are also known to occur sporadically on the Maltese Islands. An unconformity and an erosional surface separate this unit from the underlying marine sedimentary succession.

2.3. The rock formations preserved in the Study Area are:

- Upper Globigerina Limestone Member;
- Blue Clay Formation;
- Greensand Formation;
- Upper Coralline Limestone; and
- Quaternary Deposits.

2.4. **Figures 5** and **6** are geological cross sections illustrating the subsurface geology of the site and its environs.

Figure 3: Stratigraphic column

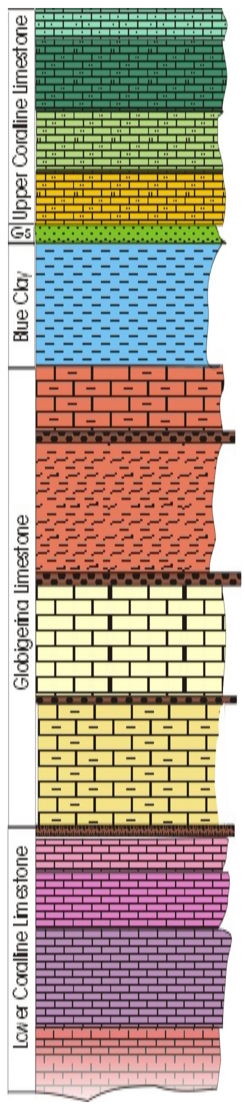


Figure 4: Geology of the environs of the site

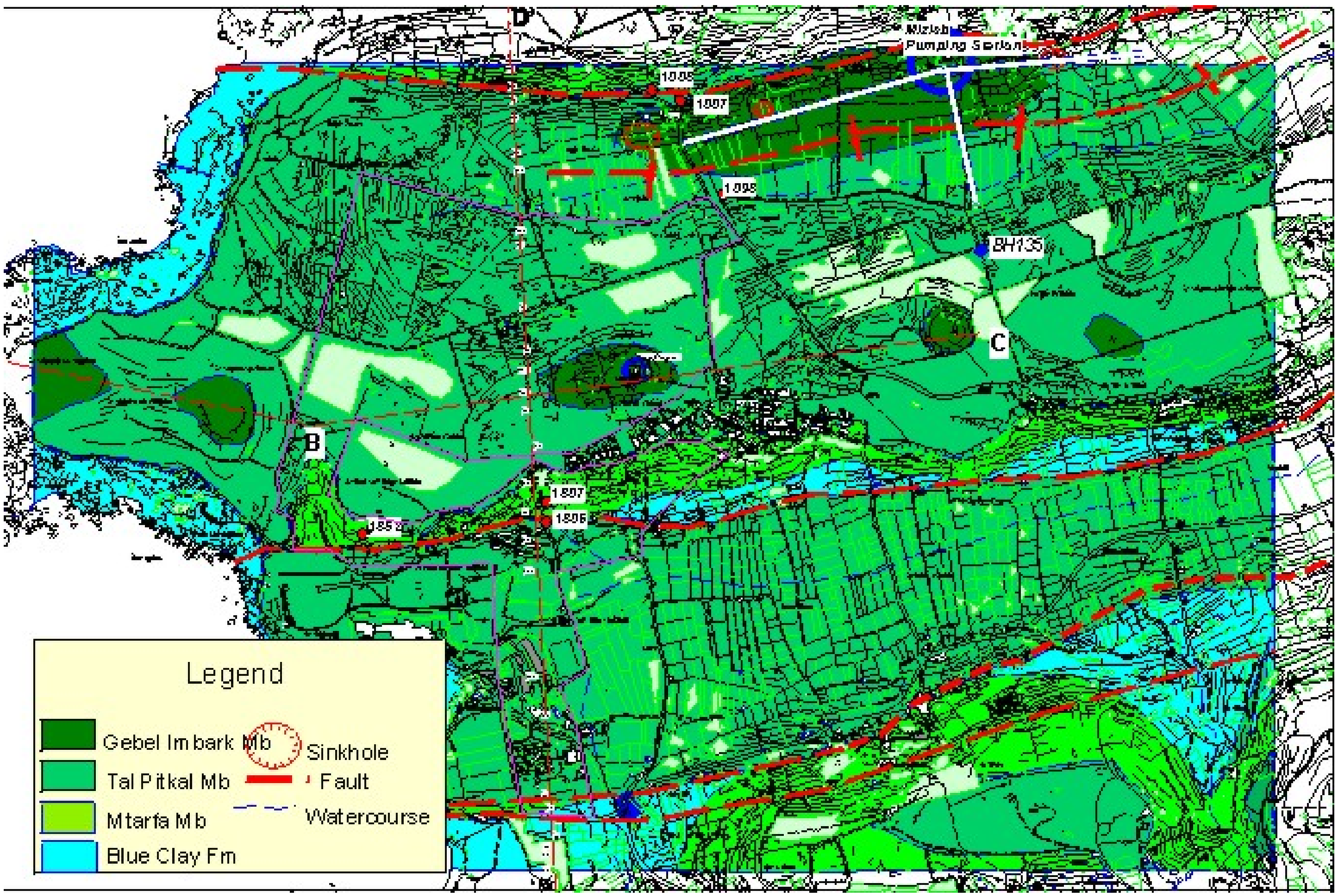
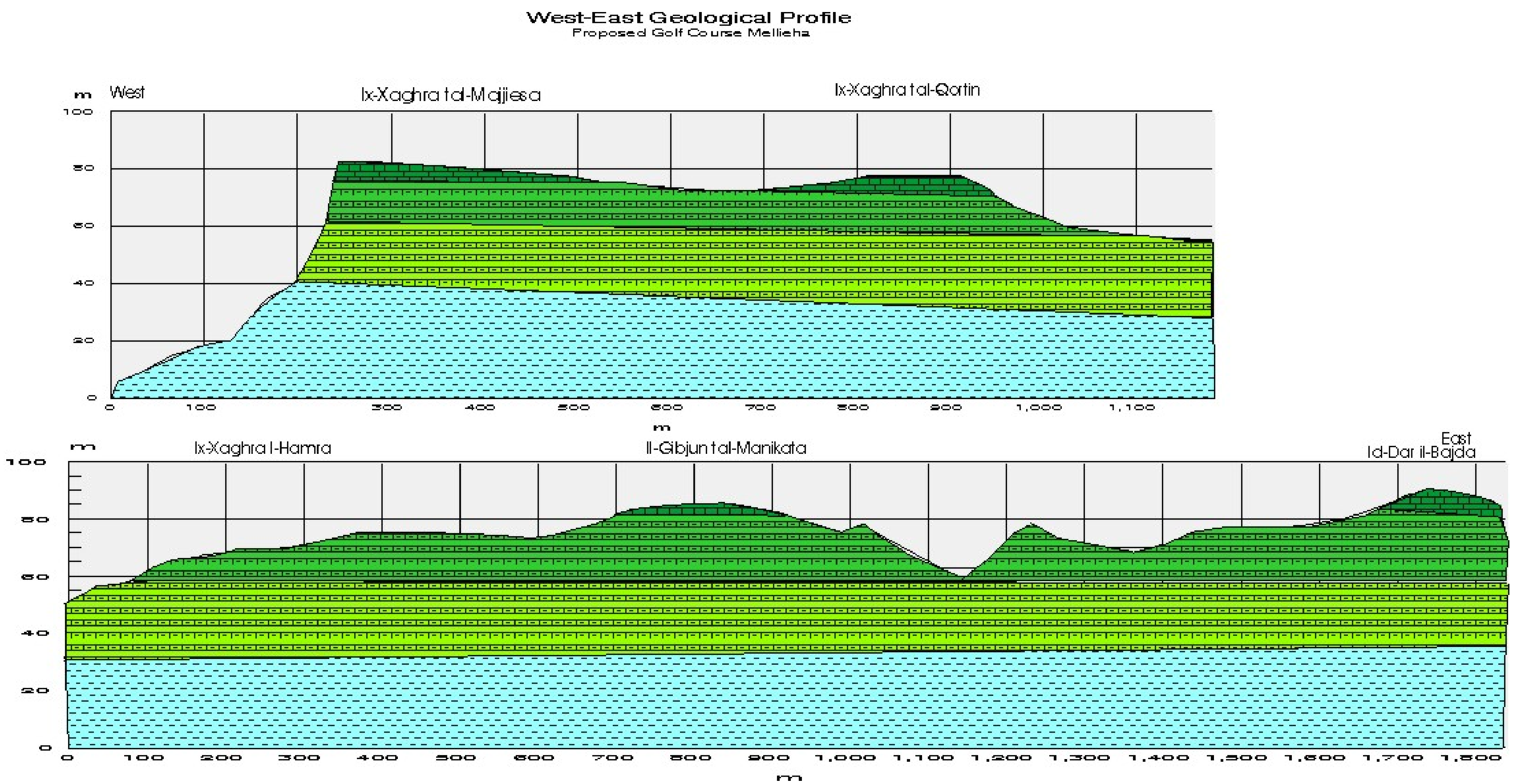
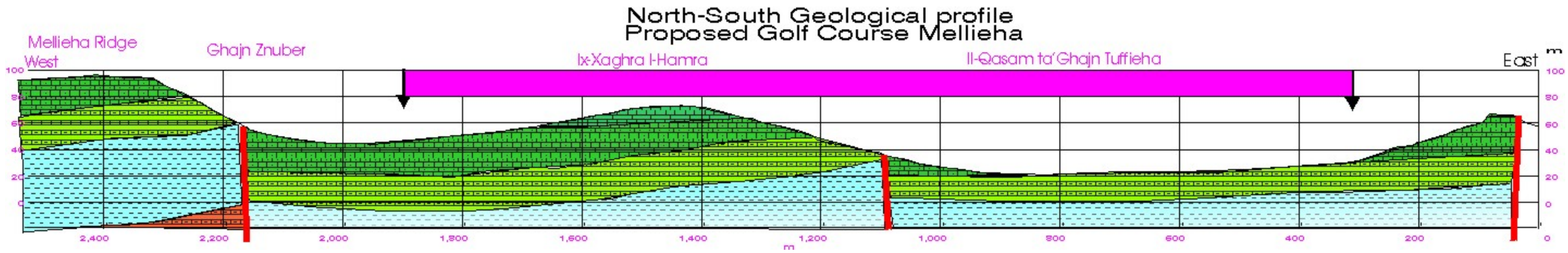


Figure 5: West to East Geological cross-section across the site



Note: For line of section see **Figure 4**

Figure 6 : North to South Geological cross-section across the site



Note: For line of section see **Figure 4**

Globigerina Limestone Formation

Upper Globigerina Limestone Member

2.5. This formation is the least exposed in the Study Area, outcropping only in a very small coastal area that makes up the wave-cut terrace south of the isthmus facing Gnejna Bay and as a faulted inlier in Wied tal-Palma. The outcrop represents the top-most bed of the Upper Globigerina Member; the remaining two beds are not exposed. This 4 m thick outcrop is composed of yellow foraminiferal wackestones with frequent oxidised goethite concretions which impart an orange mottling colour to it. Bedding is absent due to intense Thalassinoidean bioturbation. The exposed surface exhibits honeycomb weathering due to this bioturbation.

2.6. Macrofaunal remains in this Member are sparse and are mainly represented by disarticulated and often fragmented pectinid shells. Among the most common are the pteropod *Vaginella*, the gastropod *Epithonium* and the echinoid *Schizaster eurynotus*. Microfauna are very abundant and often compose the limestone itself. Planktonic globigerinid microfauna are predominant and include a number of species of *Praeorbulina*, *Globorotalia*, *Globigerinoides*, *Globigerinatella* and *Globigerina*. *Orbulina universa* makes its first local appearance in this unit. A rich assemblage of ostracofauna is also found in this bed. It includes *Buntonia*, *Ruggieria*, *Cytherella*, *Oblitacythereis*, *Bythoceratina*, *Parakrithe* and *Krithe*, among many others. Some are even restricted to this unit (Russo and Bossio, 1976). This member is interpreted to have been deposited in water depths ranging from 40m to 50m in a mid-Tethyan submarine continental rise (Felix, 1973).

Blue Clay Formation

2.7. Exposure of this formation is very common, especially in the cliff sections at Ghajn Tuffieha, Ir-Ramla tal-Mixquqa, Rdum Majjiesa, and minor outcrops on the slopes of Manikata and Wied Tal-Palma. It is also exposed intermittently between the boulders of the under cliffs of Il-Qarraba promontory and beneath Ghajn Tuffieha Tower and Ix-Xaghra tat-Torri overlooking Gnejna Bay. Maximum thickness in the area is about 55 m at Tal-Lippija. This formation represents the only terrigenous sediment of the Maltese rock succession. Its deposition corresponds to the major tectonic phase of the uplifting of the Siculo-Maghrebid chain from where the clay was derived. When exposed, it dries very quickly, especially in the dry Summer months, to form deep fissures up to 5cm wide at the surface and extending by about 2m below the ground. Subsequent wetting in autumn and winter renders this superficial layer unstable and under stagnant conditions mud-slides are produced. Because of the ease with which the Blue Clay is eroded it is only found, with few exceptions, where it is protected by a cap of Upper Coralline Limestone.

2.8. This Formation is composed of bluish grey, colour-banded, plastic kaolinitic marls and clays. The banding derives from the varying concentrations of calcium carbonate in the form of fossil tests of planktonic and benthonic foraminifera. The light-coloured layers correspond to a higher calcium carbonate content and lower kaolinite content. The clay content of the dark, almost pure clay bands ranges from 90% to 94% and are best described as marly clays while in the lighter coloured bands it ranges from 80% to 60% and, depending on the exact clay content, can petrographically be described as marly clays, clayey marls, or marls. This banding is best observed on the isthmus of Il-Qarraba (outside the Study Area). Large selenite crystals exhibiting an octahedral habit are common especially towards the base and top of the formation. Rare sapropel streaks in the form of coaly carbonized plant debris have also been reported. At about 4 m below the top of the formation there is a dark-green 1.5 m thick clayey sand or sand layer rich in glauconite and fossil assemblages.

2.9. The Blue Clay contains a rich assemblage of macrofauna represented by molluscs, echinoids, solitary corals, fish remains, and marine mammals. Most of the larger fossils have been crushed during consolidation under the weight of the overburden and subsequently pyritised during diagenesis and later altered to limonite and goethite. Macrofauna include solitary corals such as *Flabellum* and *Stephanophyllia*, cuttle bones of *Sepia*, *Aturia*, nuculid bivalves, pectinid bivalves including *Flabellipecten*, *Amussium* and *Clamys*, gastropods, spine-bearing tests of the echinoid *Schizaster eurynotus*, goethite casts of pteropod *Vaginella*. Fish remains are common in the glauconitic sand bed. These include remains of *Isurus*, *Procharcharodon*, and *Odontapsis*.

2.10. Microfauna are dominated by planktonic and benthonic foraminifera similar to those found in the underlying Upper Globigerina Limestone Member.

2.11. The presence of solitary corals such as *Flabellum* and *Stephanophyllia* within the unit indicates that, despite its terrigenous origin, sedimentation rates were low enough to permit the corals to live. Benthonic and planktonic foraminifers indicate an open marine muddy platform in water about 150 m deep. The depositional environment is similar to that of the Upper Globigerina (Felix, 1973). Benthonic and planktonic foraminifers suggest an open marine muddy platform in a shallow-water environment.

Greensand Formation

2.12. This formation is not well developed at the Ghajn Tuffieha area and is usually less than 0.5 m thick. It is sporadically exposed at the base of the cliffs fringing the coralline areas. It is unconformably overlain by either the Mtarfa or Ghajn Melel member of the Upper Coralline Limestone and is best exposed at Il-Qarraba. The contact with the overlying Mtarfa Member is gradational.

2.13. The unit consists of massive, friable, intensely burrowed, greyish-green, brown to dark grey marly limestone. The dark colour is imparted by the glauconite which, in places, appears brown due to oxidation. Petrographically, it is classified as an intensely bioturbated lithoclastic limestone rich in glauconite and gypsum grains. It is rich in the macroforaminifera *Heterostegina*, benthonic micro-foraminifera, sharks teeth, remains of cetaceans, casts of *Conus*, and encrusting bryozoans.

2.14. The unit is interpreted to have been deposited under very turbulent water conditions in a shelf or platform environment.

Upper Coralline Limestone

Ghajn Melel Member

2.15. This member is only well-developed at Il-Hotba L-Bajda outside the Study Area where the erosion of the overlying Mtarfa and Tal-Pitkal members provides good exposures of this rather sparse unit. It is only found well-developed here as this unit always occurs in conjunction with horsts, forming a sand ridge along their culmination. It is composed of thickly bedded beds of orange-red, friable, bioturbated biocalcarenites containing scattered, derived, rounded lithoclasts, light orange-brown in colour and containing a nucleus of chocolate-brown lithoclastic limestone.

Mtarfa Member

2.16. This member is subdivided into a number of beds, but only the coralline algal biostrome is found in the Ghajn Tuffieha area. It is best exposed in the cliff section from Ghajn Tuffieha Bay to Rdum Majjiesa.

2.17. This bed is approximately 5m thick and made up of alternating cream-coloured calcilutites containing coralline algal ovoidal rhodoliths 5cm to 16cm in diameter. A thin development of crustose algal marl containing *Terebratula*, *Aphelesia*, and algal debris wackestones is found at the base of this Member. Well-exposed NE-SW trending channels and erosion surfaces of high palaeo-reconstruction significance can be seen within this unit. As a whole, the biostrome is widespread; it comprises a number of laterally-linked lenses up to 16m thick spreading across western Malta and eastern Gozo over a 20 km by 5 km wide corridor broken up by a number of growth faults. A lens containing a thinly developed reef of *Porites* is also found in the lower third of the member.

2.18. A rich macrofauna is found within this bed. This includes echinoids *Schizaster*, *Brissus*, *Cidaris* and *Clypeaster*; molluscs *Clamys* and *Spondylus*; brachiopods *Megathyris*, *Argyrotheca*, *Terebratula*, and *Aphelesia*; and bryozoans. The principal constructors of the rhodoliths and the framework of the biostrome are however the coralline algae *Archaeolithothamnium*, *Lithothamnium*, *Mesophyllum*, and *Lithophyllum*.

2.19. The depositional palaeo-environment of this bed is inferred from the characteristics of the macrofauna. *Lithothamnium* develops under fairly high energy water conditions in water depths ranging from 12m to 25m, while *Archaeolithothamnium* has an optimal growth at a depth between 12m and 60m in restricted, tropical, and sub-tropical waters. The development of rhodoliths requires a delicate balance between light conditions and water motion that permits growth on all surfaces to produce a characteristic ovoidal shape.

2.20. This Member is underlain by the Greensand Formation or the Ghajn Melel Member, and is overlain by the Tal- Pitkal Member of the Upper Coralline Limestone Formation.

Tal-Pitkal Member

2.21. This member forms the exposed terrain of most of the Study Area including the Mizieb –Mistra Valley and Bajda Ridge and Pwales Valley.

2.22. The bed is approximately between 1m and 8m thick, made up of pale grey biocalcarenites. At the base the bed shows a rapid change from yellow friable algal biostrome to well-cemented bioclastic limestones predominantly composed of algal fragments in massive beds and lenses, highly resistant to weathering.

2.23. The lenticular shaped bedding within the bed represents a high energy, very shallow depositional environment in a fore- or inter- patch-reef setting in water depths less than 25m. The poor sorting of the intraclasts, derived from *Porites* and algal patch-reefs, is also suggestive of close proximity of the source.

Gebel Imbark Member

2.24. These beds are best preserved within the hanging walls of the major graben and half-graben. This rock unit forms the cone-shaped hills that rise from the limestone pavement at Ix-Xaghra tal-Qortin and Ix-Xaghra l-Hamra, extending to Id-Dar il-Bajda east of Manikata. It is composed of an alternation of two sub facies:

- White bioclastic to ooidal fine to very coarse grained grainstones that exhibit small scale cross-stratification in 1 to 20cm thick sets. Bioturbation often obliterates most of the sedimentary structures producing massive grainstone beds. The preserved fossil fauna is very sparse and is represented by rare gastropod and bivalve moulds. Bioclasts are well rounded and consist of miliolids, gastropods, coralline algae, echinoid, and indeterminate debris.
- White bioclastic fine to coarse grained packstones and grainstones usually in 10 to 30cm thick finely laminated beds. Again, sedimentary structures may be totally destroyed by bioturbation. Fossil fauna is very sparse and is represented by bivalve and gastropod moulds, calcitic bivalves, and small vermetid gastropod colonies up to 50cm across. The bioclastic debris is similar to that of the cross-stratified unit.

Quaternary Deposits

2.25. The only significant Quaternary deposits in the Study Area are the slope boulder scree lines at the toe of the cliffs at il-Minzel tal-Majjiesa. North of the Majjiesa Promontory the boulders assume a tilted block structure. Large flat-topped blocks cover the Blue Clay slopes. It appears that coastal erosion due to Blue Clay softening is more intense in this location. Fossil dunes at Ghajn Tuffieha Bay contain calcified roots (rhizoliths) set in a palaeosoil matrix. In addition to the fossil roots, the deposit also contains sparse fragments and whole specimens of land gastropods, most of which are still extant today. Sparse fossil fragments of vertebrates are also observed. The aeolian sand is made up of weakly cemented, very fine grains of limestone derived from the erosion of the Upper Coralline Limestone; it is similar to the near-by present-day beach sand.

2.26. A number of solution features were also apparent, including sinkholes in the Mizieb Basin (see **Figure 3**). These are usually filled with limestone rubble and terra rossa. Their main relevance to this study is the fact that they puncture the Mizieb Basin Blue Clay and connect the aquifer to a salty aquifer

2.27. A 2m to 4m thick red conglomerate caps a solution subsidence structure just east of the newly constructed Radisson SAS Golden Sands Resort & Spa Hotel.

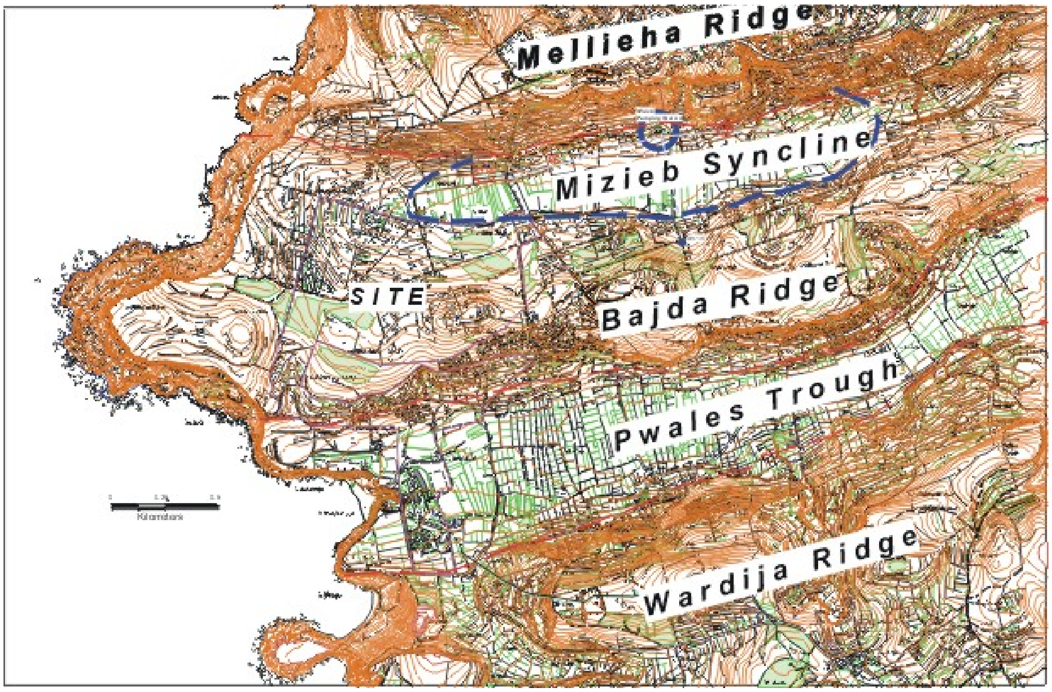
STRUCTURAL SETTING

2.28. The area under study falls within the North Malta Graben a downthrown block defined by a Master fault in the east - the Victoria Lines, and a northern Master fault termed the South Gozo Fault; both strike ENE-WSW. The region between these two Master blocks has been intensely fractured and subdivided into a series of horsts, grabens and half grabens. The surface expression of the horsts is the ridges whereas the surface expression of the grabens is the troughs or valleys bounded by the horsts

2.29. The area under study lies between the Wardija and Mellieha Ridges (**Figure 5**), both representing the surface expression of two horsts. The proposed site straddles Bajda ridge, the culmination of a half graben striking ENE-WSW deepening to the north to form the Mizieb syncline, bounded in the north by the Mellieha Ridge. The narrow corridor running from the former Military Camp to Tal-Lippija lies within the Pwales Valley, which is the surface expression of a graben bounded by Wardija Ridge in the south and Bajda ridge in the north.

2.30. Both grabens within the proposed site tilt slightly to the east such that while Blue Clay is exposed at an altitude of a few metres at Ghajn Tuffieha and Ir-Ramla tal-Mixquqa, to the east this rock unit dips below sea level. In the Mizieb syncline the rock units form a sag with its deepest location in the Blue Clay at about 35m below sea level.

Figure 7: The main structural features in the environs of the site



2.31. From north to south the main faults bounding the horst - graben system are:

- The Mizieb –Mistra fault bounding Mellieha Ridge and the Mizieb Syncline with a throw that increases from about 7m at the cliffs to the west to about 60m close to Ghajn Znuber Spring;
- The Majjiesa - Ghar Fekruna fault bounding Bajda Ridge and the Pwales Trough; and
- The Ghajn-Tuffieha - St Paul's Bay fault bounding the Pwales Trough and Wardija Ridge.

2.32 In addition to the more conspicuous faulting, the region is dissected by a network of vertical to sub-vertical fractures that could be discerned by examination of the aerial photographs. Like the major fault systems of the island, they are composed of two conjugate sets of fractures. One set of fractures is oriented NNW-SSE while a second set of fractures is oriented NE-SW. The fracture spacing is of the order of 5m to 20m.

Cliff Fissure System

2.33 A third fissure system occurs parallel to the seacliff face and at a distance of 2m to a few metres inland. The origin of these fractures is due to softening and undermining of the underlying Blue Clay and has no relation to the structural geology of the area. These fissures mark the onset of limestone block detachment from the mainland and formation of boulder fields so common on the Blue clay slopes that run parallel to the western boundary of the site.

Slope stability related to Blue Clay

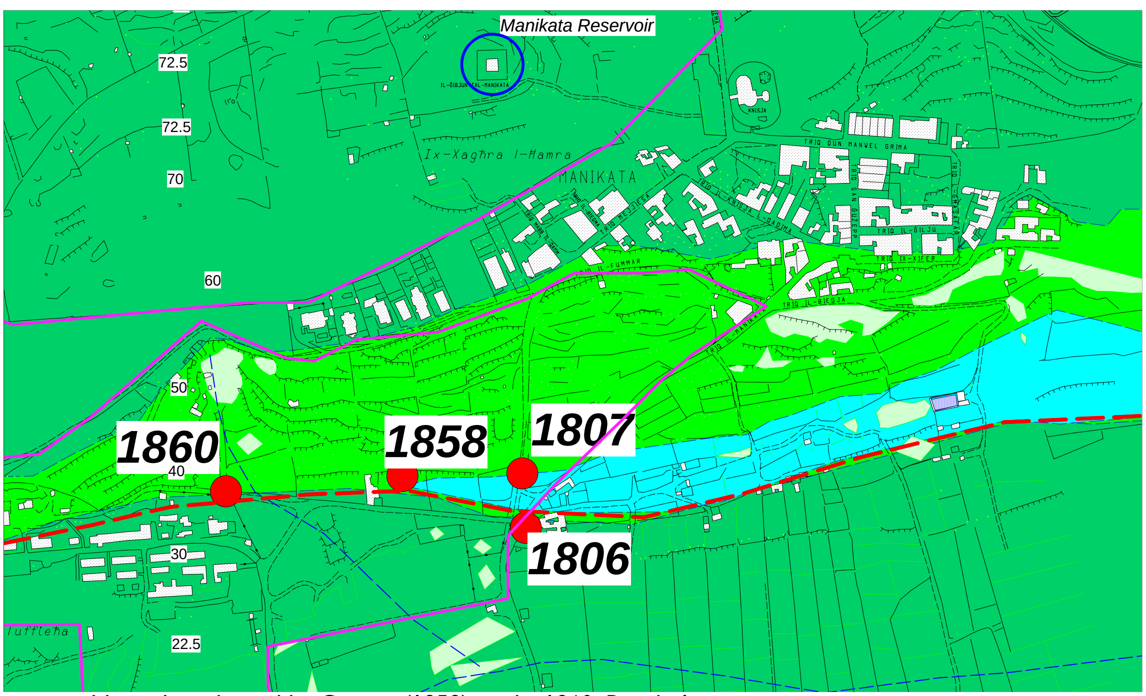
Besides being exposed at the toe of the cliff to the west of the site, Blue Clay is also exposed at several locations on the upthrow block (footwall) of the Ghajn Tuffieha-Ghar Fekruna fault.

Table 1: Well data (Costain , 1958)

BH No	G level	Depth to top of Greensand/Blue Clay
1806	23.2	35.8
1807	28.7	0.6
1858	30.0	2.4
1860	34.2	6.1

2.34. The extent of Blue Clay outcrop within the boundary of the site at Manikata is shown in **Figure 8**, drawn on the basis of a review of borehole data (Costain, 1958).

Figure 8: Blue Clay outcrops at Manikata



Note: As indicated by Costain,(1958) study. 1860: Borehole

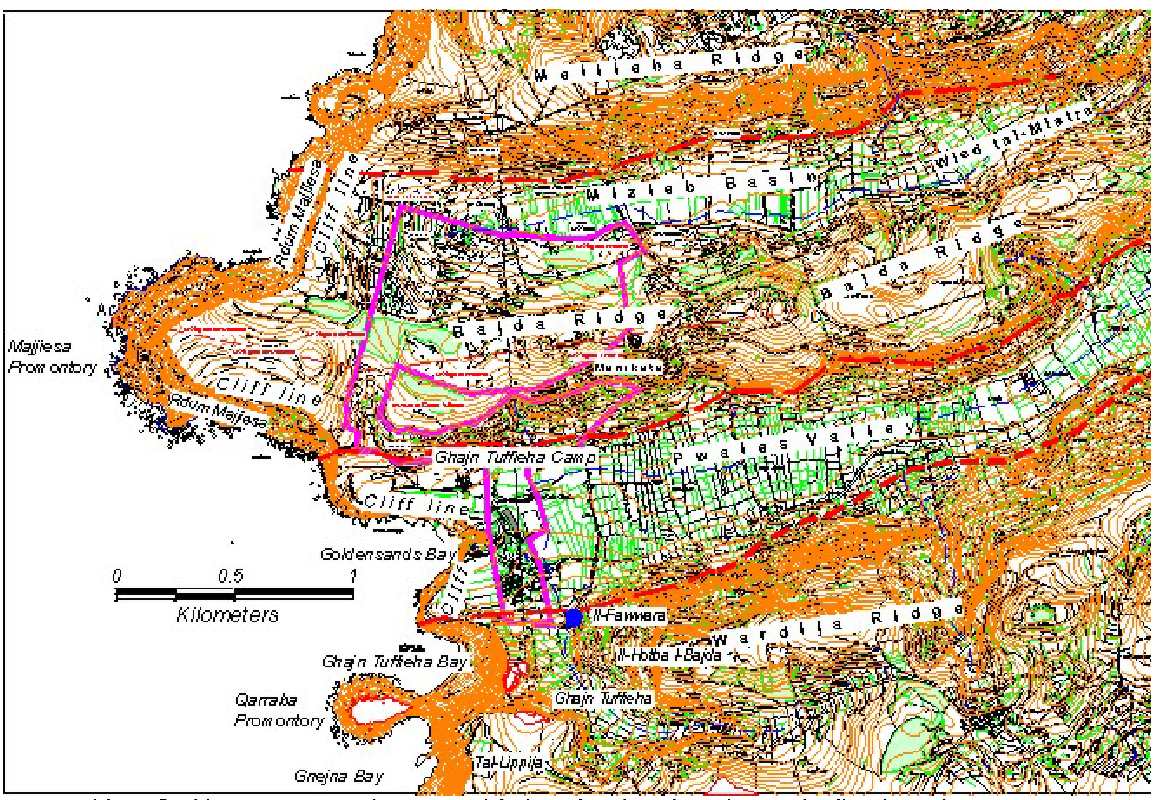
2.35. From **Table 1** it is evident that the fault throw at the location examined is about 35m. It is recommended that excavations on Upper Coralline Limestone in this region should stay well above the Blue Clay boundary. Furthermore close to the contact with the underlying Greensand / Blue Clay, the Upper Coralline Limestone is usually fractured.

3. GEOMORPHOLOGY

INTRODUCTION

3.1. The geomorphology of the Study Area is primarily controlled by the structural geology and to a lesser extent by the contrasting lithologies of the rock formations, members, and beds within it. The relief and landforms of the Study Area are predominantly controlled by structural geology and, in fact, the landform is dominated by faults that bound the main geomorphologic units highlighted in **Figure 9.** These are orientated ENE-WSW. Differential weathering and erosion has remodelled the horst and graben system, particularly at the coastline, giving rise to a system of bays bounded by headlands. Notable are the Il-Qarraba and Il-Majjiesa Promontories. Weathering and Blue Clay softening has given rise to sheer cliffs with a boulder scree at the toe running from Ir-Ramla tal Mixquqa to Rdum Majjiesa. Marine erosion has produced inlets and Bays with small pocket beaches at the head of the bays.

Figure 9: Geomorphological units in the environs of the site.



Note: Red lines represent the principal faults related to the ridges and valleys/troughs

3.2. Tributaries of the main valleys run in an East-West direction, however, they are usually very small. Of note are the Tal-Palma Valley and Ghajn Tuffieha valley, tributaries of Wied Tal-Pwales that dissect and interrupt the Wardija Ridge.

3.3. Human remodelling of the landscape by terracing, with the exception of the Wardija slopes of Wardija Ridge, is markedly absent as the site is covered by Upper Coralline Limestone; the hard limestone pavement does not permit easy working.

3.4. From South to North the major geomorphologic features within the Study Area are:

- Wardija Ridge;
- Pwales Valley;
- Bajda Ridge;
- Mizieb Trough – Wied Tal Mistra; and the
- Mellieha Ridge.

3.5. All of these features strike ENE-WSW.

3.6. Other geomorphological features are:

- The Cliffs and undercliffs running from Il-Qarraba to Rdum Majjiesa;
- The Il-Qarraba and Rdum Majjiesa Promontories;
- The Limestone pavements and other karst features;
- The bays at Ghajn Tuffieha and Ir-Ramla tal Mixquqa; and
- Fossil sand dunes.

Wardija ridge

3.7. This ridge forms the eastern margin of the Study Area. It is part of the horst-graben system that breaks up the North Malta Graben, generated by the Gnejna- St Paul's Bay Fault to the West and a similar fault to the East. It is dissected by the Ghajn Tuffieha and Tal-Palma Valleys, which shed their run-off into Pwales Valley. This ridge rises above the adjoining valley to expose a thick section of UCL with frequent exposures of the underlying Blue Clay. As a result surface ephemeral springs are common.

Pwales Valley

3.8. This valley is a graben bounded by the Wardija Ridge to the South and Bajda Ridge to the North. The valley floor is covered by UCL, which is exposed at Ghajn Tuffieha and Ir-Ramla tal-Mixquqa together with a thin section of Blue Clay. To the East the limestone floor dips below sea level and is overlain by a 9m thick marine sand that gives rise to the saline marsh at Is-Simar.

Bajda Ridge

3.9. This ridge runs uninterrupted from Ras il-Wahx in the west to Xemxija in the east and forms the culmination of a half graben that forms the Mizieb Basin. It rises above the floor of the Pwales Valley and is marked by a shear vertical scarp lined with a number of solution caverns. A number of low conical hills rise to about 15m above the surrounding terrain. The Bajda Ridge exposes Upper Coralline Limestone, usually bare forming 'Xaghra' type of limestone pavement predominantly Tal-Pitkal Member, with Gebel Imbark Member forming the low hills. The Bajda Ridge, being the culmination of a half graben to the north, it merges gradually into the Mizieb Trough.

Mizieb Trough –Wied Tal -Mistra

3.10. The Mizieb Trough is the surface expression of a syncline formed by folding of the rock sequence at the toe of the Mizieb - Mistra Fault. Similar to the Bajda Ridge, its floor is Upper Coralline Limestone with a thick Gebel Imbark rock sequence at its axis.

Mellieha Ridge

3.11. This ridge forms the northern boundary of the Study Area. It rises to 90m above the floor of the Mizieb Trough.

The Coastal Cliffs

3.12. The coastal cliffs are an imposing feature that forms the margin of the Study Area to the west and are the result of weathering and erosion of Upper Coralline Limestone underlain by Blue Clay, coupled with a regional tilt of the Maltese Islands to the Northeast. Undermining of Blue Clay has resulted in the shearing of limestone blocks that form slope scree at the base of the resulting vertical scarp or cliff representing the shear failure plain.

4. SOILS

COMPOSITION AND DEPTH

4.1. The soils of the Maltese Islands have a high carbonate content along the whole soil profile. For example, carbonate comprises 50% to 80% near the surface of the pale brown soils (Xerorendzinas) and the white raw carbonate soils and is found to increase down the soil profile. In the terra rossa soils (red) it ranges from 25% to 60% and decreases with depth. Generally soil depth is very shallow or absent on ridges, plateaus, and pavements formed of hard limestone (erosional surfaces) such as the Upper Coralline Limestone, usually ranging in depth from bare rock to 60cm with the exception of isolated pockets, where it could be deeper.

SOIL TYPE

4.2. The soils identified within the site of the proposed golf course are of three types. A large area around the ex-British Services Military Camp has been classified as disturbed (Lang, 1961). These are:

- Tas-Sigra Series and Xaghra Series of the Terra Rossa Class;
- Alcol Series;
- L'Inglin Complex; and the
- Disturbed Area originally occupied by the British Services.

The four classes of soils and their sub-divisions are shown in the soil map (**Figure 10**) and are described below.

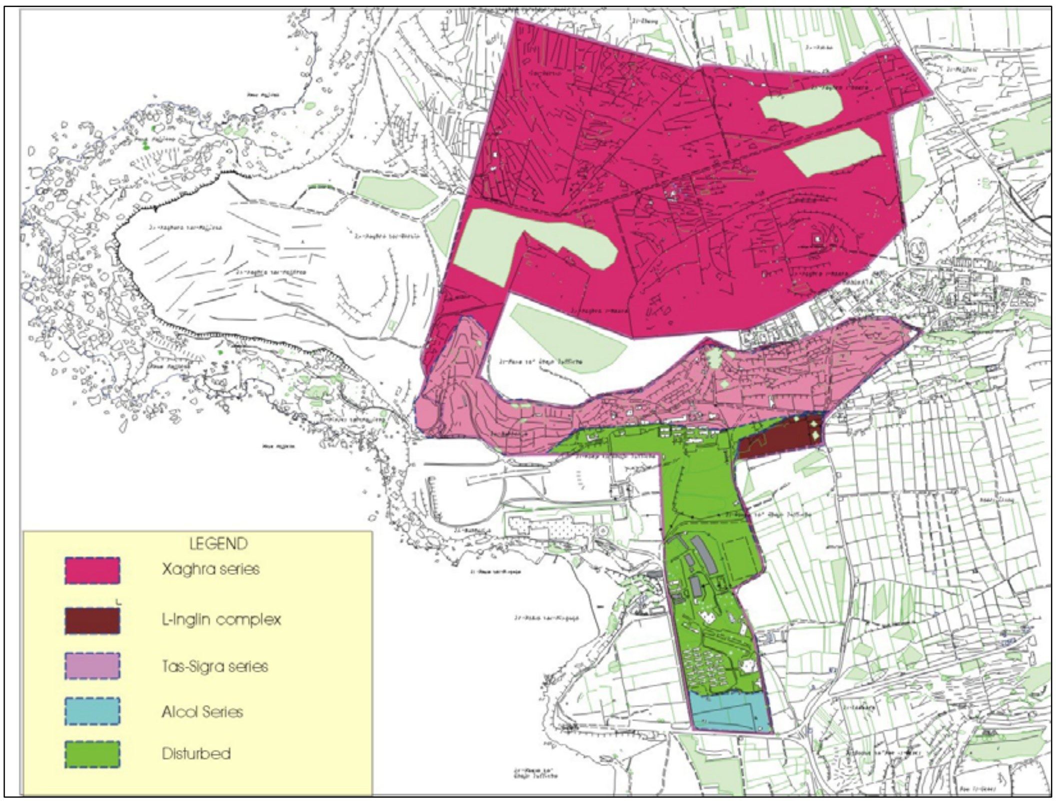
Tas-Sigra Series

4.3. This soil is confined to parts of deepest part of the Mizieb Syncline and grazes the northern boundary of the site. It is shallow to moderately deep, reddish brown, heavy textured soil. It is strongly decalcified, with a humus enriched surface layer and an organic content of about 3.0% and a pH of about 8.5. Its parent material is the decalcified residue of the weathering of the Upper Coralline Limestone with subsequent movement and deposition. In areas where this soil has been concentrated by gravity-wash and retained by rubble walls, as in the deepest part of the syncline, the depth can reach about one metre.

Xaghra Series

4.4. This shallow soil covers most of the site and occurs at Ix-Xaghra tat-Torri and Ix-Xaghra l-Hamra. It is invariably associated with karst landscape as it represents the residue left behind by the leaching of limestone, as in Tas-Sigra soil but without subsequent movement. It is a very shallow, red, heavy textured, decalcified soil with a strong sub-angular or angular block structure occurring intermittently among the limestone outcrops of the karstified Upper Coralline Limestone along solution channels, rock pools, and fissures. On the exposed high plateau, it is only found in scattered patches hence the name 'xaghra'. Total $CaCO_3$ varies between 25% and 60%, humus content is relatively high, 3% or more, and pH is about 8.1 to 8.4.

Figure 10: Soils



Alcol Series

4.5. The Alcol group of soils consists of very deep, brown, fine sandy clay loams and silty clay loams with a moderate to medium granular surface layer. They are moderately decalcified with a humus enriched surface layer and possess an A C profile on a calcareous parent material.

4.6. These soils occur on the gentle slopes of the broad valley floors. These valleys are of an erosional and/or structural origin and possess a very thick section of alluvial and colluvial deposits originating from material such as terra, renzina and carbonate raw soils eroded from the adjoining highlands during the Quaternary. The humus content of this class of soils is low though it is not confined to the thin surface layer due to widespread biological activity. The calcium carbonate content ranges from 57 to 70%.

L'Inglin Complex

4.7. This man-made soil complex is found in the terraced fields on the north-eastern slopes of the Ix-Xaghra tat-Torri step where the Ras il-Wahx - Ghar Fekruna fault has exposed soft marly limestone on the fault scarp. It is a pale brown to red, shallow to moderately deep, and light to heavy textured soil resembling Xaghra soil from which it was largely derived to form terraced fields.

Tas-Sigra Series

4.8. This series of soils is very similar to the Xaghra Series but occurs on deep alluvial deposits as in the Pwales Valley and near Marsascala. Secondary deposits of calcium carbonate are observed in several places in the subsoil and are attributed to pedological processes. The Tas-Sigra soils contain 25 to 60% calcium carbonate and the humus content is about 3.6%. This is among the highest in the Maltese Islands.

5. HYDROLOGY AND HYDROGEOLOGY

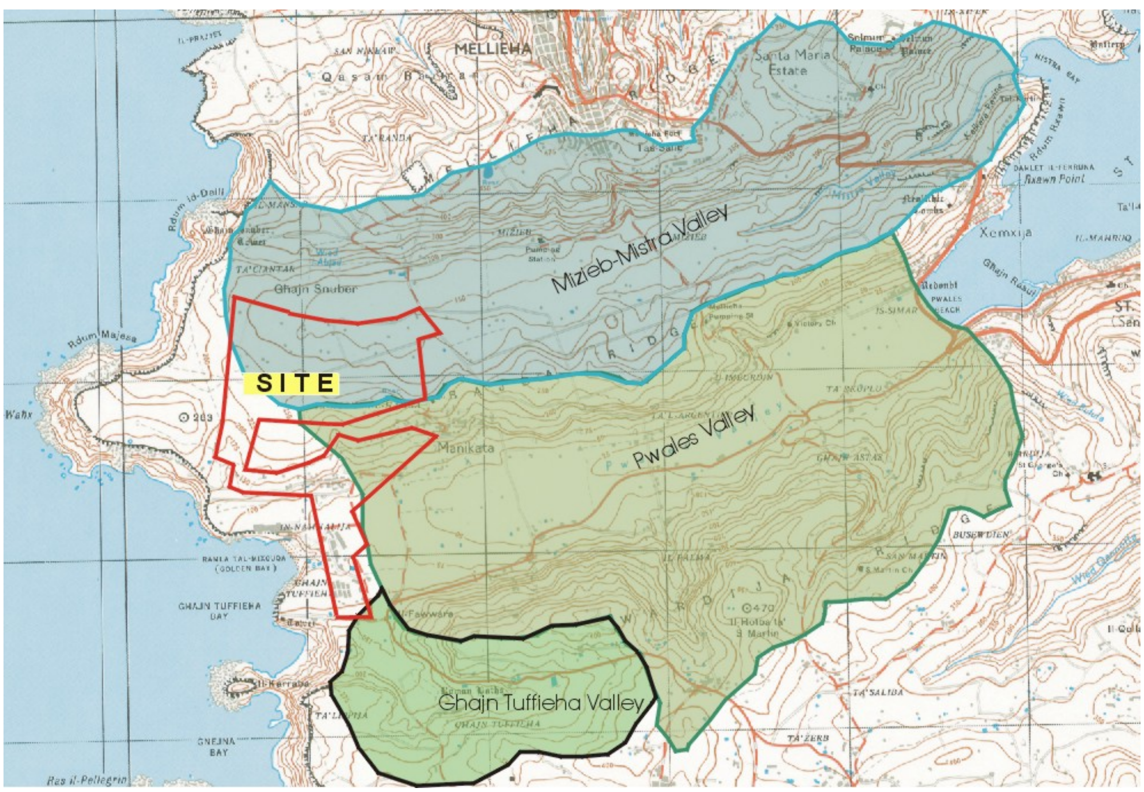
SCOPE

5.1. A hydrological / hydrogeological survey of the Area of Interest was undertaken to identify and describe the following features: aquifers, watercourses and their corresponding water catchment areas, drainage patterns of the site, springs, wells, water channels, cisterns, surface run-off, recharge, and any other hydrogeological features.

Extent

5.2. The extent of the hydrology/hydrogeology study extended to the watersheds of the valleys in which its run-off is discharged, namely the watersheds of the Mizieb - Mistra Valley and catchment of the Pwales Valley **Figure 11**.

Figure 11: Extent of the Study Area watersheds



5.3. It is seen that the site straddles the two catchments. The eastern end of the site sheds its run-off as diffuse discharge along the cliffs in the west.

THE WATER CYCLE

Run-off, Percolation, and Evapo-transpiration

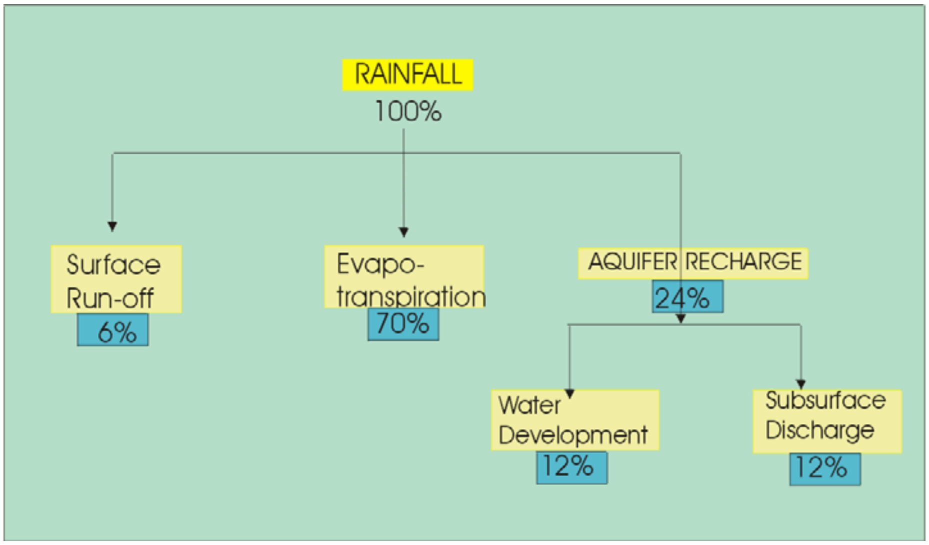
5.4. The hydrological cycle of the Maltese Islands is relatively simple and can be described in terms of a few basic processes:

5.5. The climate determines the distribution and availability of rainwater or precipitation that falls on the terrain. The average rainfall over the last 20 years is 619mm (Caruana, D., 1999). Morris, 1952, quotes 532mm as the average over 60 years. This rainwater is distributed as follows (see also **Figure 12**):

- Run-off (6%): That (small) part of the rainfall that is also termed overland flow that flows downhill into watercourses forming streams and rivers and is eventually discharged to the sea;
- Infiltration (24%): This is that part of the rainwater that enters the ground, and if it is in sufficient quantity saturates the soil and percolates downwards until it encounters a barrier, such as an impermeable bed like Blue Clay forming/recharging a perched aquifer or flows downward to sea level where, owing to its lower density, it floats over sea water forming/recharging the mean sea level aquifer.
- Evapotranspiration (70%): A part of the rainwater is retained by the soil and eventually lost to the atmosphere by direct evaporation or by transpiration from vegetation. Owing to the long dry season in the Maltese Islands this fraction is very high.

5.6. The recharge water is eventually extracted from the aquifer. Local hydrogeological practice considers that half of the recharge water (12%) is on average available for extraction all the year round, while the remaining fraction (12%) is ultimately returned to the sea by natural subsurface discharge along the coastline. (Debono, 1988).

Figure12: Water balance of the Maltese Islands



(After Debono 1988)

HYDROGEOLOGICAL AND HYDROLOGICAL FEATURES

5.7. The hydrological and hydrogeological features that in some way or another impact the Site are shown in **Figure 13**. It is seen that the site straddles Bajda Ridge and falls mainly within the catchment basin of the Mizieb-Mistra drainage basin. A smaller fraction of the area covered by the site falls in the Wied tal-Pwales. Wied ta' Ghajn Tuffieha to the east discharges into the site.

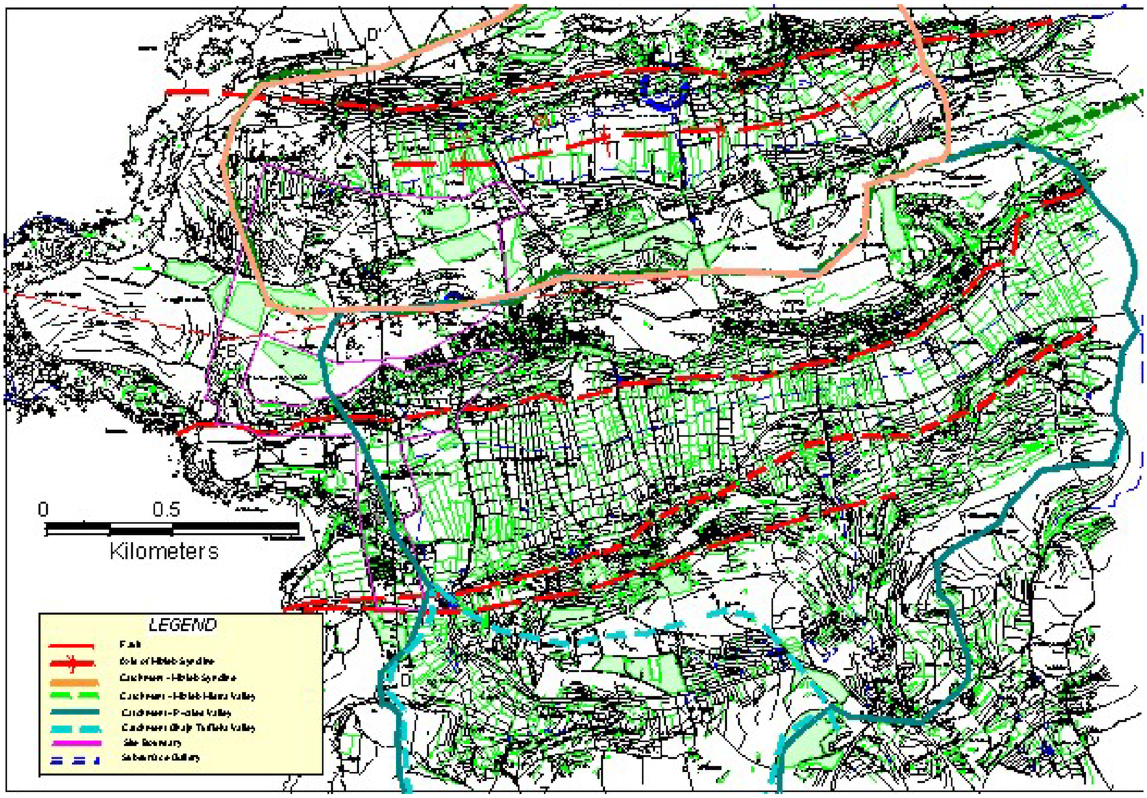
5.8. Of the total area of the site, which measures 1,060,000m^2, about 49% falls within the Wied tal-Mistra catchment basin, while about 27% falls within the Wied tal-Pwales catchment.

5.9. The hydrological and hydrogeological features comprise (from south to north):

- The coastal aquifer of Wied tal-Pwales;
- The watercourse and catchment of Wied ta' Ghajn Tuffieha;
- Tal-Fawwara spring and other intermittent surface springs;
- The aquifer of the Mizieb syncline;
- The catchment of the site.
- The watercourse and catchment of Wied tal Pwales;
- Private extraction in Wied tal-Pwales;

- Saline marsh at is-Simar designated as a Nature 2000 site; and
- The watercourse and catchment of Mizieb – Mistra Valley.

Figure 13: Catchment Basins of the Study Area



5.10. The main catchments are shown in **Figures 13 and 15**, while the respective areas of the catchments are shown in **Table 2** below:

Table 2: Area of catchments identified in the Study Area

Catchment	Area (m^2)
Proposed Site	1,333,000
Pwales Valley	5,551,000
Mizieb-Mistra Valley	4,318,000
Mizieb Basin	3,030,000

Watercourse of the Wied Tal-Pwales and its tributaries -Catchments

5.11. Wied Tal-Pwales is a broad trough orientated ENE-WSW developed on Upper Coralline Limestone between Wardija Ridge on the east and Bajda Ridge on the west.

It is parcelled into large plots of land. Owing to the high permeability of the limestone, a true watercourse is not developed. Minor tributaries are Wied ta' Ghajn Tuffieha and Wied tal-Palma.

5.12. The total catchment area including that of the tributaries is 555.1Ha

5.13. Blue Clay is exposed near sea level at Ghajn Tuffieha and Ramla tal-Mixquqa bays in the west, it dips to the NNE such that at the eastern end of the valley, at St Paul's Bay, it is deeply buried below sea level. A confined aquifer has developed, with seawater intrusion mainly possible from the east as the Blue Clay, being impermeable, inhibits upward seawater inflow. For this reason the Pwales aquifer has an exceptionally high recharge capacity; higher than that suggested by the size of the Pwales Valley. The aquifer is also recharged from the line of surface ephemeral springs along the Wardija Ridge and the leaking fault that extends from Ghajn Tuffieha to St Paul's Bay.

Downstream users

5.14. The aquifer is intensely exploited, mainly by the local farmers. Morris, 1952 says that at that time there were 70 shafts drilled to exploit the aquifer. The present number quoted is 74 (www.mra.org). Most probably the real number is much higher.

Is-Simar Salt Marsh

5.15. The eastern end of the valley formed an ancient beach and presently retains a thick sand layer on top of the Upper Coralline Limestone where the Nature reserve - Is-Simar salt marsh - is found.

Tal-Palma Spring

5.16. Tal-Palma Spring is the only significant perennial spring within the watershed of Pwales Valley on the slopes of Wardija Ridge.

Mizieb Syncline – Mistra Valley

5.17. The half graben developed between Bajda Ridge and Mellieha Ridge is the site of the Mizieb - Mistra Valley that sheds its run-off into Mistra Bay. The Mizieb segment of the valley is floored by a syncline termed the "Mizieb syncline", with the eastern continuation of the valley termed the "Mistra Valley".

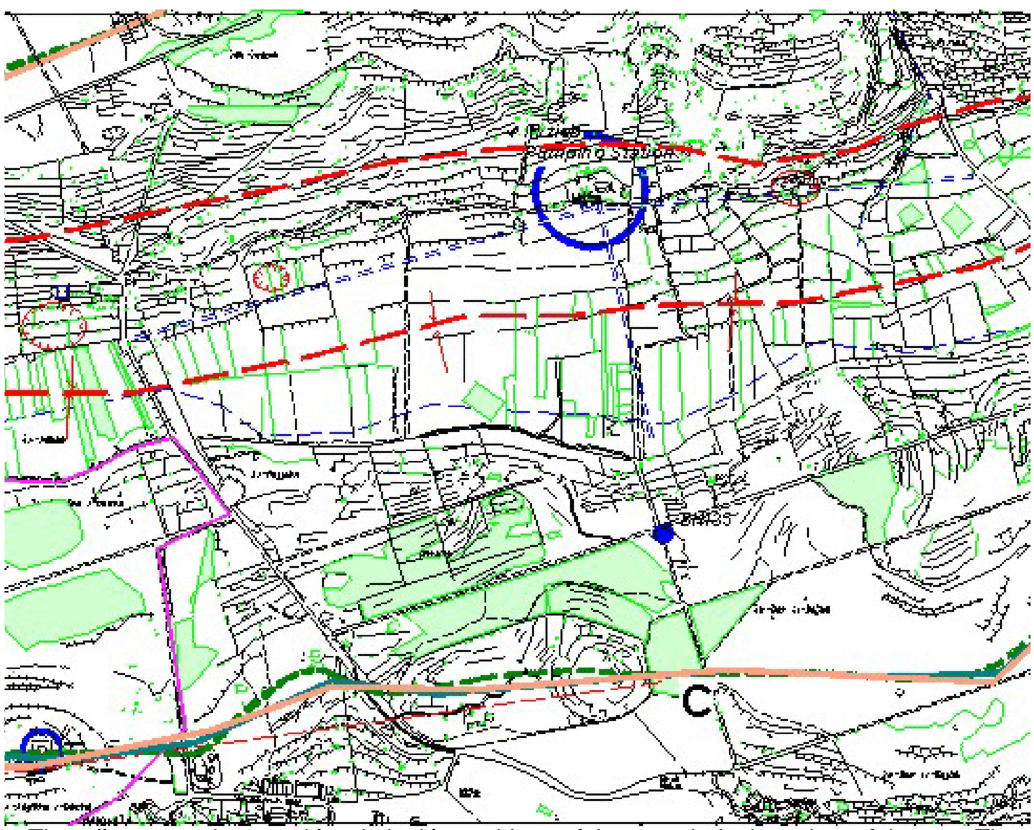
5.18. The Mizieb syncline is a synclinal fold, about 1.8km long by about 500m wide and having a catchment area of 303Ha that exposes Upper Coralline Limestone. The syncline was, generated by folding of the rock section during rock block movement when the Mizieb - Mistra fault was active, at the same time forming the adjoining Bajda and Mellieha ridges. Folding of the Upper Coralline Limestone and the underlying Blue Clay has produced a closed basin with an exceptional water storage capacity. This basin was punctured by the formation of deep sinkholes that connect the aquifer of the syncline to the mean sea level aquifer. See sinkholes in **Figures 4** and **14**. (The Mizieb section of the Mizieb - Mistra Valley is the surface expression of this syncline. It is the largest completely closed basin structure known within the Maltese Islands.

5.19. Standing water level within the basin is about 15m above sea level and up to 20m above the top of the Blue Clay.

5.20. This basin is exploited by three galleries, which lead groundwater to the Mizieb Pumping Station (**Figure 14**) which is capable of producing 500,000m^3 per year. It is recalled that presently the WSC abstracts about 16,000,000 m^3 of groundwater annually, only 6% of which comes from the perched aquifer and 94% from the mean sea level aquifer. Owing to the connection of the basin to the mean sea level aquifer via the existing sinkholes, its salinity may rise quickly through sea water intrusion. The aquifer is therefore regarded as a mean sea level aquifer.

5.21. The watersheds of the Mizieb Syncline and the larger catchment that includes Mistra Valley are shown in **Figure 15**.

Figure14: Mizieb pumping station and subsurface galleries



The galleries are shown as blue dashed lines. None of them reach the boundary of the site. The Manikata reservoir lies on the SW corner

Downstream Users

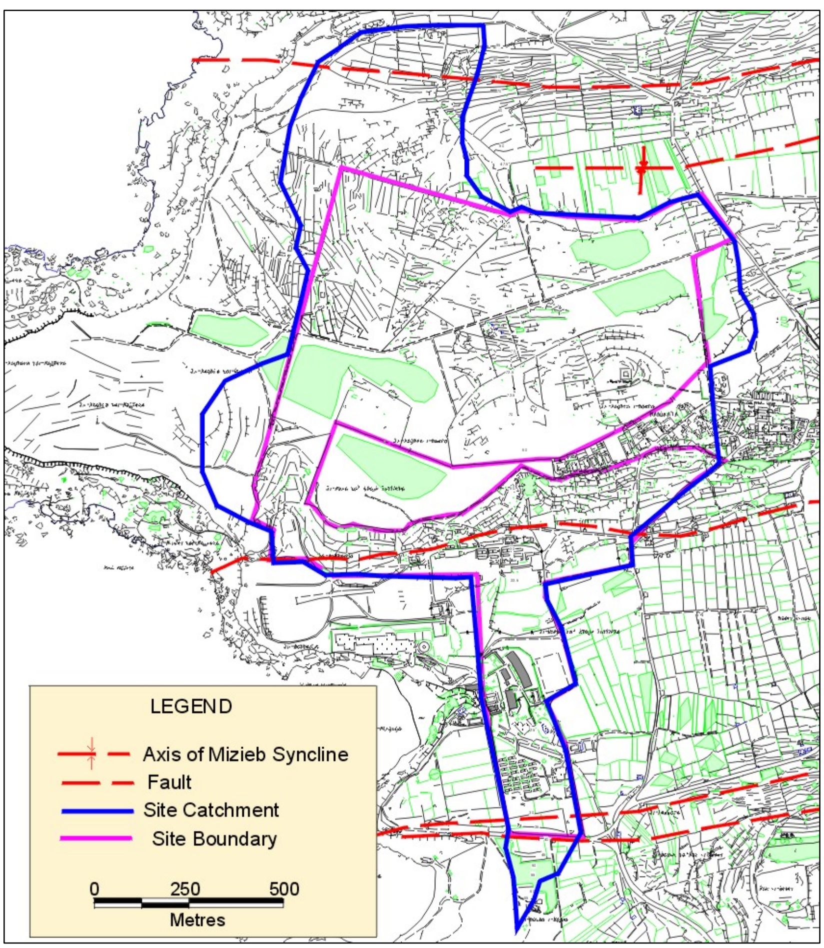
5.22. The Mizieb syncline is entirely exploited by the Water Services Corporation. Downstream in Wied tal-Mistra agriculture is very poor as it is mostly developed on Blue Clay. No groundwater is available here.

Other hydrological/hydrogeological features

5.23. **Ghajn Znuber** is the only significant perennial surface spring in the whole Mizieb - Mistra catchment. Water is drawn from a gallery about 145m driven up dip from the original natural spring at the base of the Upper Coralline Limestone beneath the Mellieha ridge.

5.24. **The Manikata Reservoir** lies on a hilltop 200m west of the Manikata church. It has a capacity of about 600m^3 and supplies water to the nearby village.

Figure15: Catchment area of the proposed site



Catchment of the Site

5.25. The site has a total area of 105.8 Ha and a catchment area of 153.2 Ha (**Figure 15**) lying entirely on exposed Upper Coralline Limestone. Its catchment partly falls within the Pwales catchment and partly within the Mizieb Basin Catchment. A small part falls in the diffuse drainage area which sheds its run-off along the western coastline.

Thickness of the unsaturated zone and hydraulic conductivity

5.26. Thickness of the unsaturated zone and hydraulic conductivity of the aquifers within the site are mainly based on the drilling results and permeability tests of Morris, 1952 and Costain 1958.

5.27. In that part of the site that falls within the Mizieb Basin, the thickness of the unsaturated zone is of the order of 33m, while the maximum preserved thickness of the Upper Coralline Limestone Formation was 42m. In that part of the site located on Bajda ridge, the unsaturated zone is up to 50 metres thick, and in the Hal-Ferh area of the site, the unsaturated zone of the Pwales Valley is about 22m. The maximum recorded thickness of the Upper Coralline Limestone in the Pwales Valley is about 65m.

5.28. Permeability tests carried out on samples of Upper Coralline Limestone gave permeability values ranging from 7.1 X 10^{-6} m/s to 2.8X10^{-8} m/s.

RUN-OFF ESTIMATES IN THE STUDY AREA

Catchment Areas

5.29. The catchment for the site and the valleys studied are shown in **Table 3**. Two methods have been adopted to calculate the run-off available in the Pwales and Mizieb - Mistra Valleys.

Method 1

5.30. The first method is based on average run-off, evapo-transpiration, and percolation measurements, as outlined in the previous paragraphs. The annual average run-off is normally expected to be about 6% of total rainfall (taken as 578mm). The shortfall of this method is that it does not give any indication of the timing during which run-off is likely to occur. This is important because the Study Area is covered by Upper Coralline Limestone, an intensely karstified rock of very high permeability, which will only permit run-off during flash floods.

Table 3: Run-off water estimates for the Study Area – Method 1

Catchment	Proposed Site	Pwales Valley	Mizieb – Mistra Valley	Mizieb Basin
Formation	**Upper Coralline Limestone**	**Upper Coralline Limestone and Blue Clay**	**Upper Coralline Limestone and Blue Clay**	**Upper Coralline Limestone**
Area of Catchment Ha.	105.8	555.1	431.8	303.0
Rainfall m^3	590,000	3,208,000	2,496,000	1,751,000
Run-off m^3 @6%	35,000	193,000	150,000	105,000
Available for Aquifer recharge @ 25% m^3	148,000	802,000	624,000	438,000
Recharge % of the total of the two valleys	10	56	44	31

Note: The Mizieb Basin forms part of the Mizieb - Mistra Valley. No mean sea level aquifer is expected to develop downstream from this basin as the predominant bedrock, Upper and Middle Globigerina Limestone, which are expected to subcrop at sea level, have very low permeability.

5.31. The average annual volume of run-off in cubic metres for the different catchments is listed in the **Table 3**. This also shows the rock formations of the catchment and the percentage run-off applied. For this purpose the average annual precipitation has been taken as 578mm.

5.32. It is seen that the recharge capacity of the site is about 9.7% of the total recharge in the two valleys impacted by the site. Note that the volume of run-off stored in the Study Area is negligible.

Method 2

5.33. The second method for estimating run-off is based on direct measurements of evapo-transpiration available from previous studies in the Maltese Islands (ATIGA, 1972) and consideration of water availability on a monthly basis, (compared with water availability on an annual average basis used in the first method). Of the total rainfall, the fraction of rainwater that is not lost in the saturation of the soil and subsoil or through evapo-transpiration is 178mm.[11] A fraction of this water percolates into the subsurface (75% of 178mm) while the remainder becomes run-off (25% of 178mm).

[11] ATIGA Consortium (1972), *Waste Disposal and Water Supply Project in Gozo* (Vol III)

Table 4: Summary of the monthly run-off available calculated on the basis of soil-moisture deficit – Method 2

Month	Precipitation Mm	Soil-Moisture Deficit mm	Run-off proposed Site	Run-off Pwales Valley m^3	Run-off Mizieb -Mistra Valley	Run-off Mizieb Basin
Jan	88.2	43.2	11430	59950	46630	32720
Feb	61.4	6.4	1690	8880	6910	4850
Mar	44.0	-7	0	0	0	0
Apr	27.5	-60.5	0	0	0	0
May	9.7	-110.3	0	0	0	0
Jun	3.4	-223.6	0	0	0	0
Jul	0.9	-228.1	0	0	0	0
Aug	9.2	-244.8	0	0	0	0
Sept	44.4	-78.6	0	0	0	0
Oct	117.9	53.9	14260	74800	58190	40830
Nov	75.5	14.5	3840	20120	15650	10980
Dec	96.0	60	15870	83270	64770	45450
Total	578.1	-774.9	47000	247,000	192,000	105,000

5.34. The second method quantifies run-off, on a monthly basis rather than on an average annual basis. (see **Table 4**)

5.35. The higher values derived in the second method are due to a higher percentage contribution to run-off. For accurate values, it is necessary to take direct measurements in the Study Area. Such measurements are not available. The two sets of results would suggest that a considerable quantity of run-off is available for possible storage.

5.36. There are no ephemeral or permanent springs within the catchment of the proposed site.

WATER QUALITY

5.37. The purpose of this section of the Report is to:

- Describe the quality of the water in the two water bodies that may be affected by the construction and operation of the proposed golf course: the aquifer underlying the Pwales Valley and the Mizieb aquifer; and

- To describe the quality of the surface water runoff from the golf course site

Ground water quality

Pwales Valley

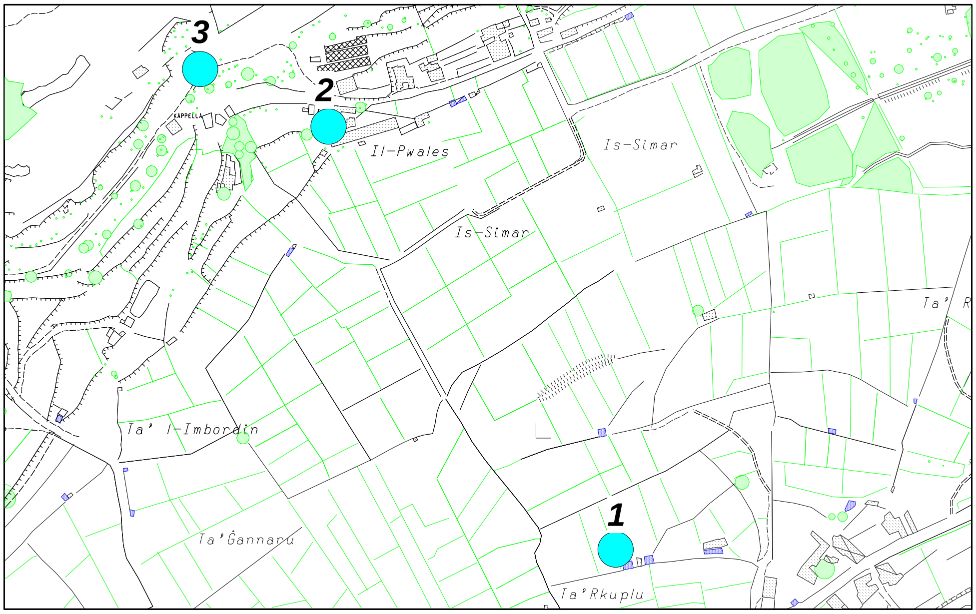
5.38. The first water quality study of the aquifer underlying the Pwales valley was undertaken by Robinson in1943. The salinity measured was about 2000ppm. In his reports, Morris, 1952, records that the water quality could deteriorate very quickly with over-abstraction, rendering it undrinkable. Experience shows that this is in fact so. Moreover, due to intensive agricultural activities on a highly permeable Upper Coralline Limestone terrain, nitrate levels are high. To assess the present water quality in the groundwater in Pwales Valley two water samples were collected from two private boreholes. A third sample was collected from a Tal-Pwales Spring which taps the perched aquifer beneath Bajda Ridge.(see **Table 5**). The location of the sampling points is shown on the map in **Figure 16**. No analysis for pesticides was undertaken.

5.39. Since abstraction is not regulated, the water quality may vary widely depending on the activities of the downstream users. Presently there are no activities within the proposed site and therefore the present quality of the groundwater found in Pwales Valley is not affected by the run-off from the proposed site. In fact, in sheet 0006 for the Pwales perched groundwater body the MRA (www.mra.org.mt) (**Appendix 1**) gives the following data on potential treats from diffuse and point sources:

Table 5: Water quality in the aquifer underlying the Pwales Valley and Bajda Ridge perched aquifer

Parameter /	Units	Sample 1	Sample 2	Sample 3	EU Standard
Locality		**Ta Rkuplu**	**Il-Pwales**	**Il-Pwales Spring (Bajda Ridge perched aquifer)**	
Chlorides	mg/l	2360	2400	290	200
Nitrates	mg/l	75.31	89.49	41.64	50
Nitrites	mg/l	<0.1	<0.1	<0.1	20
Phosphates	mg/l	<0.2	<0.2	<0.2	na

Figure 16: Groundwater sampling points



5.40. Due to its low quality this aquifer has never been abstracted for distribution in the local water supply network

Bajda Ridge

5.41. The water quality of the perched aquifer beneath Bajda ridge was assessed on the basis of one water sample (sample No 3) collected from a spring close to the chapel at Il-Pwales (**Figure 16**). The results are listed in **Table 5** together with those of Pwales Valley. The Laboratory test results show that the groundwater is of a very good quality.

Mizieb syncline

5.42. Unlike the Pwales groundwater body, the Mizieb Groundwater body is of excellent quality, hence its predominant exploitation by the WSC.

5.43. Chloride content in the presence of controlled abstraction exceeds 500ppm which is more than the accepted levels in water intended for human consumption.

5.44. The Nitrate levels are under 50ppm (www:mra.org.mt).

5.45. A main sewer pipeline runs from Pwales to Bajda Ridge, whence it crosses the Mizieb Basin and rises up to Mellieha ridge from where it runs down to the discharge point at ic-Cumnija.

Table 6: Water quality in the Mizieb aquifer

Parameter	Units	Quantity	EU Standard
Chlorides	mg/l	>500	200
Nitrates	mg/l	< 50	50
Nitrites	mg/l	na	20
Phosphates	mg/l	na	na
Pesticides	ug/l	<0.5	na

Source: (www:mra.org.mt)

Surface runoff quality

Mizieb

5.46. No analysis of surface run-off was undertaken. The runoff water quality depends a lot on the terrain on which it flows on its way to the closest watercourse. Since most of the site is devoid of any agricultural activity or animal husbandry this is expected to be low in chlorides, nitrates, nitrites, and phosphates. As it traverses agricultural land, it would be expected to become enriched in nitrates and other chemicals present in the soil and normally associated with agricultural activities like spreading of fertiliser and spraying of pesticides. As the aquifer (Upper Coralline Limestone) is highly permeable this is reflected in the water quality of the groundwater (**Table 6**).

Pwales Valley

No analysis of surface run-off of Pwales Valley was undertaken. The run-off water quality depends a lot on the terrain on which it flows on its way to the closest watercourse. Since agricultural activity in this valley is intensive, this is expected to be low in chlorides but high in nitrates and pesticides. As the aquifer (Upper Coralline Limestone) is highly permeable the quality of the run-off would be reflected in that of the groundwater. **Table 5**) shows that the nitrate content of water samples No1 and No 2 is very high.

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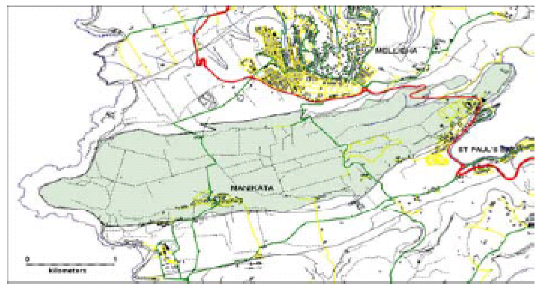
Appendix 1

Ground water bodies

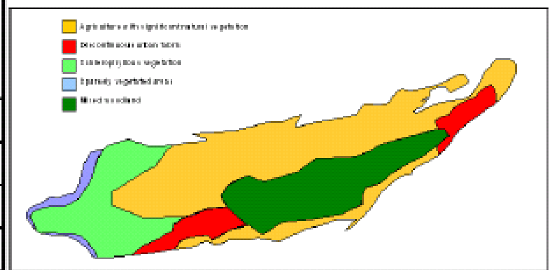
MALTA RESOURCES AUTHORITY

Groundwater Body Code	
MT006	
Groundwater Body Name	
Mizieb Mean Sea Level Groundwater Body	
Reference Year	
2004	



General Characteristics	
Location	
The Mizieb Upper Coralline Limestone Aquifer is situated in the northern region of Malta and is bounded in the north by the Mizieb-Mistra Fault and the Manikata-Simar Fault in the south. The Mizieb syncline is the largest 'closed' basin structure known within the Maltese Islands. The occurrence of the Upper Coralline Limestone underlain by the Blue Clay in a synclinal structure gives rise to an ideal groundwater storage facility.	
Area	5.2km^2
Main Aquifer	Lower Coralline Limestone
Main Aquifer Type	Fractured Carbonate Media
Groundwater Horizon	1
Maximum Length	1.3km
Maximum Width	5.7km
Mathematical centre of groundwater body	442500, 3978500
Hydro-geological characteristics	
Stratigraphy	Tertiary—Miocene
Mean Annual Precipitation	524mm
Mean Aquifer Thickness	31.5m
Main Recharge Source	Precipitation
Mean Annual Recharge	1.1hm^3
Pressures	
Main Land-Use Features (Corinne Landcover 2000)	
Discontinuous urban fabric	8%
Agriculture with significant area of natural vegetation	48%
Schlerophyllous vegetation	19%
Sparsely vegetated areas	3%
Mixed woodland	22%
Other Pressures	
Water Abstraction Purpose	Potable Supply, Irrigation
Artificial Recharge	Minimal
Associated Aquatic Ecosystems	None

MALTA RESOURCES AUTHORITY

Groundwater Body Code	
MT006	
Groundwater Body Name	
Mizieb Mean Sea Level Groundwater Body	
Reference Year	
2004	Corinne Landcover 2000

Hydrogeological Characteristics

Aquifer Description

The aquifer formation in the region is the Upper Coralline Limestone. Due to its lithographic nature and its sensitivity to weathering this formation should hosts a generalized aquifer. The UCL formation varies considerably in thickness due to erosion. The formation achieves a maximum thickness 97m in the Mizieb area and can be described shallow water deposit of variable composition.

Mean Aquifer Thickness	31.5m
Soil Type and Indicative Thickness	Main soil type is Terra Soil. Indicative thickness 70-100cm (exceeds 100cm in Mizieb valley)
Mean Hydraulic Conductivity	2.93E-6m/s
Mean Annual Groundwater Level Amplitude	n/a

Pressures—Quantitative Status

Mean Annual Recharge (Natural and Artificial)	$1.11hm^3$
Mean Annual Groundwater Demand	$0.96hm^3$
Balance	$0.15hm^3$
WSC Groundwater Sources	1 pumping station, 1 borehole (unutilized)
Registered Private Groundwater Sources	8 boreholes

Pressures—Qualitative Status

Principal Diffuse sources of Pollution	Intensive Agriculture
Principal Point sources of Pollution	Main Sewer
Nitrate Content in Groundwater	Low—less than 50mg/l
Chloride Content in Groundwater	Exceeds 500mg/l
Pesticide Content in Groundwater	Low—total pesticide content below 0.5µg/l
Other Pollutants	n/a
Direct discharges to Groundwater	No direct discharges have been permitted

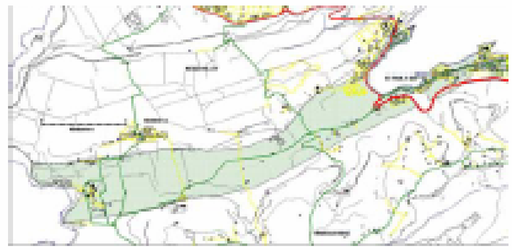
Associated Aquatic Ecosystems-Sites under investigation

No sites enclosing groundwater dependent eco-systems have been identified.

Preliminary Risk Assessment

The 'water balance' estimate for this groundwater body has a slightly positive outcome, whilst recorded nitrate levels are lower than the 50mg/l parametric limit and saline intrusion is limited. Further in-depth investigations are needed to determine current and future trends with respect to the attainment of good 'status' as required by the WFD.

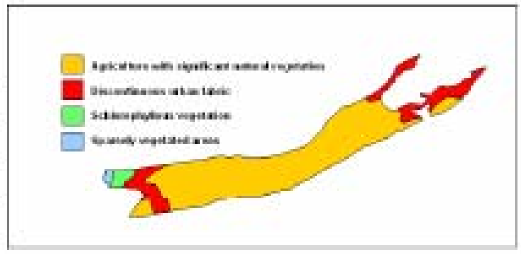
MRA
MALTA RESOURCES AUTHORITY



Groundwater Body Code	
MT005	
Groundwater Body Name	
Pwales Coastal Groundwater Body	
Reference Year	
2004	
General Characteristics	
Location	
The Pwales aquifer forms a low block between the Wardija and the Bajda Ridges, with its base rising slightly above sea level in the west, resulting in a limited area perched above sea level; whilst to the east where the Blue Clay formation dips below sea level it is in direct contact with the sea. The Blue Clay base is probably breached below sea level by sink-holes and faults allowing limited vertical contact with sea water.	
Area	2.8km^2
Main Aquifer	Upper Coralline Limestone
Main Aquifer Type	Fractured Carbonate Media
Groundwater Horizon	1
Maximum Length	0.7km
Maximum Width	5.6km
Mathematical centre of groundwater body	444000, 3977900
Hydro-geological characteristics	
Stratigraphy	Tertiary—Miocene
Mean Annual Precipitation	524mm
Mean Aquifer Thickness	n/a
Main Recharge Source	Precipitation
Mean Annual Recharge	0.7hm^3
Pressures	
Main Land-Use Features (Corinne Landcover 2000)	
Discontinuous urban fabric	17%
Agriculture with significant area of natural vegetation	80%
Schlerophyllous vegetation	2%
Sparsely vegetated areas	1%
Other Pressures	
Water Abstraction Purpose	Irrigation
Artificial Recharge	No
Possible Associated Aquatic Ecosystems	Is-Simar Saline Marshlands

MRA

MALTA RESOURCES AUTHORITY

Groundwater Body Code	 Corinne Landcover 2000
MT005	
Groundwater Body Name	
Pwales Coastal Groundwater Body	
Reference Year	
2004	

Hydrogeological Characteristics

Aquifer Description

The Upper Coralline Limestone aquifer forms a low block between ridges, with its base rising slightly to the west, with a limited area perched above sea level, while to the east it is in direct contact with the sea. This groundwater body is partly contained in alluvial fill towards the centre of the graben.

Mean Aquifer Thickness	n/a
Soil Type and Indicative Thickness	Main soil type is Terra Soils. Indicative thickness 60cm
Mean Hydraulic Conductivity	2.93E-6m/s
Mean Annual Groundwater Level Amplitude	n/a
Pressures—Quantitative Status	
Mean Annual Recharge (Natural and Artificial)	0.70hm^3
Mean Annual Groundwater Demand	0.69hm^3
Balance	0.01hm^3 (Groundwater resources are insufficient to sustain agricultural demand in overlying catchment area)
WSC Groundwater Sources	None
Registered Private Groundwater Sources	74 boreholes and 2 springs
Pressures—Qualitative Status	
Principal Diffuse sources of Pollution	Intensive Agricultural Activities
Principal Point sources of Pollution	Animal Husbandry Activities
Nitrate Content in Groundwater	Not known but expected to be fairly high due to agriculture and low depths to the piezometric surface.
Chloride Content in Groundwater	High
Pesticide Content in Groundwater	No data available; however the karstic nature of the aquifer makes it highly vulnerable to pesticide pollution.
Other Pollutants	n/a
Direct discharges to Groundwater	No direct discharges have been permitted

Associated Aquatic Ecosystems-sites under investigation

The catchment area of the Pwales aquifer encloses the Saline marshland at Is-Simar. It has been a protected area since 1993 and supports one of the most important saline marshlands in the Maltese Islands for birds and the Maltese killifish, as well as its important marshland vegetation. It has also been internationally designated as a wetland of international importance in view of the Ramsar Convention. The degree of dependence of this eco-system on groundwater is currently being investigated.

Preliminary Risk Assessment

Groundwater Body is at risk of failing to achieve the Environmental Objectives of the Regulations both from the point of view of criteria related to the achievement of 'good' quantitative and qualitative status. It should be noted that the groundwater body is also expected to be at risk of failing to achieve the objectives set in the Nitrates Regulations.