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APPROPRIATE TECHNOLOGIES AND NATURAL SYSTEMS FOR WASTEWATER TREATMENT IN LOW- AND MIDDLE-INCOME COUNTRIES

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ABSTRACT

Wastewater management is an environmental and social burden that primarily affects populations in Low- and Middle-Income Countries and the global environment. Wastewater collection, treatment, and reuse have become urgent, especially considering that 80% of the world's wastewater is untreated or improperly treated and discharged directly into water bodies. In recent years, the role of wastewater treatment plants in a sustainable water cycle has become even more critical, as they are the final destination of the collected wastewater. Indeed, the management of wastewater treatment plants should play an essential role in achieving SDG target 6.3 of the United Nations 2030 Agenda for SD. Achieving this SDG requires significant investments in new and existing infrastructures, in the realization of appropriate technologies to increase the treatment and use of wastewater, in capacity building for water resources management, and in monitoring and controlling of water and wastewater quality. In this context, water reuse, especially wastewater reuse, plays a key role.

This research focuses on investigating the valorization of wastewater resources applying Appropriate Technologies and Natural Systems for wastewater treatment in two different Low- and Middle-Income Countries, particularly in the Palestinian Territories and Sub-Saharan Africa. The research objectives are: (1) Determine the characteristics and quality of wastewater in the two case studies analysed. (2) Identify Appropriate Technology to be used in the Palestinian Territories to treat wastewater for reuse in agriculture. (3) Assess the environmental, economic, and social impacts of this project. (4) Assess the feasibility of using natural wetlands for household wastewater treatment in Sub-Saharan region.

The first study, conducted in Rafah, Gaza Strip, showed that implementing existing primary treatment plant with a natural secondary treatment plant properly optimized the wastewater quality for reuse in agriculture and was suitable for the study area.

The second case study was conducted in Cape Coast, Ghana. It shows that the natural wetland studied is currently overly polluted and threatened by various anthropogenic factors that cannot remove pollutants from the incoming domestic wastewater. Therefore, some recommendations were made in order to improve the efficiency of this natural wetland.

DEDICATION

This research work is dedicated to my parents (Elda and Rosado)

and my sister (Elena)

"Be the change that you want to see in the world "

M. Gandhi

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No words can describe the mental support I received from William, thanks for your lovely presence.

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List of Acronyms

ADA	Austrian Development Agency
AHP	Analytic Hierarchy Process
AICS	Italian Agency for Cooperation and Development
ANP	Analytic Network Process
AT	Appropriate Technology
BOD	Biological Oxygen Demand
BoQ	Bill of Quantities
CMWU	Coastal Municipality Water Utility
COD	Chemical Oxygen Demand
CW	Constructed Wetland
DEA	Data Envelopment Analysis
DICAM	Department of Civil, Chemical, Environmental and Material Engineering
DO	Dissolved Oxygen
EC	Electrical Conductivity
ECG	Electricity Company of Ghana
EHS	Environmental Health and Safety
EIA	Environmental Impact Assessment
ELECTRE	Elimination and Choice Expressing Reality
EMP	Environmental Management Plan
EQA	Environmental Quality Authority
ER	Evidential Reasoning
ESIA	Environmental and Social Impacts Assessment
ESMP	Environmental and Social Management Plan
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
FSS	Farm Structure Survey
FTW	Floating Treatment Wetland
FWS	Free Water Surface
GDP	Gross Domestic Product
GEPA	Ghana Environmental Protection Agency
GIS	Geographical Information Systems
GP	Global Programming
GSS	Ghana Statistical Service
GWCL	Ghana Water Company Limited
HF	Horizontal Flow
HHs	Households
HSF	Horizontal Flow
IUCN	International Union for the Conservation of Nature

JSCKRM	Joint Services Council of Khan Younis, Rafah, and Middle area
LGU	Local Government Unit
LMIC	Low- and Middle- Income Countries
MADM	Multi-Attribute Decision Making
MAUT	Multi-Attribute Utility Theory
MCDA	Multi Criteria Decision Analysis
MCM	Million Cubic Meters
MoA	Ministry of Agriculture
NBS	Nature-Based Solution
NGO	Non-Governmental Organization
NH_4	Ammonia
NO_2	Nitrite
NO_3	Nitrate
NPI	Nemerow's Pollution Index
NTS	Natural Treatment System
NTU	Nephelometric Turbidity Unit
NWTS	Natural Wastewater Treatment System
O&M	Operation and Maintenance
PEAP	Palestinian Environmental Assessment Policy
PMU	Project Management Unit
PPE	Personal Protective Equipment
PWA	Palestinian Water Authority
SD	Sustainable Development
SDG	Sustainable Development Goal
SMART	Simple Multi-Attribute Value Theory
SF	Subsurface Flow
TA	Total Alkalinity
TH	Total Hardness
TDS	Total Dissolved Solids
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
ToT	Training of Trainers
TP	Total Phosphorus
TSS	Total Suspended Solids
UAWC	Union of Agricultural Work Committees
UCAS	Union College of Applied Sciences
UCC	University of Cape Coast
VF	Vertical Flow
VIP	Ventilated Improved Pit
WAI	Weighted Arithmetic Index
WAWQI	Weighted Arithmetic Water Quality Index

WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WPM	Weighted Product Model
WSM	Weighted Sum Model
WSP	Wastewater Stabilization Pond
WQI	Water Quality Index
WWTP	Wastewater Treatment Plant

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CHAPTER 1.

Introduction

1.1 Background of the study

1.1.1 World's water availability, quality, and use

Climate change, depletion of natural resources, and world population growth are alarm bells for the future that must push humanity to more sustainable use of natural resources, particularly water.

Water is globally recognized as a renewable but finite resource. The increasing global population, the growing urbanization, the rapid industrialization, and the intensifying food production have put pressure on water resources and affected the number of freshwater resources available for individuals.

Global freshwater use has increased by a factor of six over the past 100 years and continues to grow at a rate of 1% per year since the 1980s (Ritchie, 2017). While freshwater withdrawals in developed countries have become stable or slightly declined, it continues to grow in most of developing countries (Ritchie and Roser, 2018).

Burek et al. (2016) estimated that global water use would likely continue to grow at an annual rate of about 1%, resulting in an increase of 20 to 30% above the current level of water use by 2050.

FAO estimates that around 69% of the global freshwater withdrawals are consumed by agriculture, mainly used for irrigation, livestock, and aquaculture, and this percentage can reach up to 90% in some developing countries (FAO/IFA/UNICEF/WEP/WHO, 2020). Industrial consumption currently accounts for 19% of global withdrawals, whiles municipalities are responsible for the remaining 12%. FAO also show an increasing competition in agricultural water use. In particular, higher demands are expected from industrial and energy sectors but also at domestic level. The increase of municipal supply is especially due to industrial development and sanitation service needs in Low-and Middle-Income Countries (LMIC) (FAO/IFA/UNICEF/WEP/WHO, 2020).

Another factor to consider is the water stress. The water stress, measured as water utilized as a function of water available supply, affects many parts of the world (see Fig. 1-1). Over 2 billion people live in countries that are water stressed (United Nations/UNESCO, 2018). About 500 million people live in areas where water consumption exceeds the locally renewable water resources by a factor of two. Mekonnen and Hoekstra (2016) estimated that four billion people live in an area that suffers from severe physical water scarcity for at least one month per year. In addition, climate change is likely increasing season variability, creating a more erratic and uncertain water force, aggravating problems in the previously water-stressed area and potentially generating water stress in a place where it has not yet been a recurrent phenomenon (WWAP/UN-Water, 2021).

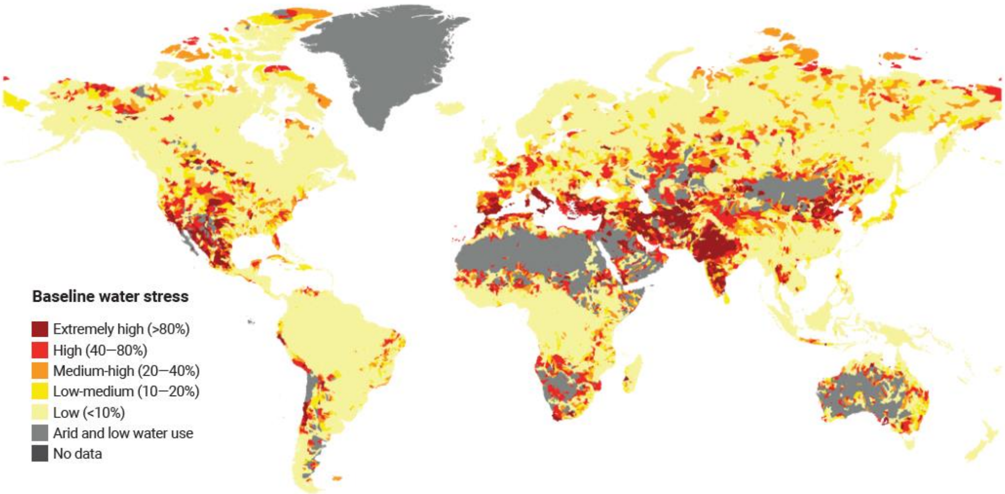


Fig.1- 1_Annual baseline water stress.

Source: WRI, 2019

To ensure the sustainability of water resources, freshwater replenishment rates have to outpace those of water withdrawals. This can be achieved through a more frequent sustainable consumption pattern and water use during the hydrological cycle. A sustainable consumption pattern can be achieved by using the available technologies and devices to reduce water consumption without significantly influencing the lifestyles of people. The second alternative relates to wastewater treatment and reuse.

The availability of water resources is also intrinsically linked to water quality, as the pollution of water sources may prohibit the different types of uses. Global water quality data remain sparse due to a lack of monitoring and reporting capacity, especially in many developing countries, nonetheless, several trends have been reported. Water quality has deteriorated due to pollution in the majority of rivers in Africa, Asia, and Latin America. Nutrient loading, which is often associated with pathogen loading, is among the most prevalent sources of pollution (UNEP, 2016).

Increased discharges of untreated sewage, combined with agricultural runoff and inadequately treated wastewater from industry, causes the degradation of water quality worldwide. Still,

water quality will continue to degrade over the coming decades, particularly in resource-poor countries in dry areas, further endangering human health and ecosystems, contributing to water scarcity, and constraining sustainable economic development (WWAP/UN-Water, 2017).
In addition, 2.1 billion people have gained access to improved sanitation facilities since 1990, 2.4 billion do not have access to improved sanitation, and nearly 1 billion people worldwide still practice open defecation (WHO/UNICEF JMP, 2021). The possibility of increased access improved sanitation services can contribute significantly to reducing health related risks but lead to increased water consumption.
In water management, improved wastewater management can help realize health gains, i.e., preventing human contact with excreta.
Water management solutions that focus on protecting existing global water resources from pollution and applying efficient water management methods are fundamental steps, but they are no longer enough. It is necessary to broaden the perspective, to consider all the resource cycles together, to change the economic structure from linear ("take-produce-use-dispose") to circular (Ellen MacArthur Foundation, 2018). Resources must be used sparingly, the efficiency of industrial processes must be improved, and waste valorised and reused as new valuable secondary raw materials.
For all these reasons, a change in the use of the water cycle may be necessary to maximize the extraction of value from water cycles at all levels (river basin, city, industrial unit, building) to increase water efficiency and prevent further degradation of the environment. A new water scheme must be implemented, in which the waste paradigm must be substituted with a resource-oriented paradigm (Ellen MacArthur Foundation, 2018).

1.1.2 Global trends of wastewater generation and treatment

Most human activities that use water produce wastewater. As direct consequence of the growth in water, higher wastewater volumes are intensely produced, generating an important increase in global pollution (WWAP/UN-Water, 2017). The consequences of releasing untreated or inadequately treated wastewater can be classified into three groups: i) harmful effects on human health; ii) negative environmental impacts; iii) adverse repercussions on economic activities.
Therefore wastewater collection, treatment, and reuse have become urgent, especially considering that 80% of worldwide wastewater are untreated or not correctly treated and directly discharged into water bodies (UN-WATER, 2015).
Wastewater treatment varies among the different income countries. On average, high-income countries treat about 70% of the municipal and industrial wastewater they generate. That ratio

goes down to 38% in upper-middle-income countries, 28% in lower middle-income countries, and only 8% for low-income countries (WWAP/UN-Water, 2017).

Data completeness regarding wastewater generation and treatment remain a challenge that must be addressed to monitor the progress on safe wastewater management and advocate the improvement of national monitoring programmes that will address data deficiencies (Thevenon and Shantz, 2021).

Although data on wastewater generation, collection and treatment is grossly lacking, it is clear that, the vast majority of wastewater is neither collected nor treated worldwide.

Fig. 1-2 shows wastewater data plotted at country level in proportional terms (m^3/yr per capita production; % of produced wastewater for collection, treatment, and reuse), by showing the comparisons between countries.

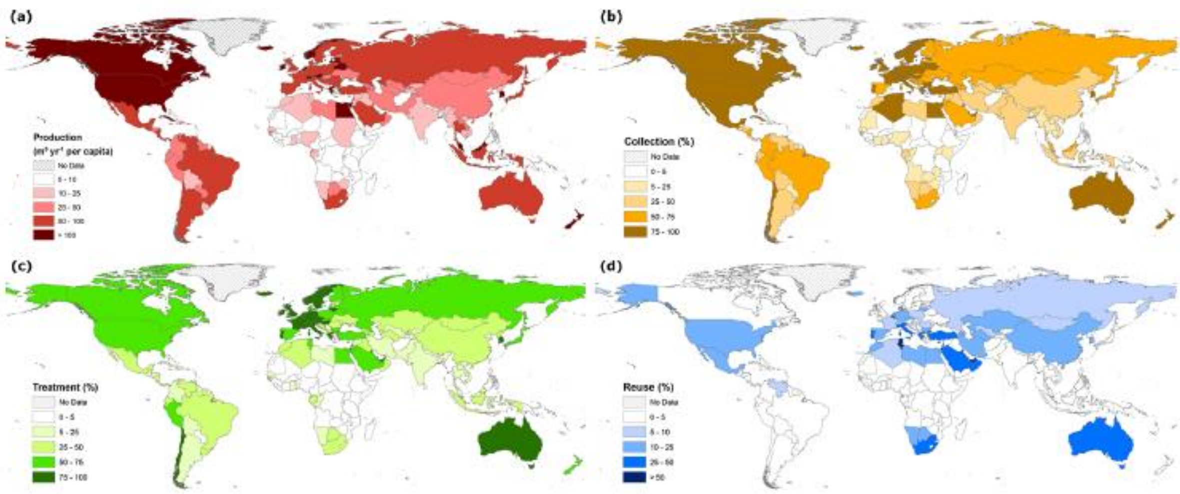


Fig.1- 2_(a) Wastewater production (m^3/yr per capita); (b) % of Wastewater Collected;(c) % of Wastewater Treatment; (d) % of Wastewater reuse.

Source: Jones et al. (2021)

Substantial differences in wastewater production, collection, treatment and reuse appear across different geographic regions and by the level of economic development.

Wastewater production per capita is notably highest in North America at 209.5 (m^3 /yr per capita), over double that of western Europe 91.7 (m^3 /yr per capita), the next highest wastewater production region per capita. Wastewater production also varies greatly with level of economic development. In fact, wastewater production per capita more than doubles at each income classification (6.4 m^3 /yr per capita) to high income (126 m^3 /yr per capita) (Jones et al., 2021).

Regarding wastewater collection and treatment, the rates are highest in western Europe (respectively 88% and 86%) and lowest in South Asia (respectively 31% and 16%) and Sub-Saharan Africa (23% and 16%). Also treated wastewater reuse is too low in area with low wastewater treatment rates, such as South Asia and Sub-Saharan Africa (Jones et al., 2021).

1.1.2.1 Focus on wastewater production and reuse in African and Asian Countries

In all Developing Countries, the vast majority of wastewater is released directly to the environment without adequate treatment, with detrimental impacts on human health, economic productivity, the quality of ambient freshwater resources, and ecosystems.

Table 1-1 shows the volume of municipal wastewater generated, collected, and treated in some African and Asian countries in 2018. The proportion of treated wastewater across Asia is far better than that in Africa. The situation in north Africa is more promising than in other parts of Africa.

Table 1- 1_Municipal wastewater generated, collected and treated, 2018

Country	Generated*	Collected*	Treated**	Country	Generated*	Collected*	Treated**
Africa				*Asia*			
Algeria	1.500	0.705	27	Iran	3.548	1.162	25
Burkina Faso	0.049	0.002	2	Iraq	1.030	0.579	55
Cameroon	0.0662	n.a	na	Jordan	0.180	0.115	82
Egypt	7.078	6.497	60	Kuwait	0.292	0.319	99
Eritrea	0.018	na	na	Lebanon	0.310	0.103	18
Ghana	0.280	0.028	8	Malaysia	4.227	na	62
Kenya	0.0805	na	0	Oman	0.108	0.094	87
Libya	0.504	0.167	8	Pakistan	3.060	na	1
Mali	0.0967	na	na	Palestine	0.122	0.071	58
Morocco	0.700	na	24	Qatar	0.274	0.258	93
Namibia	0.020	na	30	Sri Lanka	0.118	na	na
Senegal	0.070	na	16	Thailand	5.110	1.168	23
South Africa	2.420	2.769	91	Turkey	5.280	4.795	80
Tunisia	0.312	0.277	88	Vietnam	1.972	0.197	10
Zambia	0.1184	na	na				
Zimbabwe	0.138	0.0003	54				

*Note: na=No data available; * in km^3/year; **in %*

Source: FAO AQUASTAT, 2021

In 2012 only about 32% of municipal wastewater generated in Asia was reported to be treated (WEPA-IGES, 2012),and increased to more than 60% in 2018. Limited consistent data across

Africa is a challenge for reporting on wastewater treatment and reuse. The analysis of the available data by FAO shows that over 75% of the countries in Africa lack consistent data on wastewater treatment and reuse. The most common constraint to wastewater treatment and reuse in developing countries is high population, lack of financial resources, lack of well-defined policies and the shortage of qualified personnel in the field of wastewater management (AfDB; UNEP and GRID-ARENDAL, 2020).

Wastewater is considered as a valuable resource when required level of treatment is guaranteed. Reuse of treated wastewater is during the infant stage and varies across countries. The extent of reuse is influenced by political will, people perception, national regulations, among others (AfDB, UNEP and GRID-ARENDAL, 2020).

The proportions of treated wastewater directly used across Asia and Africa are presented in Fig. 1-3.

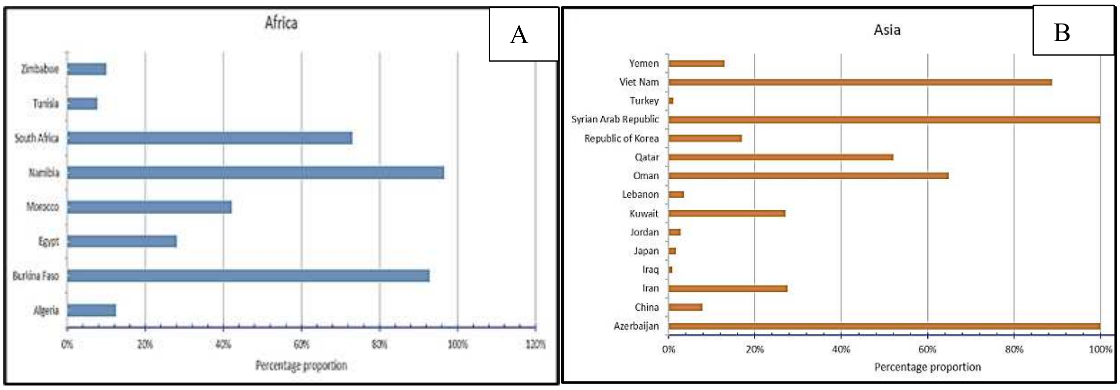


Fig.1- 3_Proportion of treated wastewater directly used across African (A) and Asian Countries (B), 2018.

Source: FAO AQUASTAT, 2021

The number of countries in Asia that reuse the treated wastewater is more than in Africa. FAO reported that only about five countries in Africa and seven in Asia reuse more than 20% of their treated wastewater (see Fig. 1-3).

1.1.3 Wastewater and the United Nations 2030 Agenda

Wastewater treatment and reuse reduce the demand for new water sources and effluent discharge into the natural environment. To ensure wastewater treatment and reuse at a global scale, wastewater management is included in Sustainable Development Goal (SDG) 6 (Clean Water and Sanitation), and it aims to "ensure availability and sustainable management of water and sanitation for all". In specific, the SDG target 6.3 states: "By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally". It commits governments to halve the proportion of untreated wastewater and substantially increasing recycling and safe reuse by 2030.

The extremely low level of wastewater treatment described in Section 1.1.2.1, reveals an urgent need for technological upgrades and safe water reuse options to support the achievement of Target 6.3, which is critical for achieving the entire United Nations 2030 Agenda for Sustainable Development (SD) (United Nations, 2015). Improved wastewater treatment and increased water reuse will support the transition to a circular economy.

In fact, wastewater reuse has been considered an alternative way of overcoming water scarcity in many parts of the world. Water reuse can close the water supply and sanitation loop and provides an alternative water source (WWAP/UN-Water, 2017). If properly treated, the treated wastewater can become an alternative source in shifting the paradigm of wastewater management from "treatment and disposal" to "reuse, recycle and resource recovery".

Reclaimed water also offers opportunities for a sustainable and reliable water supply for industries, municipalities and/or alternative water sources to meet increasing demand (Ellen MacArthur Foundation, 2018). In this perception, wastewater is no longer seen as a problem, but it is part of the solution to the current challenges faced by societies (WWAP/UN-Water, 2017). Wastewater can also be a cost-efficient and sustainable, widely available and valuable resource of energy, nutrients, organic matter, and other valuable by-products.

In order to achieve SDG Target 6.3, significant investments will be required in new and current infrastructure (grey and green, in locally appropriate combinations), in the realization of appropriate technologies to increase the treatment and use of wastewater, and develop capacity in water resources management, monitor and control the quality of water and wastewater (WWAP/UN-Water, 2020).

Effective water reuse applications can deliver environmental, economic, and social benefits.

However, for the time being, the vast potential of wastewater, as a source of resources, energy, and nutrients, remains underexploited. Continued failure to address wastewater as one of the major social and environmental problems would compromise other efforts to achieve the United Nations 2030 Agenda.

1.1.4 Role of nature-based solution for water management and wastewater treatment

As illustrated in Section 1.1.3, wastewater treatment is one of the most important aspects to ensure the achievement of SDG 6 of the United Nations 2030 Agenda. It is necessary that the

wastewater collection systems be sustainable and integrated, composed of smart collection and natural-based processing of all resources contained in wastewaters (water, contained substances, energy) to further reuse and market (Masi, Rizzo & Regelsberger, 2018).
SDG 6 also recognizes the importance of ensuring availability and sustainable management of water and sanitation.
Nature-Based Solutions (NBS) are essential to meet this goal and to help achieve water management objectives.
NBS can be cost-effective and simultaneously provide environmental, social, and economic benefits. Upscaling NBS will be central to achieving the 2030 Agenda for SD (WWAP/UN-Water, 2018).
In fact, in more recent years, there has been growing awareness and recognition of the function and importance of Nature-Based Solutions, like reforestation and wetland restoration, to reduce water risks, including water pollution, floods, droughts, and water scarcity (WWAP/UN-Water, 2018; Cross et al., 2021). NBS for adaption should be designed to profit biodiversity and may also provide multiple co-benefits, like flood mitigation, carbon sequestration, temperature regulation, and water reuse (Mara, 2006; WWAP/UN-Water, 2018; Acreman et al., 2021; Cross et al., 2021). NBS is moreover considered an innovative solution to manage water-related issues, contributing to the 2030 Agenda for SD as they offer many benefits, including human health and livelihoods, food and energy security, sustainable economic growth, and ecosystem rehabilitation (Gómez et al., 2020; Cross et al., 2021).
The NBS is also developing new approaches to the water-ecosystem nexus. The focus has shifted from looking at ecosystem impacts to ecosystem management in order to achieve water management objectives (Fig. 1-4).

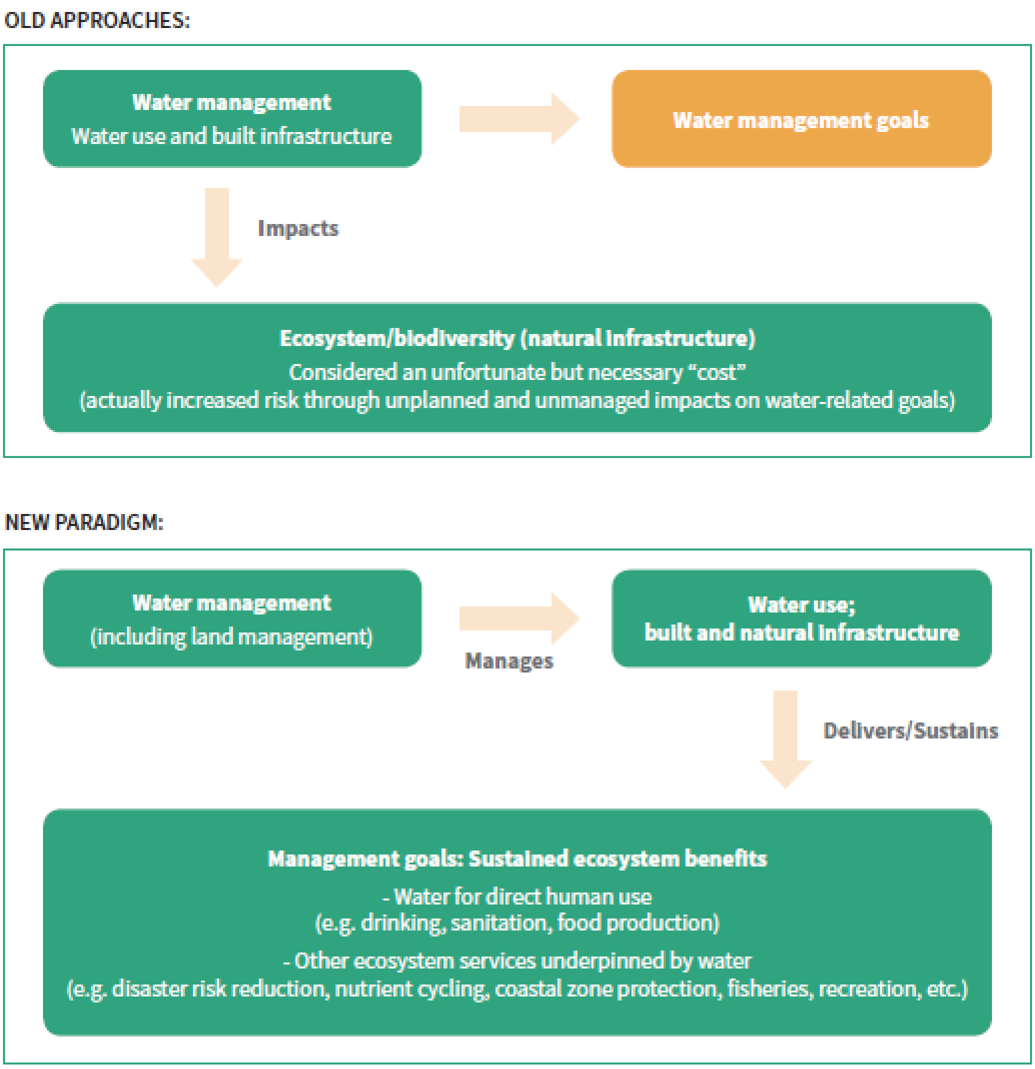


Fig.1- 4_Evolving approaches to the water-ecosystem nexus.

Source: Coates and Smith (2012)

To meet the SDGs, we need a sustainable sanitation approach that enables wastewater treatment and reuse while sustaining ecosystems. NBS have for a long time been used to treat wastewater, stretching back to the use of wetlands for wastewater disposal by ancient civilizations, for example, in Egypt and China (Cross et al., 2021).

Applying NBS in wastewater treatment aims to develop engineered systems that mimic and take advantage of functioning ecosystems with minimal dependence on mechanical elements. NBS use plants, soil, porous media, bacteria, and other natural elements and processes to remove pollutants in wastewater, including suspended solids, organics, nitrogen, phosphorus, and pathogens (Kadlec and Wallace, 2009).

In fact, NBS support a circular economy that is restorative and regenerative by design and promotes greater resource productivity aiming to reduce waste and avoid pollution, including through reuse and recycling (European Commission, 2020).
Among the NBS, wetlands play a crucial role. Wetlands alone can affect related ecosystem processes and support the achievement of several SDGs, precisely goal 1 ("No Poverty"), 2 ("Zero Hunger"), 6 ("Clean Water and Sanitation"), 12 ("Responsible Production and Consumption"), 13 ("Climate Action"), and their specific targets (Seifollahi-aghmiuni, Nockrach & Kalantari, 2019; Gómez et al., 2020).

1.2 Problem definition

In the recent years, the role of Wastewater Treatment Plants (WWTPs) has become even more important in the context of a sustainable water cycle, as they are the final destination of the collected wastewater. Indeed, management of WWTPs should play an important role in achieving SDG target 6.3 of United Nations 2030 Agenda for SD.
Implementing best practices in the management of WWTPs management not only enable to the minimisation of energy consumption and the maintenance of the effluent concentrations under the law thresholds, but also the achievement of various goals such as the reuse of wastewater for industry or irrigation, energy production and the storage of raw materials. An incentive to increase the efficiency of WWTPs performances comes from the possibility of reusing the treated wastewater. Water scarcity has become more increasingly evident in the recent decades, increasing the need for new practices for efficient water management. Reusing and valorization of water from WWTPs can contribute to solving this problem. In this context, water reuse and particularly wastewater reuse play a key role.

1.3 Aim and Objectives of the Research

The aim of this Ph.D. Thesis is to investigate the valorization of wastewater resource through the application of Appropriate Technologies and Natural Systems for wastewater treatment in two different Low- and Middle- Income Countries.
In order to achieve the aim, the research focused on the following specific objectives:

1. Determine the characteristics and the quality of wastewater in the two case studies analysed.

2. Identify Appropriate Technology to be applied in the context of Palestinian Territories to implement wastewater treatment for reuse in agriculture by Evidential Reasoning Approach and preliminary qualitative assessment of the local criticalities.
3. Assess the environmental, economic, and social impact of the Gaza Strip project.
4. Assess the feasibility of using Natural Wetlands as domestic wastewater treatment in Sub-Saharan region, in order to protect the environment and improve the treatment efficiency processes in a country with poor or no conventional wastewater treatment.

To attain these objectives, the application of Appropriate Technologies and Natural Wastewater Treatment Systems is illustrated in two case studies in order to study the assessment of these technologies in countries with limited resources and lack of infrastructure.

1.4 Structure of the Thesis

This Thesis is structured into Six Chapters as follow.

Chapter 1 is this introductory Chapter and provides a background to the research including an overview on the role of wastewater resource and NBS in the framework of United Nations 2030 Agenda, statement of the research problem, aim and objectives of the research.

Chapter 2 and 3 present a literature review relevant for the study. Specifically, Chapter 2 discusses on Appropriate Technologies for Developing Countries and Multi Criteria Decision Analysis (MCDA) for water management and wastewater treatment. Chapter 3 presents a literature related to the Natural Wastewater Treatment Systems, focusing on the specific one for the case study.

Chapter 4 shows the first Case Study concerning the international cooperation project developed in Rafah, Gaza Strip Palestine on Reuse of Wastewater for agriculture purpose.

Chapter 5 describes the second Case Study in Cape Coast, Ghana on the use of Natural Wetlands for domestic wastewater treatment performed during my Ph.D. period abroad.

Finally, Chapter 6 summarises the conclusions from the studies presented and report conclusive remarks of the work carried out, in view of further improvements or developments related to the implementation of the wastewater management and reuse in LMIC countries.

CHAPTER 2.

Appropriate Technologies for Water Management and Wastewater Treatment

2.1 Concept of Appropriate Technology (AT)

Mahatma Gandhi was one of the pioneers of Appropriate Technology (AT), much before the world recognised its importance and usefulness. In fact, the Indian ideological leader Mahatma Gandhi is often cited as the ‘‘father’’ of the appropriate technology movement.

The first idea about the AT is attributed to Mahatma Gandhi. He advocated for small, local, and predominantly village-based technology to support villages in India to become self-reliant. He differed with the idea of technology that benefited a minority of people at the expense of the majority or that put people out of work to increase profit (Akubue, 2000).

Nevertheless, the first definition of AT was introduced many years ago by E. F. Schumacher, a British economist, in his famous book Small Is Beautiful (Schumacher, 1973), and is widely used and accepted in the scientific community. According to him, AT is an approach to technology that builds a strong sense of community and encompasses benefits from a social, environmental, cultural, economic, and spiritual point of view. Other past definitions, still accepted and used, prescribe that AT should be small-scale, require low capital investment per worker, be energy efficient, environmentally friendly, and controlled and maintained by the local community. However, in the 1980s, Ranis argued that “the appropriate process for a poor labor surplus economy is not always labor intensive and an appropriate good is not always a basic good” (Ranis, 1980). Also, UNESCO publications (Ntim, 1988) criticized the standard AT requirements such as “low investment cost per workplace, small scale operation, use of locally available resources, low cost of the final product”, because this is not always possible or easy to achieve and can be contradictory implying bad results.

Today, we can say that AT not only refers to the tools and techniques used for problem-solving in a development setting, but it also includes the less tangible aspects such as knowledge transfer mechanisms and social, cultural, and gender issues. The most important aspect of an AT is its sustainability, which is the long-term balance of technical, social, economic, environmental, cultural, and spiritual values. Effectively, the definition of AT expands on the conventional concept of appropriateness and suggests that AT is always contextual and situational. It is a strategy that enables men and women to rise out of poverty and improve their economic situation by meeting their basic needs, through developing their own skills and capabilities while making use of their available resources in an environmentally sustainable manner (Strategy, 2008; Murphy, McBean & Farahbakhsh, 2009).

Moreover, these solutions must have a low environmental impact and a low cost and they have to be easily managed by the communities in order to allow people to improve their socio-economic conditions (Feige and Vonortas, 2017).

Many researchers have developed criteria and indicators for the appropriateness of a technology (Clarke, 1973; Henderson, 1975; Reddy, 1977; Bowonder ,1979; Date, 1984; Wicklein, 1998). The nuances of appropriate technology vary between field and applications. It is generally recognized as encompassing technological choice and application that is small-scale, decentralized, labor-intensive, energy-efficient, environmentally sound, and locally controlled (Hazeltine, 2003; Mara, 2003)

The present-day advocates of AT also emphasize the technology as people-centered. AT is sometimes used and promoted by advocates of sustainability and alternative technology. Thus, features such as low cost, low usage of fossil fuels, and use of locally available resources can give some advantages in terms of sustainability (Sianipar et al., 2013; Durgamohan Musunuri, 2014).

Borthakur (2019) suggests that developing and diffusing appropriate technology in emerging countries and markets mainly requires the following initiatives: (1) radically redefining the identity of technology in terms of both functions and technical structure to meet local needs; (2) simplifying the product technology through modularized design to enable a low-cost production mode.

2.2 Appropriate Technologies in Water Management

Above all, in the field of water and sanitation, the appropriateness of a technology depends on several factors, mostly related to social and economic aspects. Indeed, a crucial role is played by the willingness to spend money on technologies, the empowerment and the ownership, the educational level and the cultural customs (e.g., the possibility to use bone char as filtration material to remove fluoride in drinking water), among others (Sorlini et al., 2015). Even environmental/natural factors influence the design of an appropriate technology, such as the type of resource (sea, surface water, groundwater) and the type and concentration of contaminants.

An appropriate technology is one that is consistent with all the components of a community's capacity to finance, build, operate and manage the technology over its planning horizon (Bouabid and Louis, 2015).

Improving access to safe water and sanitation facilities in developing countries can be made by water supply solutions to provide access to drinking water or water for production (e.g., for livestock and agriculture), water treatment solutions to improve water quality, especially at household points; and sanitation solutions to treat wastewater and excreta and to improve hygienic conditions and health (Jain, 2012; WHO, 2017).

In water treatment operations Appropriate Technology has been applied at community-scale and household-scale point-of-use designs. Some appropriate technologies that have been used in water supply measures and treatment include the following (Oladoja, 2017):

1. Deep wells with submersible pumps;
2. Shallow wells with lined walls and covers;
3. Rainwater harvesting systems with storage method;
4. Fog collection system;
5. Air well, a tool designed to promote the condensation of atmospheric moisture;
6. Bore chain, to remove fluoride in water;
7. The roundabout play pump, developed and used in southern Africa which harnesses the energy of children at play to pump water;
8. Treatment ponds and constructed wetlands which help to purify sewage and greywater.

2.3 Appropriate Technologies for Wastewater Treatment

The selection of appropriate wastewater treatment technologies that enable sustainable development presents a challenge for national, regional, and local policy-makers. They represent a decision support tool for the selection of wastewater treatment technologies that are urgently needed to improve in developing countries. Limited access to improved municipal sanitation services is primarily a problem in lower-income countries, particularly in Asia and Africa (WHO, 2017). However, it is crucial to identify the problem of lower-income communities, which are those most afflicted by the lack of wastewater services. Technical, environmental, economic, institutional, and social aspects must be considered in all phases of improvement wastewater treatment projects in developing countries, including decision-making, planning, implementation, and management (Alshuwaikhat, 2005).

Recent developments in wastewater treatment technologies provide many options for wastewater treatment. Since the 19^{th} century, many technologies have been developed to treat wastewater. The most widely used is the conventional activated sludge process. Many other technologies have been developed that employ various treatment processes, both aerobic and anaerobic, highly mechanized to not highly mechanized, including trickling filters and bio towers, up-flow anaerobic sludge blanket reactors, rotating biological contactors, aerated lagoons, sequential batch reactor, and others (Metcalf and Eddy, 2003b).

Apart from these, a set of Natural Wastewater Treatment Systems (NWTSs) is also successfully applied in various countries, i.e., India and tropical countries (Arceivala and Asolekar, 2007). Some of the NWTSs are waste stabilization ponds, duckweed ponds, constructed wetlands (CWs).

The challenge in wastewater management is the selection of the appropriate technology for the specific wastewater treatment objective at a particular site. Many factors, such as capital costs, operation, and maintenance (O&M) costs, and land requirements, are involved in the decision-making process. It is also necessary to develop a decision-making framework that incorporates sustainability indicators to help developing countries in selecting the appropriate technologies for wastewater management (Kalbar et al., 2012).

2.4 Multi Criteria Decision Analysis for the selection of the Appropriate Wastewater Treatment Plant to the context

Water and sanitation projects for solving the problems of communities in developing countries are complex in nature and involve complex decision-making, which must consider technical, socio-economic, and environmental dimensions. Multicriteria Decision analysis (MCDA) is a suitable decision-aid method that scores a finite number of options on the basis of a set of evaluation criteria (Garfì and Ferrer-Martí, 2011).

MCDA is a flexible and multidisciplinary tool which ranks or scores a finite number of options based on a set of evaluation criteria (Saaty; 1994; Al-Kloub, A1-Shemmeri & Rearman, 1997; Wilson, Whiteman & Tormin, 2004).

Various studies, described below, have been done also to solve wastewater reuse related problems considering different criteria, using multi-criteria decision analysis (MCDA).

Graae et. al. (1998) developed a framework, considering a set of socio-economic, physical and technological criteria, for evaluating wastewater treatment alternatives. The environmental issues were not considered in the study and were considered equal relative weights for each treatment technology for the considered criteria.

Balkema et al. (2001) developed a framework to identify the sustainable treatment option for domestic wastewater. From this study was outlined that optimizing all criteria at the same time for a specific option is not possible.

Hidalgo et al. (2007) developed a multi-criteria decision-making framework to assist authorities in safe and sustainable reuse of treated urban wastewater for irrigation. The output of the methodology was a set of treatment systems, prioritized by their costs, with the ability to produce the effluent with the required quality.

Muga and Mihelcic (2008)developed a set of indicators to evaluate environmental, societal, and economic sustainability of wastewater treatment technologies. The study concluded that the selection of a set of indicators is dependent on the geographic and demographic background of the community, but there are different levels of sustainability that can be achieved by each treatment technology.

Gomez-Lpez et al. (2009) applied the technique for order preference by similarity to ideal solution using TOPSIS method to rank disinfection technologies of wastewater prior to reuse. They considered the environmental, economic, and social impacts of each technology. The results showed that for tertiary treatment technologies, chlorination is the most suitable alternative for wastewater reuse in urban, agricultural, and industrial sectors, and ultraviolet light disinfection is the most preferable alternative for recreational and environmental uses.

Chamberlain et al. (2014) developed a decision support framework to assess sustainability of wastewater solutions with regard to environmental, economic and social criteria to assessed six alternatives: wastewater treatment system, volume of municipal wastewater, amount of heat and electricity recovery, industrial waste heat, chip or buy wood for gasifier, and scope of resource recovery.

Kalbar et al. (2012) utilized a Multi-Attribute Decision Making (MADM) methodology to assess the selection of wastewater treatment alternative for municipal wastewater in India. Six scenarios are developed and TOPSIS has been selected to rank the alternatives.

Di Iaconi et al. (2017) assessed the sustainability of a conventional activated sludge (CAS) wastewater treatment plant upgraded with a sequencing batch biofilter granular reactor, from a techno-economic and environmental point of view. In general, the technical and economic assessment showed that the upgrade has been positive.

From the various studies results those many different MCDA methods have been extensively applied. The most widely used traditional MCDA methods are Analytic Hierarchy Process

(AHP), Analytic Network Process (ANP), Data Envelopment Analysis (DEA), Weighted Sum Model (WSM), Weighted Product Model (WPM), Global Programming (GP), Elimination and Choice Expressing Reality (ELECTRE), Multi-Attribute Utility Theory (MAUT), Simple multi-Attribute Rating Technique (SMART), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Simulated uncertainty Range Evaluations (SURE) (Abdullah, Siraj, & Hodgett, 2021), Multi-Attribute Value Theory (MAVT) (Marttunen, Lienert & Belton, 2017), Evidential Reasoning Approach (Ngan, 2015). In MCDA problems, the decision maker has multiple choices, called alternatives to assess based on defined criteria. The alternatives could be prioritized considering the goal of the assessment. Omran et al. (2021) used the WSM method to assess the sustainability of 13 wastewater treatment plants (WWTP) in urban areas of Iraq. Gherghel et al. (2020) considered 6 alternative schemes to design a large wastewater treatment plan. In this regard, they developed an approach based on MCDA and assessed the alternatives according to 6 evaluation criteria. Paul et al. (2020) implemented MCDA integrated with Geographical Information Systems (GIS-MCDA), with the AHP to evaluate the potentiality of treated water use for agricultural irrigation in California. They considered multiple qualitative and quantitative criteria. Cunha (2020) proposed the MCDA approach in assessing the performance of a set of alternative designs for the reinforcement of existing water networks. Gómez-López et al. (2009) implemented the Technique for Order Preference by TOPSIS method to prioritize disinfection technologies as the tertiary treatment for wastewater reuse. In assessing the sustainability of four tertiary wastewater treatment technologies in producing recycled wastewater, Plakas, Georgiadis & Karabelas (2016) applied Simple multi-Attribute Rating Technique exploiting ranks (SMARTER) weighting technique.

2.5.1 Multi-Criteria Decision Analysis applied to the Case Study of Rafah, Gaza Strip

In the following study presented in Chapter 4 Section 3 of the Thesis, a MCDA has been applied to implement a wastewater treatment plant. This method was used for selecting the best secondary wastewater treatment technology alternative for the case study. Evidential Reasoning (ER) approach for sustainability assessment of wastewater secondary treatment technologies consists of five main steps: 1. Identification of potential wastewater secondary treatment alternatives; 2. Determining contributing criteria in the assessment (with regard to economic, environmental, technological, and sociological/cultural aspects of wastewater reuse) and identifying the relative weights of the criteria using Analytic Hierarchy process (AHP); 3. ER distributed modelling framework for the identified wastewater secondary treatment technology criteria. 4. Recursive ER algorithm for aggregating multiple identified wastewater secondary treatment technology criteria. 5. Utility interval-based ER ranking method, which is designed to compare and rank the alternatives. The results of the application are shown in Chapter 4 Section 3 of this Thesis.

CHAPTER 3.

Natural Wastewater Treatment Systems

Among the Nature Based Solutions, in this Chapter the Natural Wastewater Treatment Systems (NWTSs) are examined.

The term "natural system" as used in this context is intended to describe those processes that depend primarily on their natural components to achieve their intended purpose.

Since the 1950s, NWTSs, such as wetlands, have evolved into a reliable wastewater treatment technology able to treat high loads of wastewater to the desired effluent quality while maintaining the surrounding ecosystem (Vymazal, 2011).

NWTSs are biological, land-based approaches used to remove pollutants from organic solid wastes and wastewaters. NWTSs require no or very little electrical energy, use minimal or no chemical products, have low maintenance and installation costs (Mara, 2006), and produce relatively small amounts of residual solids, providing a sustainable system for water recycling and reuse (Crites, Middlebrooks & Reed, 2014; Pinninti et al., 2021). They are also a good substitute for conventional wastewater treatment plants (Vymazal, 2010).

Many studies (Vymazal, 2007; Sonkamble et al., 2018) have suggested natural treatment systems (NTSs) as an effective method for decentralized, cost-effective wastewater treatment in peri-urban areas (Pinninti et al., 2021).

3.1 Existing Natural Wastewater Treatment Systems

The following sections describe existing natural wastewater treatment systems, specifically wetlands, both natural and artificial, phytoremediation and various types of stabilization ponds and lagoons.

3.1.1 Wetlands

Wetland has numerous definitions however, that of Ramsar Convention accepted by many organizations, such as the International Union for the Conservation of Nature (IUCN) worldwide will be presented in this Thesis.

The importance, protection, and conservation of the wetland reserves certainly had a fundamental recognition with the signing of the Convention on Wetlands took place in 1971 in the Iranian town of Ramsar, which represents the primary multilateral intergovernmental environmental agreement. According to the Ramsar Convention, art.1.1, wetlands are "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters”.

Wetlands vary widely due to regional and local differences in soil, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance (US EPA, n.d.).

Wetlands can be divided into the following two main categories (US EPA, n.d.):

1) Coastal/Tidal Wetlands. They are closely to estuaries, where seawater mixes with freshwater to create an environment of varying salinities. The saltwater and therefore the fluctuating water level (due to tidal action) create a challenging environment for many plants. Consequently, many shallow coastal areas are unvegetated mud flats or sand flats. Some tidal freshwater wetlands form beyond the upper edges water stops.

2) Inland/Non-Tidal Wetlands. They are most common on floodplains along rivers and streams (riparian wetlands), in isolated depressions surrounded by dry land, along the margins of lakes and ponds, or in vernal pools and bogs. Inland wetlands include marshes and wet meadows dominated by herbaceous plants, swamps dominated by shrubs, and wooded swamps dominated by trees. Many of these wetlands are seasonal and, particularly within the arid and semiarid West, maybe wet only periodically. The number and the timing of water present determine the functions and the role of wetlands in the environment.

They are usually recognized into five classification system by Ramsar Convention, that are:

- marine (coastal wetlands including coastal lagoons, rocky shores, and coral reefs);
- estuarine (including deltas, tidal marshes, and mangrove swamps);
- lacustrine (wetlands associated with lakes);
- riverine (wetlands along rivers and streams);
- palustrine (meaning “marshy” - marshes, swamps, and bogs). In addition, there are human-made wetlands such as fish and shrimp ponds, farm ponds, aquaculture ponds, irrigated agricultural land, canals and drainage channels salt pans, dams, reservoirs, gravel pits, wastewater treatment ponds and canals.

There are many different types of wetlands, each determined by their hydrology, water chemistry, soil properties, and vegetation composition. All wetlands have one characteristic in common: the presence of a surface or near-surface water, at least periodically. Wetlands might be characterized as dominated by trees, shrubs, or herbaceous vegetation. They may be fed by precipitation, runoff, or groundwater, with water chemistry ranging from acidic to alkaline.

There are four major wetland types found around the globe. They are swamps, marshes, bogs, and fens as describe below (Davis, 1995; Keddy, 2010; Smardon, 2014; Finlayson, Milton & Prentice, 2018; Balwan and Kour, 2021; US EPA, n.d.).

The wetlands hydrology is containing slow flows and either shallow waters or saturated substrates. The slow velocity of flow and shallow water depths allow sediments to settle as the water passes through the wetland. This slow flow allows sedimentation through the wetland. The complex variety of organic and inorganic materials and the big opportunities for phase interchanges develop a diverse community of microorganisms that decompose or transform a wide variety of substances.

- Marshes: these are nutrient-rich wetlands that are periodically inundated by standing or slowly moving water. Marshes can be freshwater, or saltwater and the amount of water in the marsh can change with the seasons. They boast a great variety of vegetation that has adapted to live in saturated soil. Marshes vegetation includes cattails, reeds, rushes, and sedges; and wildlife includes beavers, alligators, newts, shrimp, and turtles. There are several sub-categories of marsh, including freshwater, saltwater, inland and coastal and each of these have their distinct ecosystems and can be found all over the world.

Fig.3- 1_Tidal marsh along the Edisto River, South Carolina

Source: US EPA, n.d.

- Swamp: this is a wetland permanently saturated with water and dominated by woody plants. There are two main types of swamps: freshwater swamps and saltwater swamps. The first type of swamp is common in inland areas, and the second protect coasts from the open ocean. Swamps, like marshes, are generally found in warm climates.

Red maple, *Acer rubrum*, is a common species ih wooded swamps such as Beckville Woods in Indiana. Donald J. Leopold

Fig.3- 2_Swamp

Source: David et al. (1995)

- Bogs: these are characterized by more acidic waters and spongy peat deposits and a covering of sphagnum moss. Unlike marshes and swamps, bogs tend to get their wetness from precipitation rather than waterways such as streams or runoffs from rivers. These wetlands are fantastic for preventing downstream flooding since they absorb precipitation as it falls and prevents the swelling of rivers and other waterways. There are two sorts of bogs, namely northern bogs and pocosins. Bogs are more common in cold or even Arctic areas in North America, Europe, and Asia.

Lost Pond, in the Adirondacks of New York, is only a small part of this bog which includes the black spruce, *Picea mariana*, and tamarack, *Larix laricina*, forest in the background. Donald J. Leopold

Fig.3- 3_Bogs

Source: David et al. (1995)

- Fens: like bogs, fens are peat-forming wetlands, although they usually get wet from groundwater rather than precipitation, which means that they are slightly less acidic. They tend to support a greater array of wildlife, from plants to fish to birds and everything in between. Like bogs, fens are beneficial because they can help prevent the flooding of land elsewhere since they soak up water from the ground and prevent it from seeping anywhere else.

Fig.3- 4_Fens
Source: US EPA, n.d.

In common culture, wetlands have historically been considered insane and not proper for human life, thus, till anthropocentric vision of the world has prevailed, they have been completely set aside also by the scientific world.
In the early 1950s, many studies on the wetland's ecosystems for treating wastewater led to the change of this negative perception (Vymazal, 2010).
However, the natural treatment of domestic wastewaters has ancient origins. In Rome, during the imperial period, it was used to unload the maximum cloaca in the Pontine Marshes with the precise purpose of exploiting their self-purifying power. In China, the custom is still common today, the millenary tradition to create lagoons for fish farming where, to increase fish production, appropriate quantities of domestic sewage, containing a high concentration of nutrients (phosphorus and nitrogen) are periodically released in.
In addition, wetlands play a crucial role in climate change, biodiversity, human health, provide key ecosystem services and economic values to human beings (Ramsar Convention Bureau, 2001; Brink and Russi, 2016; WWAP/UN-Water ,2018; Xu et al., 2019).
However, doubt of the importance and the potential benefits of wetlands in the past was the genesis of the conflict between human and wetlands.
Natural, and more importantly anthropogenic factors have not only decreased the global wetland size but also deteriorated it quality and potential (Finlayson, 2012; Davidson, 2014). In fact, human activities cause wetland degradation and loss by changing water quality, quantity, and flow rates; increasing pollutant inputs; and changing species composition. Many research identified that agriculture and urbanization, are the two main human activities, that directly cause wetland loss (USEPA, 2016; Hu et al., 2017). Wetlands around the world had degraded by about 87% since 1700 in data existing regions, and the degradation occurred

mainly in the 20^{th}, and at the beginning of 21^{st} centuries (Finlayson, 2012; Davidson, 2014). It is also estimated that about 50% of the global wetland area is lost in the 20^{th} century (Finlayson, 2012; Davidson, 2014; Xu et al., 2019).

Wetlands are found from the tundra to the tropics and on every continent except Antarctica (Davidson, 2014; Balwan and Kour, 2021). Globally, wetlands cover at least 6% of the Earth's terrestrial surface, of which some 125–130 million hectares occur in Africa, and 200–280 million hectares in Asia (Davidson, 2014; Finlayson, Milton & Prentice, 2018).

The distribution of different types of wetlands are discrepant in the six continents. In specific, inland wetland are mainly distributed in Africa (58% of the total area of wetlands); marine/coastal wetlands are mainly distributed in North America and Africa and human-made wetlands are most distribute in Asia and Europe (Davidson, 2014; Xu et al., 2019). More than half of the wetlands site are under threat and the wetland management plans and protection play a crucial role in this process (Davidson, 2014; Xu et al., 2019).

3.1.1.1 Benefits of wetlands

Wetlands, as mentioned before, have a wide range of functional values, both ecological and economic, as each wetland depend on its location, size, and relationship to adjacent land and water areas (US EPA, 2016), and are crucial for both chemical decomposition and as carbon sinks (US EPA, n.d.). Their values include habitat for aquatic birds and other animals and plants, numerous threatened and endangered species; production of fish and shellfish; provision for agriculture; water storage, including mitigating the effects of floods and droughts; water purification; timber production; food production; education and research, and recreational value (Keddy et al., 2009; Davidson, 2014; Balwan and Kour, 2021).

As several wetland functions and values became more widely known, wetlands are increasingly seen as productive and valuable resources that deserve protection and restoration. These benefits become increasingly significant as they still lose wetlands around the globe.

Since there are several different types of wetlands, there are many benefits that each one offers. Not all of them provide equivalent benefits to animal or plant life, but all of them are essential, and it is vital to protect both them and the energy they support (Keddy et al., 2009; Balwan and Kour, 2021).

The following there are some of the benefits of wetlands (Keddy et al., 2009; Mitchell, 2013; Balwan and Kour, 2021):

- Wetlands are crucial components of watersheds and are essential for ecosystem sustainability;

- Wetlands recharge water supplies and also have the potential to store the runoff;
- Wetlands can act as natural filters that can improve water quality, reduce the threat of eutrophication and climate controller;
- Wetland help flood protection through the storage of a large amount of water;
- Wetlands stabilize the shoreline, retaining sediment and reducing erosion;
- Wetlands maintain biodiversity, and they can be a wildlife nursery and enhance the habitat;
- Wetlands can be a carbon sink, with essential implications for global climate change;
- Wetlands produce consumer products such as fish, and shellfish, rice, timber, etc. and have an economic value;
- Wetlands release vegetative matter, and they serve as storm and wind buffers and mitigate the sea level rise;
- Wetlands are used for a range of recreation activities, and they have an aesthetic value;
- Wetlands provide opportunities for public education regarding the value of these resources and their protection;
- Wetlands offer a jobs hub.

3.1.2 Natural Wetlands

Natural wetlands represent one of the most important types of productive ecosystems and areas of high biodiversity worldwide and are under severe threat from a range of human activities (Brink and Russi, 2016; Hu et al., 2017; Xu et al., 2019).

The natural wetland is hailed as the kidney of the earth because it has a great capacity to purify water. Numerous studies have been conducted on the mechanism of nitrogen and phosphorus cycling in wetlands (Ready et al., 1999; Saunders and Kalff, 2001). Since the redox conditions in wetlands are variable, they also have a significant influence on the migration and transformation of some redox-sensitive heavy metal elements in water (Jiang et al., 2021).

Therefore, for centuries, natural wetlands were considered and used only as storage reservoirs for wastewater prior to discharge into the final receiver water bodies, rather than as a true depuration plant. In many cases, the uncontrolled discharge of wastewater into these natural wetlands and the incorrect assessment of the environmental impact of wastewaters resulted in irreversible damage and degradation of ecosystems (Vymazal, 2010).

Natural wetlands usually purify and improve the quality of water passing through the system acting as ecosystem filters (Dordio, Carvalho & Pinto, 2008).

Natural wetlands are characterized by extreme variability in their functional components, which has resulted in improvements in effluent quality being observed after conversion in natural wetlands, although it has not yet been possible to accurately quantify their treatment capacities (Brix 1997). It was noted that treatment in natural wetlands could become a useful natural wetland treatment plant if the wastewater inflow is properly controlled. In the 1970s and 1980s, the idea of preserving the existent natural wetlands began to be explored, and the possibility of implementing a suitable wetland system for wastewater treatment was investigated (Vymazal, 2010).

3.1.3 Constructed Wetlands

Constructed Wetlands (CWs) treatment are complex, integral systems of water, plants, microorganisms, and the environment.

CWs are man-made wastewater treatment systems consisting of shallows, ponds, or channels planted with aquatic plants that rely on natural microbial, biological, physical, and chemical processes to treat wastewater. They typically have impervious clay or synthetic liners and engineered structures to control the flow direction, liquid retention time, and water level, depending on the type desired (U.S. EPA, 2000)

However, CWs are often used as secondary treatment for municipal or industrial wastewater, greywater, stormwater runoff. They can also be used as a polishing stage for secondary wastewater treatment (Davis, 1995). The distinction between constructed wetlands for secondary treatment and enhancement systems for tertiary treatment is critical to understanding the limitations of wetlands in each of these states (EPA, 2000).

A Constructed Wetland consists of a well-designed basin containing water, a substrate, and usually vascular plants (macrophytes). Wetlands can be constructed almost anywhere by reshaping the land surface to capture surface water and sealing the basin to retain the water with a relatively impermeable subsurface layer that prevents surface water from percolating into the soil. Soil, gravel, sand, rocks, and organic materials can be used as substrate for wetland. Because of the low flow rate of water in the basin, waste and sediments can accumulate in the wetland. Both vascular plants (the higher plants) and non-vascular plants (algae) are important in constructed wetlands because the photosynthesis of algae increases the dissolved oxygen content of the water, which leads to a nutrient and metal reaction. Thus, these are ecological systems that combine physical, chemical, and biological processes in an engineered and managed system that is used in wastewater treatment instead of conventional centralized treatment plants that require higher costs and maintenance.

3.1.3.1 Typologies of Constructed Wetlands

CWs are built depending on the characteristic of the wastewaters, soils, and lands. CWs for wastewater treatment can be further divided into categories depending on the specific characteristics of the system, e.g., the direction of water flow through the system, the type of vegetation (Fig. 3-5). Depending on the direction of flow in the system, there are two broad types (Vymazal, 2007; Kadlec and Wallace, 2008): - Free water surface constructed wetlands (FWS CWs) (Fig. 3-6), and - Subsurface flow constructed wetlands (SF CWs) (Fig. 3-7).

In dedicated FWS CWs, water flows slowly over a substrate medium, creating a free water surface and a water column depth typically of a few centimeters. In contrast, in SF CWs, water flows within a porous substrate. Depending on the direction of water flow, SF CWs can be subdivided into horizontal flow (HF) or vertical flow (VF) (Fig. 3-8). To prevent clogging of the filter material, HSF and VF wetlands are typically used for the secondary treatment of wastewater.

Sometimes hybrid configurations are used to take advantage of both systems to achieve higher efficiency (Vymizal and Kropfelova, 2008).

Another classification can be made based on the growth characteristics of the vegetation. Thus, one can distinguish (Vymazal, 2007): - Floating treatment wetlands (FTWs) (Floating Islands) (Fig. 3-9), - Emergent macrophyte wetlands, and -Submerged macrophyte wetlands. They utilize the application of naturally occurring plants as floating hydroponic mats on the water surface. The floating macrophytes promote the hydraulic flow of water under and through the plants, with the root system acting as a natural filter (Colares et al., 2020).

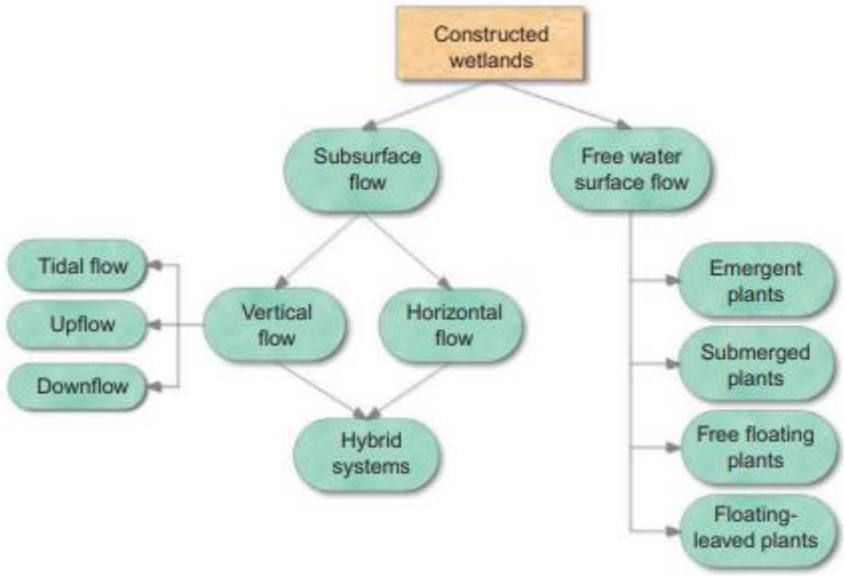


Fig.3- 5_Classification of CWs for wastewater treatment

Source: Stefanakis, Akratos & Tsihrintzis, 2014

The various example of typologies of CWs are shown in the figures below.

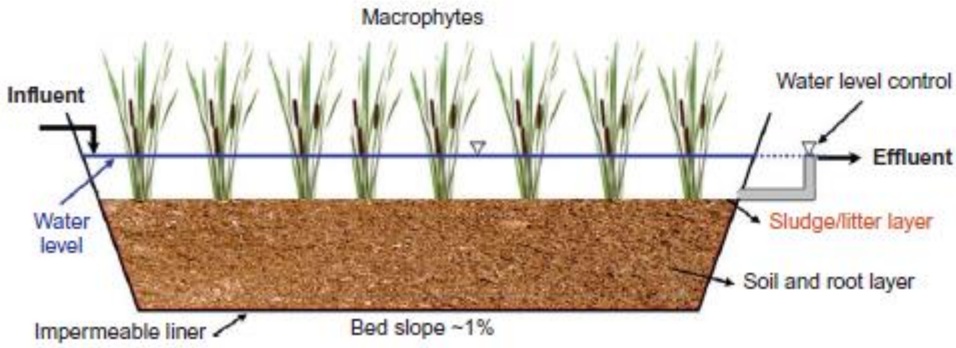


Fig.3- 6_Schematic representation of Free Water Surface CWS

Source: Stefanakis, Akratos & Tsihrintzis, 2014

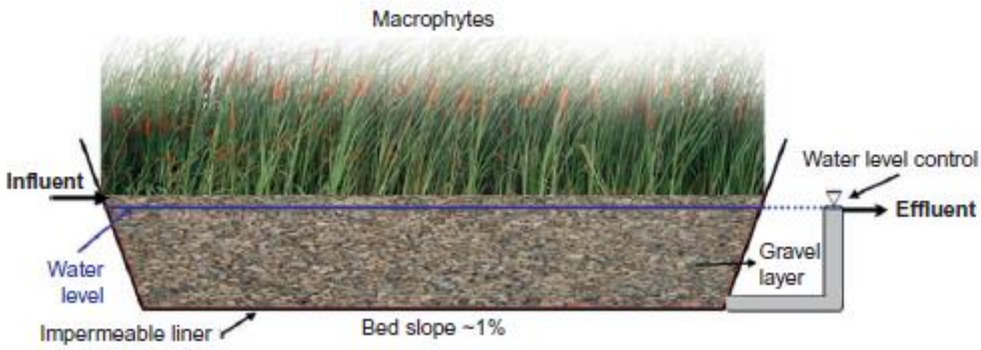


Fig.3- 7_ Schematic representation of Horizontal Subsurface CWs

Source: Stefanakis, Akratos & Tsihrintzis, 2014

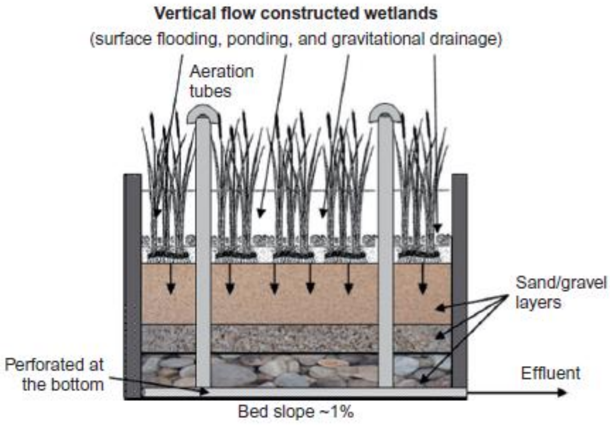


Fig.3- 8_Schematic representation of Vertical flow CWs

Source: Stefanakis, Akratos & Tsihrintzis, 2014

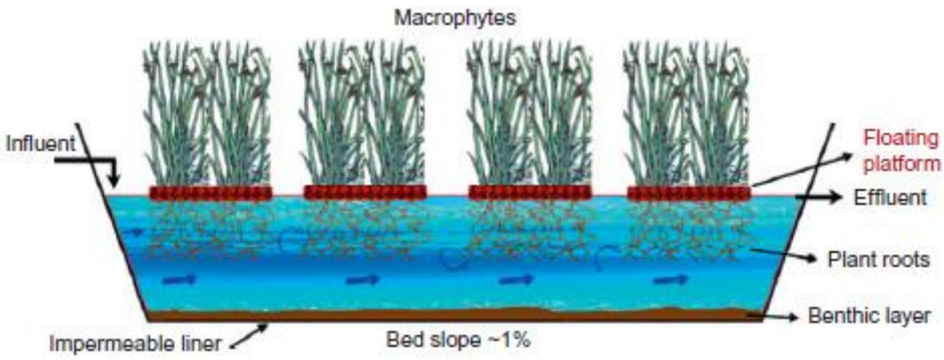


Fig.3- 9_ Schematic representation of Floating Treatment CWs

Source: Stefanakis, Akratos & Tsihrintzis, 2014

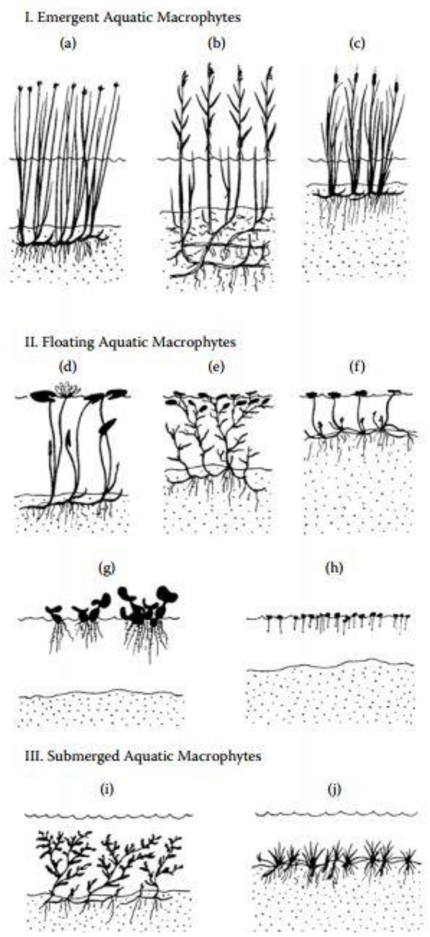


Fig.3- 10_Sketch showing the dominant life forms of aquatic plan

Source : Kadlec, R.H., & Wallace, 2008

The species shown in Figure 3-10 are: (a) Scirpus (*Schoenoplectus*) lacustris, (b) Phragmites australis, (c) Typha latifolia, (d) Nymphaea alba, (e) Potamogeton gramineus, (f) Hydrocotyle vulgaris, (g) Eichhornia crassipes, (h) Lemna minor, (i) Potamogeton crispus, (j) Littorella uniflora (Brix & Schierup, 1989).

There are a variety of adaptations for plants growing in wetlands. These include physiological responses, morphological adaptations, behavioural responses, reproductive strategies, and others.

Plants commonly used in Constructed Wetlands are persistent emergent plants, such as bulrushes *(Scirpus),* spikerush *(Efeocharis),* other sedges (Cyperus). Rushes *(Juncus),* common reed (*Phragmites*)*,* and cattails *(Typha).* Not all wetland species are suitable for wastewater treatment because plants in wetlands should be able to tolerate the combination of constant flooding and exposure to wastewater or stormwater containing relatively high and variable pollutant concentrations (Davis, 1995).

3.1.4 Phytoremediation

Phytoremediation is a process in which green plants are used to remove or render harmless pollutants from the environment (Hou and O'Connor, 2020). Due to its competitive performance, cost-effectiveness, and environmental friendliness, it is considered a new and promising technology for the remediation of polluted sites. Phytoremediation is an emerging technology that uses certain plants to remediate soil, water, and air contaminated with environmental pollutants through degradation, extraction, or immobilization of pollutants (Willey, 2007).

In particular, Phytoremediation is recognized as an integrated, economically viable technology that uses green plants to degrade, remove, and detoxify chemical pollutants from contaminated soils, sediments, or waters (Clayton, 2007).

Constructed wetlands (CWs) are designed to use many of the same processes that occur in natural wetlands, but in a more controlled environment (Vymazal, 2010; Herath and Meththika, 2015). Phytoremediation of constructed wetlands has been used to improve the quality of contaminated waters by serving as a sink for various pollutants originating from wastewater, industrial and agricultural effluents, landfill leachate, and stormwater runoff (Vymazal, 2007; Herath and Vithanage, 2015).

There are several processes associated with phytoremediation, depending on the contaminant being treated and site-specific conditions. Based on the physiological effects of plants, at least ten different processes have been identified that help in the treatment and management of polluted soil, water, and air (Yan et al., 2020). The major processes include phytoextraction, phytodegradation, phytostimulation, phytostabilization, rhizofiltration, and phytovolatilization (Clayton, 2007).

In this system, plants have the role of promoting the creation of microhabitats suitable for the growth of microbial flora, the real protagonist of biological purification.

The ability of plants to degrade, absorb, or tolerate the effects of pollutants is an essential component of phytoremediation. The potential of plant species for phytoremediation has been considered in much previous researches (Willey, 2007; Vymazal, 2007; Vymazal, 2010; Herath and Meththika, 2015). For example, microalgae can simultaneously grow in wastewater and produce valuable biomass while removing organic carbon and inorganic nutrients (nitrogen and phosphorus) from the wastewater. Therefore, microalgae can play a very important role in phytoremediation, especially in the final stage of tertiary treatment at the WWTP (Mohsenpour et al., 2021).

3.3 Wastewater Stabilization Ponds and Lagoons

Wastewater Stabilization Ponds or Stabilization Lagoons are an important part of natural treatment pathways. The desired treatment effect is achieved through physical, chemical, and biological processes occurring in the aquatic environment in the presence of aquatic and wetland biocoenoses (bacteria, phytoplankton, and zooplankton), higher vegetation, and organisms (Rozkosny et al., 2014).

The wastewater stabilization pond or stabilization lagoon is one of the simplest forms of biological treatment. This versatile facility serves many basic purposes, including: (a) storage or impoundment of wastewater; (b) settling and removal of suspended solids; (c) storage or impoundment of settled solids; (d) equalization; (e) aeration; (f) biological treatment; and (g) evaporation. The simplicity and low operating costs of a stabilization pond make it the preferred technology for handling, treating, and disposing of municipal and industrial wastewater for small communities (Mara et al., 1992; Shammas, Wang & Wu, 2009).

Wastewater Stabilization Ponds (WSPs) are large man-made water bodies in which wastewater, greywater or faecal sludge are treated by natural processes under the influence of sunlight, wind, microorganisms and algae (D. Mara 2009) . The ponds can be used individually or in series for improved treatment. There are three types of ponds, (1) anaerobic, (2) facultative and (3) aerobic (maturation), each with different treatment and design characteristics. WSPs are inexpensive to operate and BOD and pathogen removal is high. However, large surface areas and expert design are required. The effluent still contains nutrients (e.g., N and P) and is therefore suitable for agricultural reuse, but not for direct recharge to surface waters.

Wastewater stabilization ponds can be divided into the categories listed in Table 3-1 according to treatment technologies (Rozkosny et al., 2014).

Table 3- 1_List of basic types of Stabilization Ponds and possibilities of their use

Stabilization	**Pond/Lagoon Type**	**Division**	**Possibilities of Utilization**
Treatment and stabilization of Physical, Chemical and Biological Properties	Aerobic Ponds	Low-loaded	Polluted wastewater treatment
		High-loaded	Municipal wastewater treatment
		Continuously aerated	Intensive municipal wastewater treatment
		Final Treatment	Final treatment of treated wastewater after mechanic-biological treatment
	Facultative	Temporary ponds on inflow	Form the transition of anaerobic and aerobic process in the pond
	Anaerobic Ponds	Flow	Anaerobic wastewater treatment
		Sedimentation	Prolonged sedimentation of municipal and industrial wastewater
		Accumulative	Wastewater treatment of campaign producers

Source: Adapted from Rozkosny et al. (2014)

3.3.1 Advantages and disadvantages of stabilization ponds

The advantages of stabilization ponds:

- Environmentally friendly treatment of pre-treated wastewater using natural methods that take place in the aquatic environment.

- Low energy requirements, significantly lower operating costs with comparable investment costs with artificial (mechanical) pre-treatment methods.
- Relatively fast incorporation, the possibility of short- and long-term operational shutdown, resistant to short-term hydraulic and pollution overloads.
- Comparable efficiency in the removal of contaminants with conventional methods of wastewater treatment, high efficiency in the removal of bacterial contaminants.
- The use as a third treatment stage in wastewater treatment.
- The favourable combination with the other natural treatment methods and final wastewater treatment, especially by means of irrigation with treated wastewater, aquaculture, etc.
- •The advantageous integration into the environment and natural landscape.

Disadvantages of using stabilization ponds are:

- The main disadvantage is the relatively large area required for the construction of the system of biological tanks. This disadvantage is not outweighed using barren or otherwise economically unusable land
- Slightly lower pollution removal treatment effect in wintertime when the lack of oxygen must be supplied by artificial aeration.
- The need to capture and subsequently use excess biomass from the tanks.
- The removal of sediments (sludge treatment) of particular tanks and their subsequent utilization. The need of the sludging process of tanks is significantly reduced by quality mechanical pre-treatment.
- Increased costs on maintaining the riparian zone and area surroundings tanks (mowing of grass vegetation)
- If no sediments or biomass is harvested, odour may occur due to the biological breakdown.

3.4 Importance of application of Natural Wastewater Treatment Systems in Low- and Middle-Income Countries

In many countries, especially Low- and Middle-Income Countries (LMICs), natural treatment systems are being successfully used as alternative methods for wastewater treatment (Sonkamble et al., 2018). Rapid population growth, economic pressures, energy shortage, deforestation, and natural habitats destruction in some LMICs are forcing the implementation of natural treatment principles to protect the natural environment, especially in area affected by water scarcity (Stefanakis, 2020).

Also, the current economic crisis in many developed and developing countries is forcing the implementation of low-cost natural treatment systems for domestic and industrial wastewater treatment.

If technological wastewater treatment systems are installed in many developing countries, the energy input is difficult to afford given the global energy crisis and high operating costs. All these factors force to apply the principles of ecological engineering not only for wastewater treatment, but also for conserving biological communities in poor countries of the world (Pinninti et al., 2021).

The description and advantages of various Natural Wastewater Treatment Systems have already been discussed. In the following Chapters, the application and use of some Natural wastewater Treatment systems are presented in order to evaluate and investigate their working efficiency in the cases presented.

CHAPTER 4.

Case study I: Reuse of Treated Wastewater in Rafah, Gaza Strip, Palestine

4.1 Definition of the project

In Autumn 2018, the Italian NGO Overseas-Onlus, together with the University of Bologna (Italy), the Union of Agricultural Work Committees (Palestine), and the University of Applied Sciences (Palestine), started an international cooperation project in the Governorate of Rafah, Gaza Strip, entitled "Reuse of Treated wastewater in Agricultural Sector in the Al-Masawi District – Rafah, Gaza Strip, founded by the Italian Agency for Cooperation and Development. The duration of the project was three years and it is intended to promote the revitalization of the southern Gaza Strip's agricultural sector, combining training approach and the transfer of technical expertise (training ToT) to both beneficiaries and local counterparts (Union of Agricultural Work Committees (UAWC) and the University College of Applied Sciences (UCAS) with income-generating activities (crop diversification and access to credit for farmers). The project is in Rafah's Governorate – Al-Mawasi district, involving a population with an estimated number of 300 families (indirect beneficiaries).

4.1.1 Goal of the project

The Goal of the entire project is to contribute to economic development of agricultural sector in the Gaza Strip, Palestine, through new synergies between the research system and the Civil Society Organizations. Specifically, the aim of the project is to study and carry out a wastewater finishing plant, implementing an existing primary treatment plant, and considering a water recycling system for agriculture utilization in an area located in the north-east of the city of Rafah, Gaza Strip.

Surface water is a need particularly important in Gaza Strip, where the groundwater is the only available water source. In fact, this area suffers from water scarcity due to constantly over-pumping and the huge gap between water demand and water supply. In this region, agriculture represents the second highest sector for water consumption, using more than 50% of water from the stressed polluted Gaza's coastal aquifer (Gharbia et al., 2016). In this issue, using treated wastewater for the purpose of irrigation of agricultural crops can be an available and environmental-friendly option.

The following is the specific objective of the project and the intended results.

The specific objective is the promotion of the reuse of treated wastewater for agricultural purpose and high efficiency water systems for a higher resilience in the agricultural sector through innovative solutions.

Intended Result (1) is the improvement of the availability of treated wastewater for agricultural use through new technology, efficient and sustainable.

Intended Result (2): improved agricultural productivity in the North-East sector of Rafah Governorate (Al-Mawasi district) thanks to use of treated wastewater in open fields and greenhouses, and the introduction of hydroponic greenhouses.

Intended Result (3): improve knowledge and raise awareness among local actors on the use of treated wastewater in agriculture.

4.1.2 Actors involved

Table 4-1 is a summary of the project partners and their roles in the project.

Table 4- 1 Project partners and role in the project

Partner	Details and Countries	Role
Italian Agency for Cooperation and Development (AICS)	AICS is one of the key innovations established by Italy. The Agency began operating in January 2016, with the aim of aligning Italy with its principal European and Global Partners in the endeavour of development.	Donor of the project
Overseas-Onlus	Overseas is an Italian NGO operating in the fields of WASH, agricultural development, solid waste management, and environmental awareness in Palestine.	Coordinator of the project
UAWC	UAWC was established in 1986. This Palestinian Union was founded as a non-profit organization by a group of volunteers and agronomists in the West Bank and Gaza Strip, Palestine.	Support in the realization stage through their engineer and local coordinator, in the connection with local farmers, and active role in the governance of the system at the end of the project.
UCAS	UCAS is a Palestinian University n Gaza Strip, Palestine. It was established in 1998 to provide academic, technical, and vocational education in Gaza Strip.	Role in the design, planning the wastewater treatment plant and field test in collaboration with DICAM -UNIBO. Also, in the

Partner	Details and Countries	Role
		social and economic study of the impacts of the project.
DICAM-UNIBO	Department of Civil, Chemical, Environmental and Material Engineering -University of Bologna, Italy.	Realization of the design, maintenance and monitoring of the wastewater treatment plant. Collaboration in the socio-economic study of the project and aim to reinforce the link between research and practical application, as well as between university and civil society.
DISTAL-UNIBO	Department of Agriculture and Food Sciences - University of Bologna, Italy.	Rehabilitation of green-house and introduction of hydroponics.
MoA	Ministry of Agriculture, Gaza Strip, Palestine	MoA will oversee the management of the new wastewater treatment. MoA will play a key and active role in the management committee of the project. Moreover, the MOA will play a key intermediary role with other programs and ongoing projects, and facilitator with the other Ministries and institutions interested in wastewater.
PWA	Palestinian Water Authority was established under Presidential Decree of 1995. PWA aims to achieve integrated and sustainable asset management of ed water resources, protection, and preservation within organizational tools.	PWA will have an external role mainly focused on supporting the process of wastewater qualitative standard and on the coordination of the action with other similar projects.

4.1.3 Project Phases and Components

The project components included the following:

I. Context analysis of Governorate of Rafah, Gaza Strip and identification of the Appropriate Technology (AT) for wastewater finishing plant.

II. Scale modelling design of the new system by DICAM - UNIBO and the local partners.

III. Monitoring phase of scale model through the analysis of treated wastewater and field observations.

IV. Monitoring and evaluation of treated water quality. The water analysis will be followed and monitored by UCAS, UAWC, DICAM, and Overseas during the entire project implementation.

V. Finishing wastewater treatment plant on a real scale. The executive planning and realization of the finishing wastewater treatment plant, design the operational project, approved by MoA and the Project Committee, prepared the tender documents and supervised all the realization and construction of the new system.

VI. Direct Services and benefits to the farmers. Selection for a greenhouse, open fields and cash for work, and activation of local committees for the agricultural use of treated water.

VII. Install of the distribution network systems to collect the treated wastewater from the plant to the open fields.

VIII. Rehabilitation of greenhouses: (40% hydroponic), distribution of seeds and plants to beneficiaries, installation of rainwater collection system, realized by DISTAL of the University of Bologna.

IX. Socio-economic study. The DICAM and UCAS University coordinated a socio-economic study about the project's impact.

X. DICAM ToT training: for MoA, Palestinian Water Authorities (PWA), Coastal Municipality Water Utilities (CWMU) and UAWC technicians on management and maintenance of wastewater treatment system.

X. Strengthening and training of local committees and beneficiaries to manage of wastewater and use it for agricultural purposes, to facilitate the change towards innovative management systems of agricultural water realized by UAWC and UCAS, coordinated by DICAM.

4.2 Study context

The serious situation in Gaza about water supply is worldwide considered as a humanitarian crisis (UNRWA, 2019): the primary freshwater source is, after all, represented by groundwater, which is severely contaminated, and, at current yields, there is almost no water of acceptable quality for domestic use. Gaza Strip is one of the most water-poor countries with water needs far exceeding the available supplies (Salem, Yihdego & Hamaaziz Muhammed, 2021) arising from pollution, climate change, population growth, rising demand for water, and political restrictions.

The coastal aquifer is considered the only source of freshwater for the Palestinian population in the Gaza Strip and the only natural source of water supply for all activities (domestic, irrigation, and industrial supply) (Weinthal et al., 2005; Al-Najjar, Ceribasi & Ceyhunlu, 2021).

4. Case study I: Reuse of Treated Wastewater in Rafah, Gaza Strip, Palestine

Considering the presence of about 2 million inhabitants in Gaza, the water availability is inadequate, both in terms of quantity and quality, with severe risks for public health. According to the latest Palestinian Water Authority (PWA) database, municipal water consumption is about 103.34 million m^3 (52%), of which 13 million m^3 is suitable for drinking purposes and agricultural water consumption about 95.3 million m^3 (48%) (PWA, 2014). The annual net deficit in the groundwater aquifer was about 90 million m^3 in 2016, and it is expected to reach 180 million m^3 by 2035 because of the massively over pumping for freshwater supply purposes. The aquifer shows clear signs of imminent failure or collapse, with resulting degradation and robust depletion of the water resources (Al-Dadah, 2013; Aiash and Mogheir, 2017). At the same time, there is an increasing water demand in Gaza Strip depending on the unexpected rise of the population.

Therefore, the water crisis in Palestine has a significant impact on agriculture and ultimately on food security. Also, because agriculture is an important part of the Palestinian economy in terms of the number of people it employs and its contribution to the gross domestic product (GDP) (McKee, 2012). Demand for freshwater to support agricultural development is high.

Wastewater recovery and reuse for agricultural irrigation are therefore recognized worldwide as a key strategy in reducing the water crises and filling the growing water needs gap in Palestine (Samhan et al., 2010, Gharbia et al., 2016). In this regard, wastewater reuse in agricultural irrigation has become a global practice with lower environmental impacts and contributes to rural development (Metcalf and Eddy, 2003a; Jaramillo and Restrepo, 2017; WWAP/UN-Water, 2017) . Treated wastewater can be an additional water source intended to increase agricultural production in Gaza Strip, where irrigation supplies are not sufficient to meet crop water needs (Al-Dadah, 2013).

The most critical consideration for wastewater reuse is to meet the sustainable development requirements by protecting surface and groundwater, human health, the environment, and natural habitats. This is achieved through meeting local wastewater reuse standards.

In this regard, the project presented focuses on preserving the water resource and its quality while guaranteeing its conscious use in agriculture addiction to environmental and health protection.

4.2.1 Description of the project area

The project has been developed in Rafah, a Palestinian city and refugee camp in southern part of the Gaza Strip. It is located within longitudes 34° 20′ and 34° 25′ east and latitudes 31° 16′ and 31° 45′ north covering a land area of 64 km^2 (see Fig. 4-1). The Governorate of Rafah is the site of the Rafah Border Crossing, the sole crossing point between Egypt and the State of Palestine. The 2020 population was projected as 252,703 inhabitants (PCBS, 2021) with a population density of 3,949 inhabitants/km^2. The climate of Rafah falls within the transitional zone between the Sinai Peninsula desert climate and the semi humid Mediterranean climate with hot dry summers and mild winters (Aish, Ayesh & Al-Najar 2021). Agricultural land constitutes over 50% (33 km^2) of the total land area (Eljamassi and Abeaid, 2013). Groundwater is used for domestic, industrial and irrigation purposes with about 80% of the water supply managed by the Coastal Municipality Water Utilities (CMWU).

In specific, the area for the project is in Al-Mawasi Rafah, one of the 2 administrative sections of Rafah, a narrow strip of fertile land in the western part and it represents about 3% of the total area of the Gaza Strip.

Fig.4- 1_Location map of Rafah, Gaza Strip.
Source: Google map

4.2.2 Description of the Rafah WWTP

Municipal wastewater is collected, transported, and treated by the Rafah wastewater treatment plant. About 65% of Rafah City is connected to the existing wastewater system, with 35% using septic tanks.

4. Case study I: Reuse of Treated Wastewater in Rafah, Gaza Strip, Palestine

The Rafah Wastewater Treatment Plant (WWTP) (see the location in Fig. 4-2) , managed by the Coastal Municipality Water Utilities (CMWU), treats about 10,000 -12,000 m^3/day, with a pick of 18,000 m^3/day (ICRC, 2013). Since its construction in 1989, the treatment plant has been expanded from 1,800 m^3/day (equivalent to a population of 21,000 inhabitants) to 20,000 m^3/day in 2011.

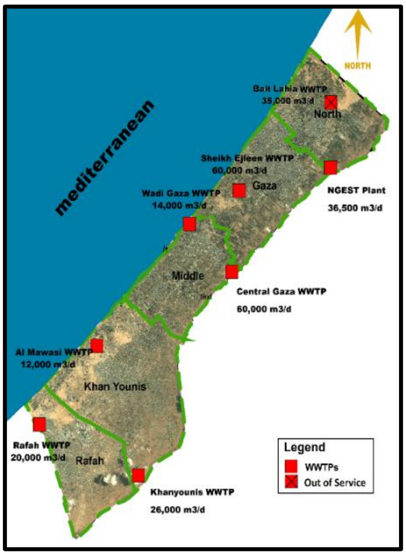


Fig.4- 2_Location of WWTP in Gaza Strip.
Source: Self-designed

The first phase of the construction had involved the realization of two anaerobic ponds, a new grit removal chamber, sludge drying beds and other improvements of the station. The second phase aimed at the construction of two bio-towers and related pipe-works as well as improving the pipeline for the treated waters collection to the sea (Fig. 4-3).

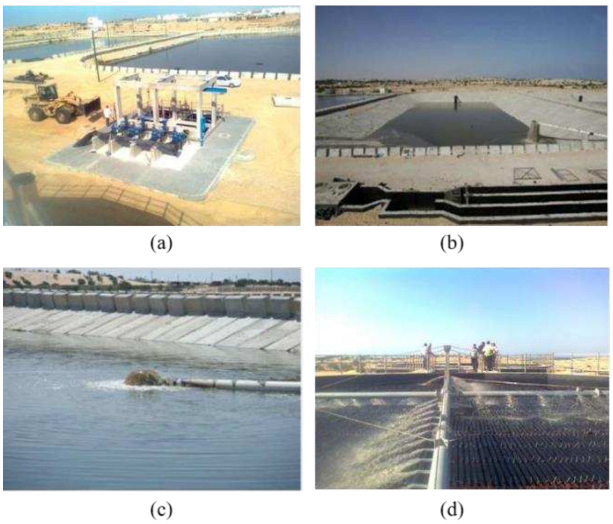


Fig.4- 3_ Representation of Rafah WWTP: (a) Pump station, (b) Grit removal and lagoon, (c) Aeration Lagoon, (d) Bio-Towers.
Source: ICRC, 2013

Despite the poor quality of the effluent, it is still disposed into the Mediterranean Sea. In fact, however, the renovation of the WWTP has allowed to slightly improve the quality of the effluent, which is although under the recommended values.

The main monitoring data of the effluent of Rafah WWTP are shown in Fig. 4-4.

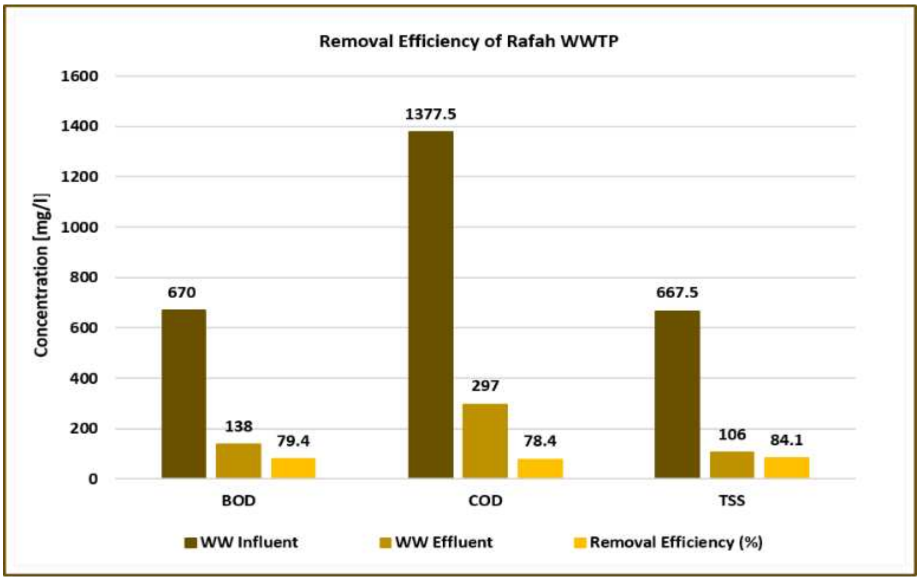


Fig.4- 4_ Removal Efficiency of Rafah WWTP.
Adapted from CMWU (2018); PCBS (2018)

4.2.3 Characterization of wastewater effluent

In order to test the effluent coming from the Rafah WWTP, a weekly sampling activity has been conducted for two months in terms of Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Ammonia, Nitrite, Nitrate and Total Phosphorus (TP). Their average concentrations are shown in Fig. 4-5.

These preliminary results confirm the poor quality of the treated wastewater and the unsatisfactory performances of the existing plant. In this condition, the output water cannot be reused for irrigation purposes or safely collected and discharged, and it can be dangerous for the health of workers and utilizers.

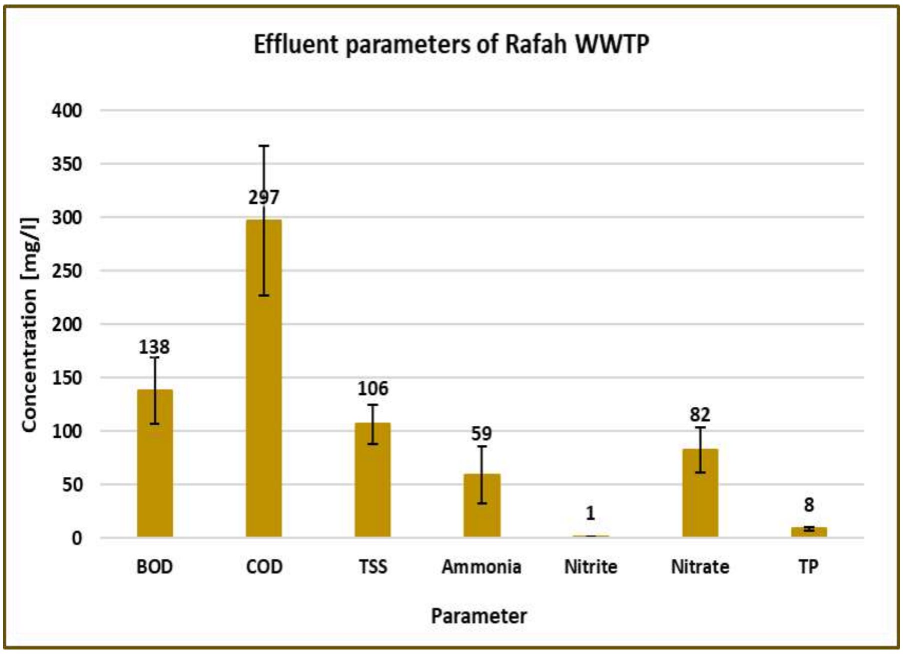


Fig.4- 5_Effluent Parameters of Rafah WWTP.
Source: (Bonoli et al., 2020)

Since reclaimed water reuse became an integral component in water supply and management in many countries, several organizations and authorities have implemented water reuse guidelines and regulations (James Crook and Surampalli, 1996; Metcalf and Eddy, 2003; EPA, 2012). In specific, the Palestinian standards for wastewater (WW) reuse in irrigation are shown in Table 4-2.

Table 4- 2_ Palestinian Standards of WW Reuse in Irrigation

Treatment Level	***Quality Characteristics***		***Possible Uses in Irrigation***
Primary	-	-	Not allowed
Secondary low	BOD_5 COD Total SS DO	60 mg/l 150 mg/l 50 mg/l 0.5 mg/l	Cotton, sugar beets, dry fodder, forests, seeds, cereals
Secondary high	BOD_5 COD Total SS DO	45 mg/l 110 mg/l 40 mg/l 0.5 mg/l	Green fodder, olives, peanuts, citrus, banana, almonds, nuts
Secondary high + disinfected	BOD_5 COD Total SS DO Coliform (unit /100 ml) Residual Chlorine	35 mg/l 60 mg/l 30 mg/l 0.5 mg/l 250 0.15 mg/l	Green vegetables for cooking, fruits for canning, deciduous fruits trees, groundnuts, sports grounds.

Treatment Level	*Quality Characteristics*		*Possible Uses in Irrigation*
Tertiary	Total BOD_5 COD Total SS DO Coliform (unit /100 ml) Residual Chlorine	15 mg/l 40 mg/l 15 mg/l 0.5 mg/l 12 0.5 mg/l	Unrestricted use in irrigation, vegetables for fresh consumption, public parks, lawns.

Source: PWA and MOA (2012); Aiash and Mogheir (2017)

4.3 Choice of Appropriate Technologies for the Case Study

In order to reuse the effluents coming from the Rafah's primary treatment plant, it has been considered the opportunity to implement a finishing phase by an Appropriate Technology (AT) approach, which is context-specific and depending on the local conditions where they are applied (as described in Chapter 2). In this case, useful preliminary information was collected from local agricultural organization, and the PWA, considering the area's critical environmental, economic and social issues and the existing water management system. This has allowed to understanding difficulties, threats, and opportunities of the context.

The starting points for choosing the appropriate technology are:

- the analysed local criticalities suggesting to carry out a treatment system with low energy consumption avoiding chemical reagents in order to obtain cheaper treated wastewater, to be destined mainly to agriculture purposes.
- Previous excellent experiences in other areas, i.e., a case study carried out in Mozambique, that has been considered comparable in terms of weather condition, soil properties, and water issues.
- A sustainability assessment approach, enabling comparing the various finishing wastewater treatment technologies feasible in this case study (Kakavand, 2019). The results are shown in Section 4.3.1 of this Chapter.
- A preliminary analysis of wastewater coming from the existing primary plant in the city of Rafah, provided by Coastal Municipalities Water Utility (CMWU) Central Lab – State of Palestine (see Appendix A) and preliminary analysis of Effluent of Rafah WWTP carried out during the first year of the project (see Table 4-5).

4.3.1 Selection of Appropriate Technologies with evaluation through Evidential Reasoning approach

Many different wastewater treatment technologies are applied in Palestine Territories, including bio-tower (Nassar et al., 2010; PWA, 2012) activated sludge, membrane bioreactor (MBR) (Taha and Al-Sa'ed, 2017), trickling filter, waste stabilization ponds, sand filters (Rashed Al-Sa'ed, 2000), extended aeration, aerated lagoons (Samhan et al., 2010) and constructed wetlands (Masoud 2011; IRIDRA, 2021). The challenge in wastewater management for potential reuse is selecting the best technology to meet the wastewater treatment objective at the specific site. Numerous factors, such as capital costs, operation and maintenance (O&M) costs, and land requirements, are involved in the decision-making process. It is also necessary to use a decision-making framework that incorporates sustainability indicators to select appropriate technologies for wastewater management. To fulfill the sustainability commitments, many country-specific points must be considered including economical, technological, environmental, social, and political aspects. The multifaceted nature of sustainability makes selecting the most favoured technology a complex multi criteria decision analysis (MCDA) process consisting of various conflicting objectives.

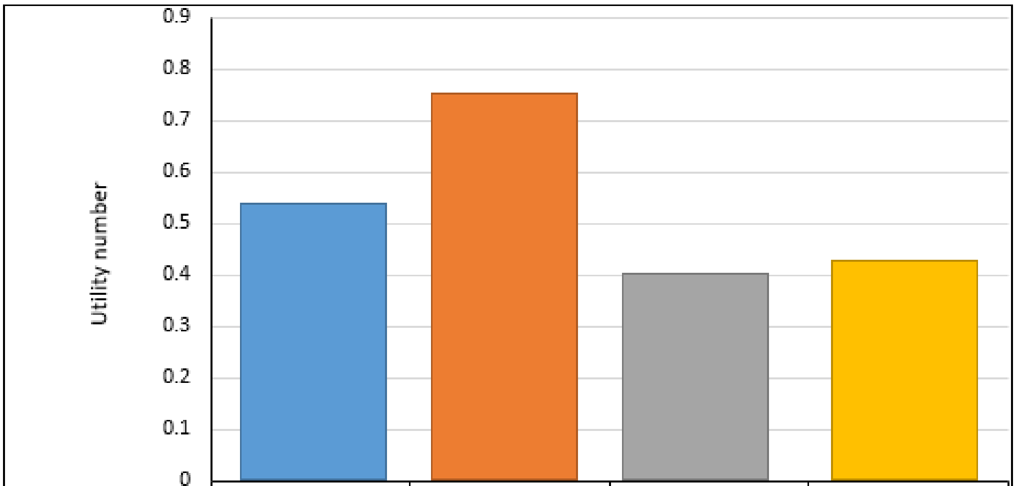
Water and sanitation projects for solving the requirements of communities in developing countries are complex in nature and involve complex decision-making, which must consider technical, socio-economic, and environmental dimensions. Multicriteria Decision analysis (MCDA) (Garfi and Ferrer-Martí, 2011) is a suitable decision-aid method that scores a finite number of options on the basis of a set of evaluation criteria, as describe in Chapter 2 section 4 of this Thesis.

More recently, the Evidential Reasoning (ER) approach which was developed in 1990s is considered as one of the premier methods for MCDA problems (Ngan, 2015) primarily because it is capable to deal with both qualitative and quantitative criteria under different uncertainties and ignorance (Wang, Yang, and Xu 2006). The ER approach provides a procedure for modelling multiple attributes using the distributed assessment framework (belief decision matrix) and the Dempster–Shafer (D–S) theory of evidence for attribute aggregation. The ER distributed modelling framework through the belief structure provides a uniform framework and an effective and trustworthy method to deal with various human judgments (Akhoundi and Nazif, 2018). Each attribute is assessed using a set of collectively exhaustive and mutually exclusive assessment grades (Yang et al., 2006). Many researchers have applied the ER approach to environmental problems such as ranking different wastewater reuse alternatives in

Tehran, Iran (Akhoundi and Nazif, 2018), Environmental Impact Assessment (EIA) (Wang, Yang & Xu, 2006), evaluating resilience of water resources management scenarios (Behboudian and Kerachian, 2021), risk assessment of water quality failures in water distribution pipelines (Sadiq, Kleiner & Rajani, 2007; Garfì et al., 2011), evaluating different water supply and quality management policies (Estalaki, Kerachian & Nikoo, 2016), solid waste management (M. Garfì, Tondelli, and Bonoli, 2009; Abed-Elmdoust and Kerachian, 2012), evaluation of land degradation (Thiam, 2005), and condition assessment of buried pipelines (Hawari et al., 2018). The results showed that ER approach could be applied to assess the sustainability of decision alternatives for addressing environmental challenges with different kinds of uncertainties (ignorance or vague) based on qualitative criteria, quantitative criteria or both.

In this case study to reuse the effluent from the Rafah WWTP in agriculture, it was necessary to study, select and construct a secondary treatment plant for the wastewater treatment system, considering a new water recycling system followed by disinfection. In fact, the ER approach was applying to assess the sustainability and to aid in the selection of the best secondary treatment technology alternative for wastewater reuse in agriculture in the City of Rafah, Gaza Strip.

Four secondary treatment technologies (sand filter, phytoremediation, activated sludge, bio-tower) were selected based on expert advice. The sustainability of the technologies was assessed using four sustainability dimensions and thirty-three sub-criteria. The dimensions and sub-criteria were evaluated qualitatively through local experts' (those working on the current project, members of agricultural NGOs, and selected local University professors) knowledge and judgement obtained through questionnaire survey. The Expert Choice software and the Intelligent Decision System software package were used for data analysis. Based on the utility interval-based ER ranking method both with and without ignorance, the wastewater treatment technology alternatives were ranked as phytoremediation>sand filter>bio-tower>activated sludge. The average utility number for the phytoremediation technology was 0.7399, on a scale of 0 to 1 (see Fig.4-6). The sub-criteria of the Environmental dimension with total relative weighting of 0.0864, on a scale 0 to 1, was the highest influence on prioritization of the best secondary wastewater treatment technology alternatives (Kakavand, 2019).



	Sand Filter	Phytoremediation	Activated Sludge	Bio-Tower
Utility number	0.5351	0.7399	0.4039	0.4271
Rank	2	1	4	3

Fig.4- 6_ Ranking of alternatives with regard to the best treatment technology.

4.3.2 Technologies selected

The technologies selected for this case study focused on implementing a finishing WW treatment were phytoremediation followed by natural disinfections, aiming to optimize the overall wastewater treatment process and manage them for irrigation purposes. The choice of these two technologies should ensure the standard effluent quality required for water reuse purposes.

There are many applications of natural purification techniques, carried out throughout the world (i.e., in Great Britain, France, Denmark, Germany, Sweden, Slovenia, USA, Australia, etc.) (EPA 2012), which have provided positive answers both in terms of landscape insertion and environmental efficiency and in terms of depurative efficiency and of cost-effectiveness of implementation and management. In addition, agriculture is one of the worldwide significant destination sectors of reclaimed water (EPA, 2012), and Constructed Wetlands (CWs) are widely applied as a low-cost alternative or supplementary system for wastewater treatment. In addition, proper management of recycling wastewater for agricultural purposes will help decrease soil and plant contamination and moderate water shortage (FAO, 2003).

The phytoremediation system has been selected because of the absence of energy and chemical reagents and its high efficiency in removing the main physico-chemical pollutants and nutrients by using plants for environmental depuration, more effective than traditional methods based on chemical extraction of xenobiotics. Biological methods do not cause secondary pollution, and phytoremediation techniques are cheaper when compared with conventional techniques (such as activated sludge process, biofilters, trickling filters, etc.) (Materac et al., 2015). However, phytoremediation can present some limitations: it requires a large surface to construct the system and provides a slow rate of the process.

If combined with a phytoremediation system, the aerated lagoon unit represents the final treatment stage. The aerated lagoon can be considered as a pervading finishing system. It also needs a large surface and a good brightness that allows the penetration of light and consequently the photosynthetic production of oxygen all over the lagoons. The system supports aerobic bacterial degradation with artificial oxygen supply provided by surface turbo-aerators or submerged aerators or diffusers with blowers to augment the oxygen supplied from natural means, such as re-aeration surface or photosynthesis (FCM, 2004). Aerated lagoons, typically from 2 to 6 meters deep, provide the mixing of the reactor and high removal of the main microbial groups.

4.4 Design and realization of the pilot plant

4.4.1 The design phase of pilot plant

After the selection of technologies, in order to study and monitor effluent contamination parameters and understand the real efficiency of the system, a wastewater finishing pilot plant has been designed and constructed with a capability of about 6 m^3/day.

The pilot plant dimensions have been assumed on the base of the USA Environmental Protection Agency indications (Davis, 1995). Fig. 4-7 shows the scale model drawing. In Table 4-3 the main dimensions are reported.

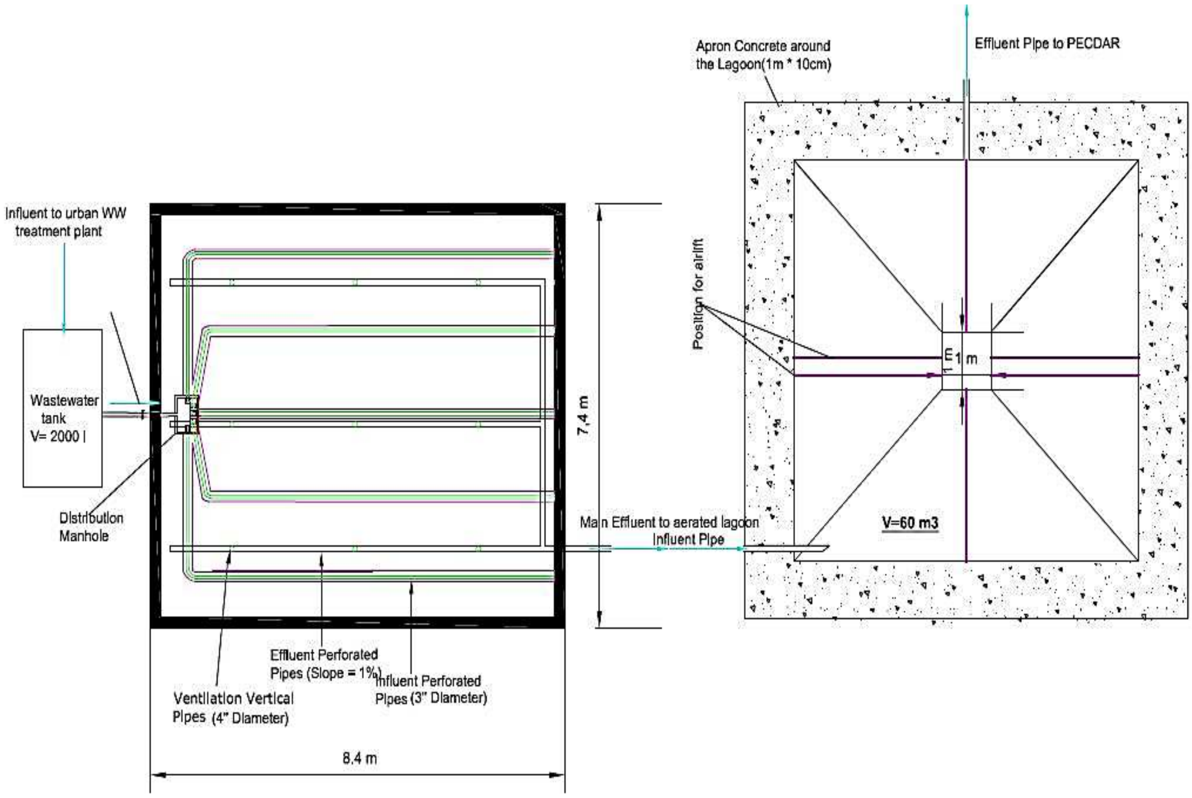


Fig.4- 7_Plant and dimension of scale model design.
Source: Self-designed

Table 4- 3_Dimension of the scale model

Area of the phytoremediation system	A $_{Phytoremediation}$ = 62 m^2
Volume of Aerated lagoons ***(considering Depth: H = 3 m and Area: A = 20 m^2)*** ***Capacity of a storage tank***	V $_{Useful}$ = 60 m^3 C tank = 2000 l

The phytoremediation pilot-scale system presents 3 layers, composed by the following materials: from bottom to top, respectively a big gravel, a washed sand and a vegetative soil and plants (Fig. 4-8(A)). The plants selected are “persistent emergent plants”, a mixture of gramineous and legumes, that have two different functions. During their growing, plants provide adhesion places for microbial development and contribute to create a vegetative mass that regulates the water flow direction, while their death creates a release of organic carbon functional for the microbial metabolism (Willey, 2007). Plants also influence the wastewater quality by optimizing various removal processes and consumption of organic matter and other physico-chemical elements (Ko et al., 2011; Ong et al., 2010).

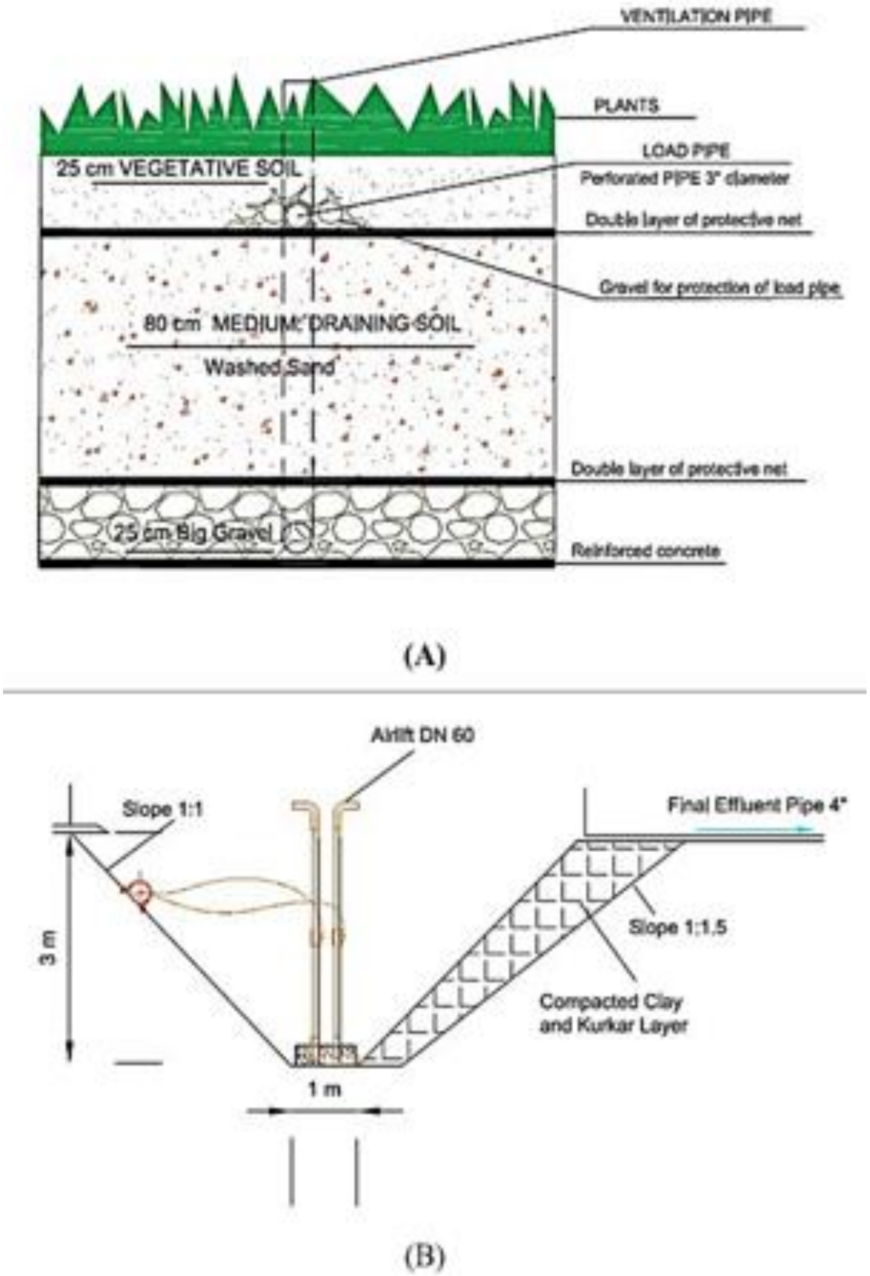


Fig.4- 8_Cross-section of the (A) 3 layers in the phytoremediation system, (B) aerated lagoon.
Source: Self-designed

4.4.2 The construction phases of pilot plant

The construction phase of the pilot plant was started during our mission conducted in the field in May 2019 and completed in October 2019. The pilot-scale plant has been fed by the real sewage coming from the municipal WWTP after the primary treatment. Fig. 4-9 shows a few pictures of the various construction phases of the pilot plant.

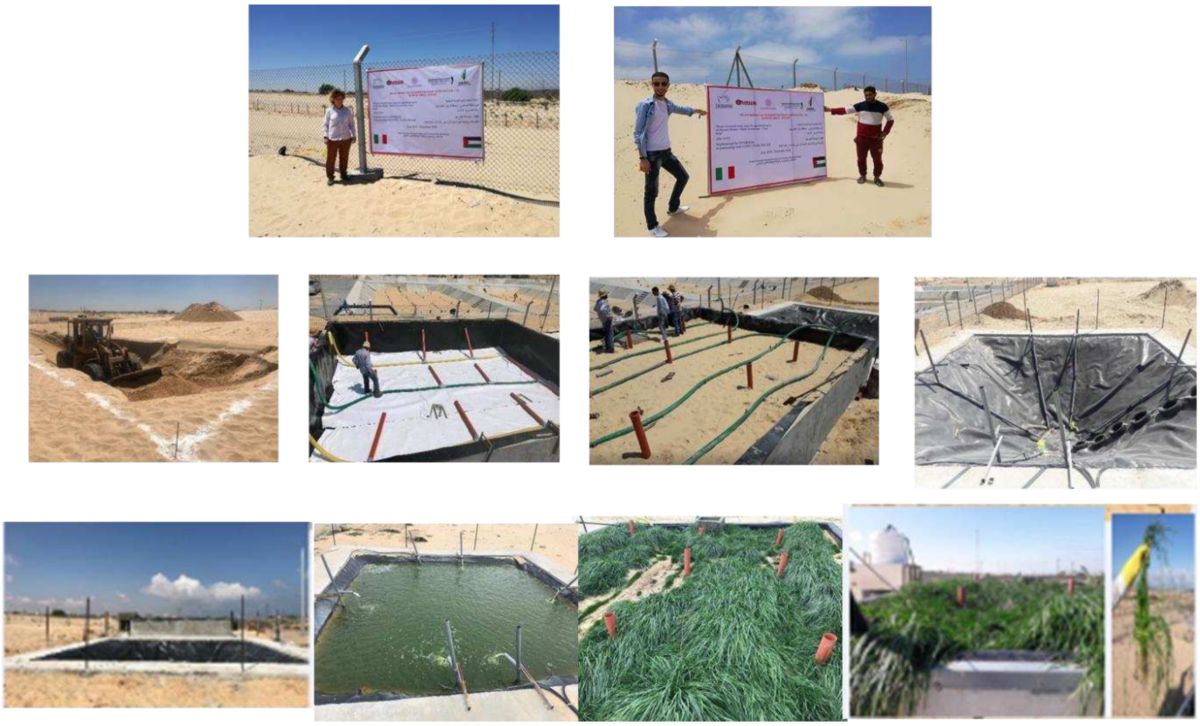


Fig.4- 9_Pictures showing the main construction phases of the pilot plant.
(Photo credit: Authors)

4.4 Preliminary results of the pilot plant

4.4.1 Sampling Points

The performance of the pilot plant system has been assessed by evaluation of influent and effluent parameters at each treatment unit. Influent and treated wastewater samples have been collected every week for two months, from 2nd December 2019 to 3rd February 2020, respectively at the storage tank (Point A), where the influent of the designed system corresponds to WWTP effluent, after the phytoremediation pond (Point B) and after the lagooning system (Point C) (Fig.4-10). All samples have been collected using sterile bottles (see Fig. 4-11) and transported to the "Coastal Municipalities Water Utility (CMWU) Central Lab – State of Palestine" for further analysis, that have been performed according to standard methods for water and wastewater tests (APHA, AWWA, 2005). The quality of the effluent has been compared to the Palestinian legal limits for wastewater reuse in irrigation (as shown in Table 4-2). Influent and treated wastewater samples were analysed in order to test the following parameters: Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Total Phosphorus (TP), Chloride, Free Active Clorine, Ammonia (NH_4); Nitrite (NO_2); Nitrate (NO_3).

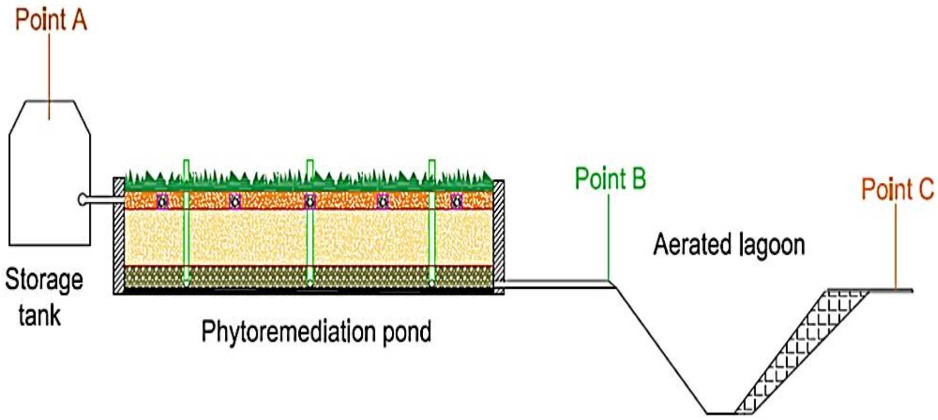


Fig.4- 10_Sampling points in the scale-pilot plant.
Source: Self-designed

Fig.4- 11_Various Samples.
(Photo credit: Authors)

4.4.3 Monitoring phase

In the monitoring phase the Biological and Chemical Oxygen Demand (BOD_5 and COD) values and nitrification and denitrification processes taking place in the plant have been measured. These parameters should respect pollutants concentrations limits and be below the Palestinian legal limitations (see Table 4-2), maintaining a good efficiency of the process.

4.4.4 Preliminary results

The values of physico-chemical parameters, recorded at the different sampling points for the entire monitoring period, are reported in Fig. 4-12.

Rafah WWTP is treating municipal wastewater having higher organic pollutant levels, especially for BOD_5 and COD, than the common expected ones.

However, they seem to be in line with the typical wastewater values for the specific area, due to the problem of water scarcity that leads to a high ratio of organic load/water and without a proper dilution. In addition, the high organic load may be due both to several different local sources of organic pollutants, such as domestic or restaurants' exhausted cooking oils, agricultural and soil leachate, laundries wastewater, etc. and to a very bad and irregular maintenance practices and to the unreliable electricity supply.

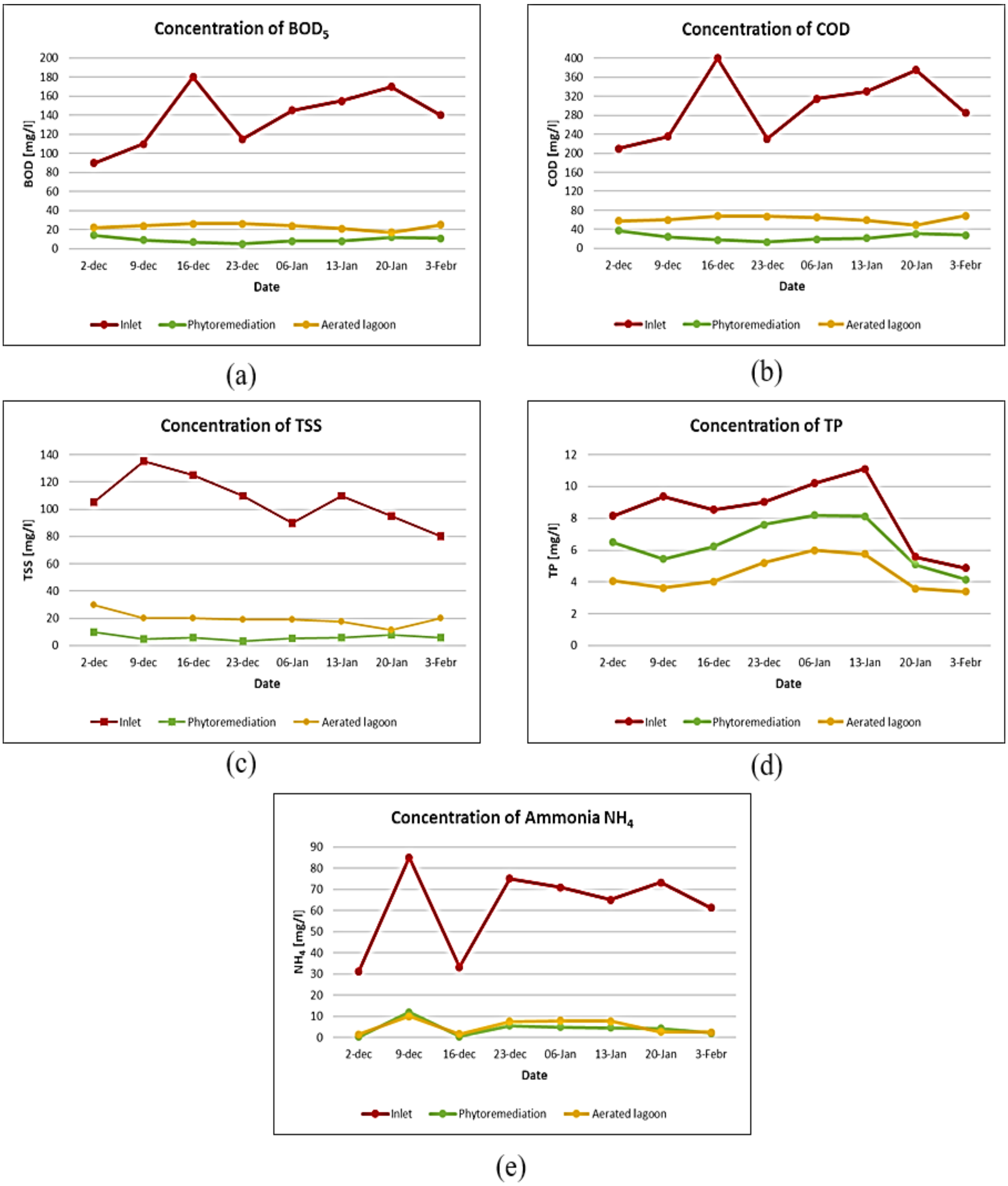


Fig.4- 12_Concentrations [mg/l] of the physico-chemical parameters at the different sampling points: (a) BOD$_5$, (b) COD, (c) TSS, (d) TP (e) NH$_4$.
Source: Bonoli et al. (2020)

So high values, mainly in terms of BOD_5 and COD, do not conform to the limits needed for agricultural use or for a safe collection and release in the environment. Inside the aerated lagoon, residual nutrients are transformed in biomass. In that way, during the first phases of treatment, some parameters, such as BOD_5, phosphorus, and ammonia, are destined to grow, related with the presence of a convenient and effective biomass, while pathogens decrease. Algae maintain a high level of oxygen, avoiding anoxia risks. Downstream the pilot plant treatment, as shown in Fig. 4-12, the concentration values are lower than the Palestinian limits for agriculture (Table 4-2). In this way, it is possible to use the treated wastewater for irrigation also for food production purposes, such as for green vegetables, fruits, deciduous fruits trees, groundnuts and sports grounds.

In addition, Fig. 4-13 shows the average value of inflow and outflow wastewaters and the removal efficiency.

The average TSS and BOD_5 values, respectively 20 and 23 mg/l, have been resulted within Palestinian limits for agricultural reuse. Average TSS concentration (106 mg/l in phytoremediation influent) dropped to 20 mg/l, showing a mean removal efficiency of about 81%, that is mainly due to physical processes, such as sedimentation and filtration (Vymazal and Kröpfelová, 2008).

The mean reduction of organic matter concentration during the detention period is about 83% for the BOD_5 and 79% for the COD. The mean percentage of organic components removal is significantly the same for COD and BOD_5, since municipal wastewaters usually contain elevated concentrations of easily degradable organic compounds (Vymazal and Kröpfelová, 2008). The effluent provides BOD_5 values between 17 and 25 mg/l, with a mean value of 23 mg/l, and COD values between 49 and 69 mg/l, with a mean value of 62 mg/l. Both results are compatible with regulatory limits for reuse. The nutrients removal efficiency is 92 % for NH_4 and 50% for TP. Their average values, after the treatment processes, are 5 mg/l and 4 mg/l. The strong reduction of the nutrient's concentration is due to the lagooning unit with the aerobic decomposition of algal substances.

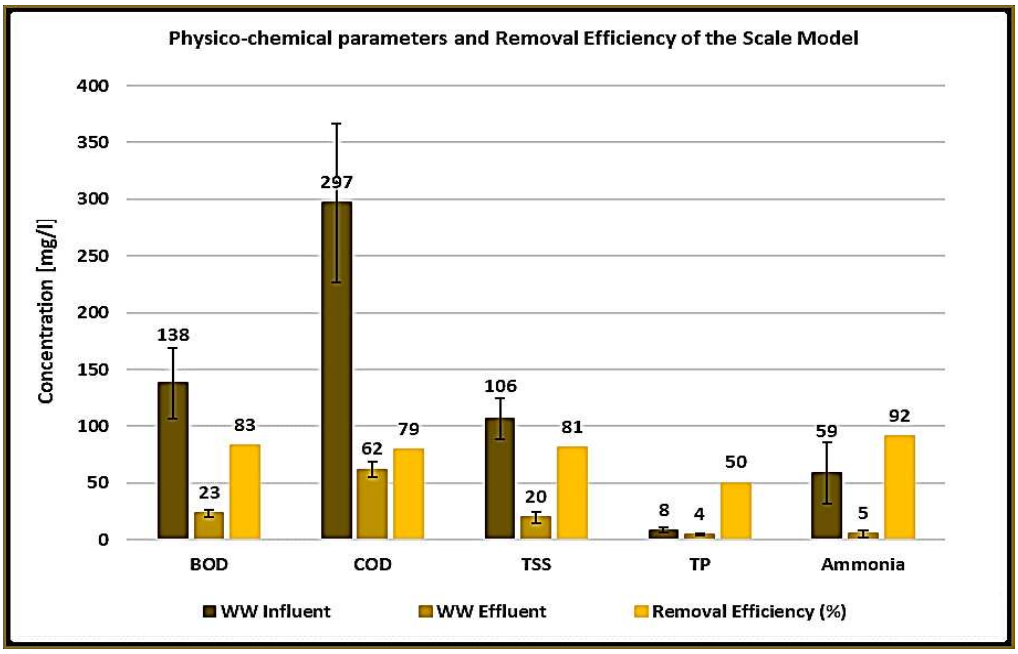


Fig.4- 13_Influent and effluent quality for specific pollutants at the scale-plant: average values. Source: Bonoli et al. 2020

The finishing pilot-scale plant, designed to evaluate the feasibility of municipal wastewater reuse in Rafah (Gaza Strip), has shown a very good efficiency, according with the Palestinian regulation for wastewater reuse in agriculture.

The preliminary results highlight that the phytoremediation system, followed by a natural disinfection, improve the overall wastewater treatment process. The analysis of the effluents demonstrates that, under controlled conditions, treated municipal wastewater can be used for agriculture purposes with of effective economic and environmental benefits.

The preliminary pilot-scale results are encouraging to construct a real scale finishing treatment plant, in the same area, able to treat a municipal wastewater flow of about 1000 m^3/day that will be used for local crops (such as olives, citrus, potatoes, grapes and guava) by many farmers who are the final beneficiaries of the project.

4.5 Findings and technical limitations

Continuous monitoring of the pilot plant revealed the strengths and technical limitations that need to be improved in order to build the full-scale plant.

The results of the analysis of the effluents from the pilot plant demonstrated that the implemented system is suitable for the case study. The results of the pilot and constant meetings on project developments between project actors, ministries, and stakeholders on site led to the approval for the full-scale implementation of the plant.

Furthermore, through the technical training (shown in Section 4.8), the direct and indirect beneficiaries of the project also accepted the newly installed wastewater treatment system.
However, technical limitations slowed down the project work and highlighted the need to implement technical details in the full-scale plant.
The limitations can be clustered around the various legislative approvals for connection to the primary Rafah wastewater treatment plant, for carrying out the analyses for monitoring the pilot model, and the acceptance of the use of specific instruments for the treatment plant by the Israeli government.
In fact, some equipment, i.e., air pumps or airlifts, are considered double-products use and require prior authorization with a specific indication of actual use within the Gaza Strip.
In addition, to reduce better the higher organic pollutant present in the effluent coming from the Rafah wastewater Treatment Plant, septic tanks have been installed before the phytoremediation plant, and more ventilation has been added to the plant.
Also, identifying the final beneficiaries of the project has been problematic because of an initial mistrust towards the use of treated wastewater for agriculture. Secondly, some fields and areas initially identified were destroyed by the constant armed conflicts within the Gaza Strip.

4.6 Design and realization of the real plant and the distribution network

Due to the positive results obtained from monitoring the pilot plant, the two partner universities of the project continued their research with the design of a real scale finishing treatment plant, in the same area as the pilot plant, able to treat a municipal wastewater flow, from Rafah wastewater treatment plant, of about 1000 m^3/day.
First the design of the operational project was carried out. The structural, mechanical, and hydraulic design of the real plant is seen in Appendix B1. In addition to the design of the real plant, a Bill of Quantities (BoQ) was drawn up, which can be seen in Appendix B2.
After receiving approval from the local Ministries, a tender document was presented, and after an evaluation of the best offer of the various contractors by the project coordinating team, the plant's construction was started. The construction phase of the real plant was started in January 2021 and completed in December 2021. Fig. 4-14 reports the general pictures of the main construction phases of the plant on a real scale.

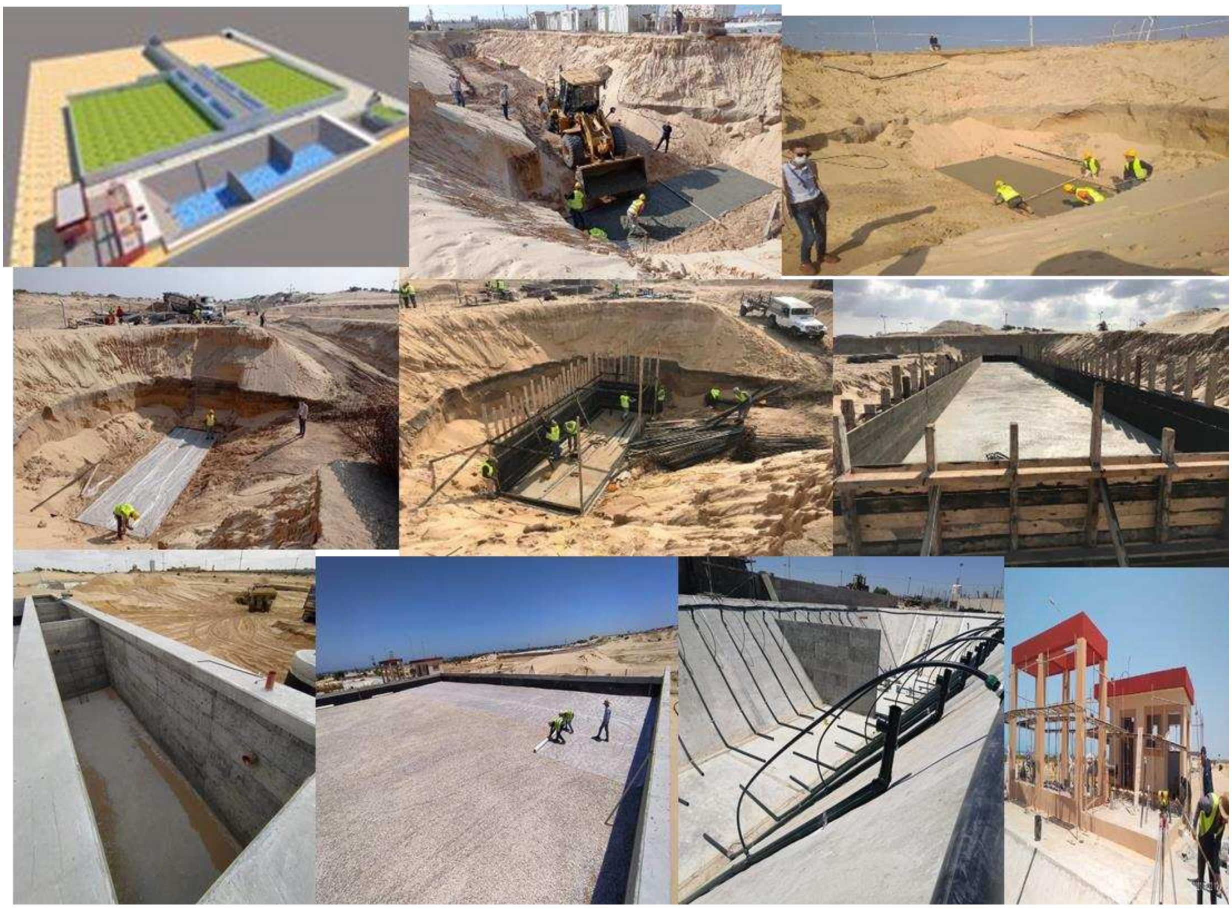


Fig.4- 14_General pictures of the main construction phases of the plant in real scale.
(Photo credit: Authors)

Also, the full-scale plant has been fed by the real sewage coming from the municipal WWTP after the primary treatment of Rafah. The first moments of the start of the plant is shown in Fig. 4-15.

All the construction phases of the real plant were monitored by local staff of the project and remotely by DICAM staff.

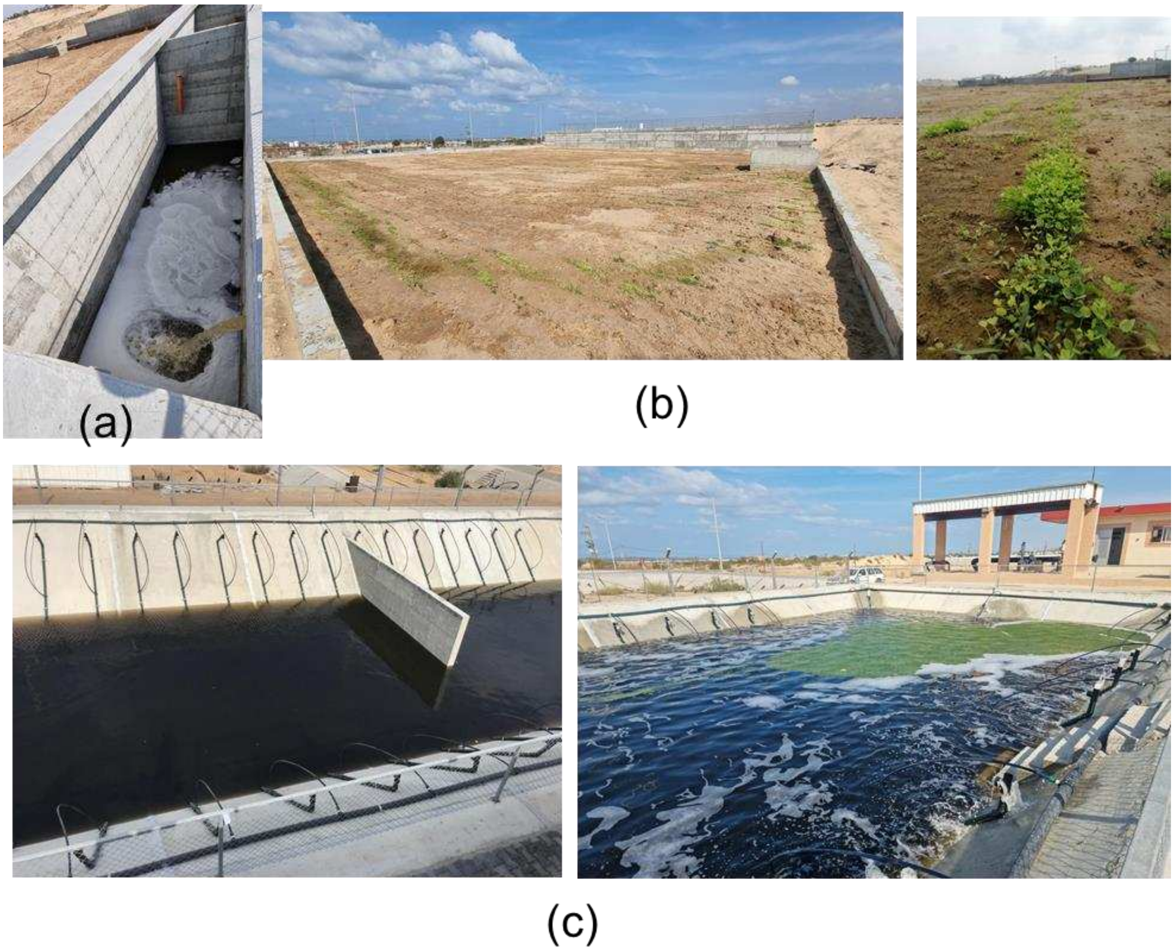


Fig.4- 15_General pictures of the component of the plant: (a) septic tank; (b) phytoremediation; (c) aerated lagoon.
(Photo credit: Authors)

In parallel, the design of the irrigation network to transport treated wastewater to the farmer, beneficiaries of the project, was also realized.

The structural and mechanical design of the irrigation network is shown in Appendix B1.

The tender of the irrigation network included about 6,000 meters pipes that allow the water to flow from the finishing WWTP system to the agricultural fields (distance of 1,5 km) (see Fig. 4-16).

The construction was realized from the same contractor and started in March 2021 and completed in December 2021.

Fig.4- 16_The Project Location, Main Pressure Line, and the Irrigation Networks.
Source: Self-designed

General pictures of the main construction phases of the plant on a real scale pipe works is reported in Fig. 4-17.

Fig.4- 17_ Pictures showing the main construction phases of the irrigation network.
(Photo credit: Authors)

4.7 Environmental and Social Impact Assessment

Another key component of this project is the Environmental and Social Impact Assessment (ESIA) in order to evaluate the environmental and Social impacts of the project and satisfy the Palestinian Environmental Law and Palestinian Environmental Assessment Policy (ESCWA, CAMRE, UNEP, DESA, 2001).

This project is categorized as a "B" project in accordance with Palestinian Environmental Assessment Policy (PEAP) and requires the preparation and implementation of a Preliminary Environmental and Social Assessment Study including an Environmental and Social Management Plan (ESMP). For category "B" projects, no major negative environmental impacts are envisaged since the project will comprise activities that support rehabilitation and improvements of infrastructure. Potential negative impacts that are localized and limited in nature will be avoided by providing instructions in the contract document, which specifically address environmental issues in a manner acceptable to the Palestinian Environmental Assessment Policy, as well as following Good Management Practices during construction and Operation.

An ESMP is realized to ensure that the project will be developed in a sound manner and will not cause negative impacts to the environmental resources and social issues. Also, to coordinate the policies, plans, programs, and decisions of various parties involved in the project during implementation and monitoring phases. The assessment includes a survey of the local applicable regulatory standards and guidelines, description of the existing environment, potential impacts of the development, mitigation measures that needs to be implemented, required training program and schedule of implementation.

4.7.1 The Objectives of the Preliminary ESIA

The main objective of preliminary ESIA are to:

i. Investigate and ascertain the possible environmental and social impacts of the project sub-components.
ii. Detail the possible environmental and social impacts of the construction and maintenance works.
iii. Manage, mitigate, and monitor any possible negative impacts during the design, construction, and operational phases of the project.
iv. Enhance positive impacts where possible.

v. Propose the required institutional set up and capacity building activities to implement, enforce and monitor the mitigation measures.

4.7.2 ESIA Process and Methodology

The following sections present the features of the study and detailed methodology.

4.7.2.1 Scope and Features of the ESIA

The ESIA consists of several core components. Table 4-4 summarizes the environmental assessment tasks and components of the (ESIA-ESMP) study.

Table 4- 4_The Tasks and Components of the (ESIA) Study

Components	Detailed Tasks
1. Project Description	- Review of the project components and details - Review and Analysis of possible alternatives to the project/project design
2. Legislative, Regulatory Organizations and Standard,	- Review of relevant local and international Legislative and Regulatory Considerations - Describe the pertinent Palestinian laws, regulations, standards, and guidelines - List the requirements of all stakeholders
3. Baseline Data	- Definition of the area “a Zone of influence” - Collection of Baseline data (Summary of key items without detailed assessment) - Collect, summarize, consult, analyze, judge, etc.
4. Assessment of Potential Environmental Impacts	- Very summarized section - Analysis; identify risks and impacts - Assess the significance - Summarize the findings in tables (Resources, impacts) criteria and Weights)
5. Development of ESMP	- Prepare an ESMP - Identity and analyze potential risks - Analysis of the project Phases - Propose alternatives and mitigation measures - Mitigation/optimization Measures and Residual Impacts - Matrix of impacts and mitigations - Roles and responsibilities - Monitoring Plan
6. Institutional Setup and budgeting of the EMSP	- Institutional Assessment - Institutional Overview and Strengthening - Training and Capacity Building required
7. Scoping / Stakeholders consulting	- Stakeholder consultation workshops or meetings (in parallel with other components of the study)

4.7.2.2 Data collection phase

The data collection phase includes the following items.

- **Desk Study**. During this phase, the available documents (project resume, local statistics, reports, and publications of MoA) were collected and reviewed.

  A desk study was carried out to review and extract relevant information from all available documents relating to the project. The team collected other relevant and available references, studies, and reports to ensure a comprehensive review of project components. The study team reviewed the available relevant documents including environmental studies, design reports, master plan, development, and strategic plans for the related sectors. Moreover, the team collected data available on the different services and organizations targeted at the national or local level as well as state standards, policies, and regulations.

  The collected and reviewed resources cover the following areas:

  - project objective and components;
  - project phasing, schedule of activities, operation and maintenance activities;
  - project alternatives and no project scenarios;
  - social Issues (economy, demographic, health, education, etc.);
  - infrastructure services in the area (water, wastewater, roads, electricity, telecommunications, etc.);
  - natural and biological environment;
  - standards, policies, and regulations.
- **Consultation Process.** The local partners during the planning and prefeasibility phase as well as the study team conducted consultations with local institutions, local community, and farmers. The opinions and concerns of institutions and community committees were collected and considered in the alternative’s analysis, and different components of the study, “no project” scenario, potential environmental and social impacts, mitigation measures, and monitoring plan. The study team conducted several meetings and groups discussions with the project partners, stakeholders, and different groups in order to present the key findings of the assessment, potential impacts, and discuss the proposed mitigation measures, prior to commencement of the project.
- **-The Questionnaire**. A questionnaire was designed for the baseline survey of the farmers. The questionnaire was prepared in English and Arabic in order to facilitate the dealing with farmers. A sample of questionnaire is presented in Appendix C. The

surveyed topics included Households (HHs) characteristics, type of cultivated areas, crops and production, access to water for agricultural. Also, the environmental resources and social issues that are of particular interest to the study were surveyed.

- **Sampling**: the survey targeted the proposed direct beneficiaries. The sample included 67 (out of the 77 planned) beneficiaries.
- **-Focus Groups Discussion (FGD)**. FGD is the most effective tool to discuss one issue in a collective way and to raise as many ideas and opinions as needed. Two Focus groups were conducted with the targeted beneficiary farmers.
- **-Site visits**. A site visit was arranged for the whole targeted area; location of the scale-model, route of the treated water pipeline, and the targeted beneficiaries. Site visits to the project site were conducted to assist in describing, assessing the existing conditions, and summarizing the related potential impacts.
- **-Data Analysis, reporting and Presentation**: following the data collection phase the team entered the data, tabulated the data, developed charts and figures, and then the first draft baseline report was elaborated.
- **Legislations and Standards Review**. A detailed survey of the organizational structures, the relevant draft or adopted laws, standards and policies that are relevant to the project details and components is prepared and summarized. Reference was always made to local environmental management standards. In case of lack of relevant domestic legislation regarding any issue, reference was made to the corresponding internationally applied and accepted standards.

Figures 4-18 and 4-19 present the target land and targeted farmers beneficiaries of the project.

Fig.4- 18_Targeted Land.
Source: Self-designed

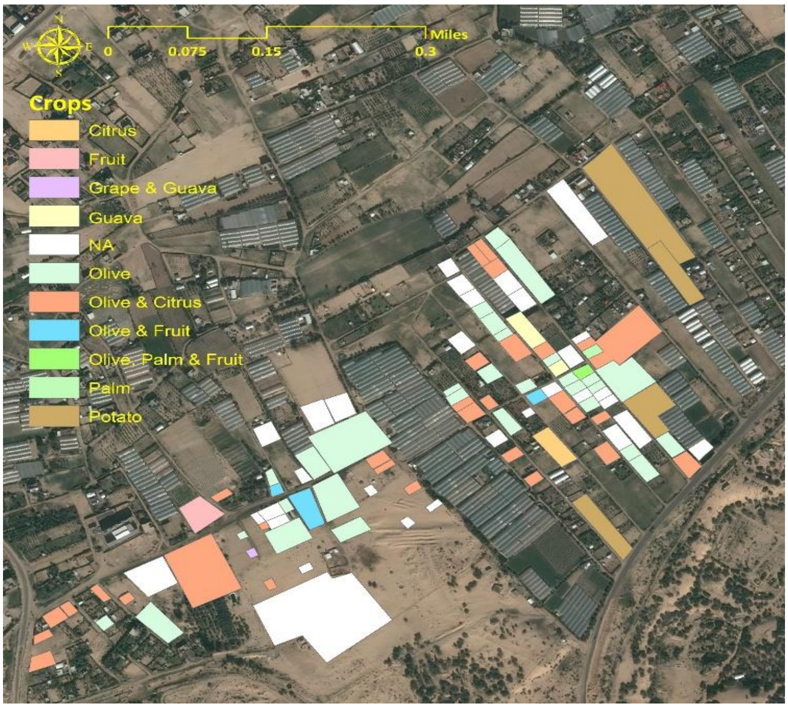


Fig.4- 19_Targeted Farmers.
Source: Self-designed

4.7.2.3 Mapping of Issue and Indicators

From the results of Questionnaire, Sampling and first consultancy the indicators that are important to provide evidence-based data for decision makers as well as to improve accountability are delineated. The use of indicators, also, allows data collection to be conducted in a systematic manner, in accordance with recognized standards. Indicators are also necessary to enable reliable and consistent reporting of quantifiable data that inform food security actions and measure output, outcome, and impact along the interventions. The Table 4-5 presents the key indicators that were developed during the study and were required during the next phases of the project.

Table 4- 5_ The Key socio-economic and agriculture indicators

Indicators	Description	Baseline Value
A. Households demographic profile		
Gender	% of HHs is Male	92.5%
Area	% of HHs lives in Rafah	100%
Education	% of HHs have Bachelor	38.8%
Family size	% of HHs sizes ranged between 6-10 persons	54.7%
Percentage	% of HHs have experience ranged between 5-10 years	33%
B. Income Indicators		
Percentage of people do not have sufficient income		
Sufficient income	% of HHs with Sufficient income	3%
Insufficient income	% of HHs with Insufficient income	74.6%
Sufficient vs. Insufficient	% of HHs moved from insufficient to sufficient income	*
Change in income in last month		
Increase	% of HHs reported increase of their income	3.1%
Decrease	% of HHs reported decrease of their income	87.7%
No change	% of HHs reported no-change of their income	9.2%
Change in main source of income		
Changed / developed additional sources	Additional income from a non-agricultural source	*
Changed / improved the available source	Additional income from the agricultural activities	*
No change	Source of income has not change	*
Change in production compared to last year		
Products	Value of increase of production in tons / product	*
	Improvement of product quality	*
Crops	Number and type of the cultivated additional crops	*
Households unable to plant next season		
Areas Percentage	Average cultivated area per HH	*
	% of land from the total lands have not enough resources to be planted next season	*
Farmers who have enough water to grow	Number of farmers who got new / additional quantities of water	*
	% HHs cannot cover their water needs	*
Beneficiaries receiving agricultural input	Number of HHs have received agricultural inputs as an aid	*
C. HHs agricultural holdings		
areas of the householders	% HHs own Less than 1 donum	70%
Type of Agricultural Activities	% HHs have cultivated and planted their lands	48%
	% HHs unable to plant their lands	52%
Type of crops	% HHs have cultivate Citrus	1.5%
	% HHs have cultivate olive	26.8%
	% HHs have cultivate olive & vegetables	41.8%
Marketing channels of agricultural crops	% HHs have benefit directly from personal consumption	45%
Environmental and external factors affected the farming activities	% HHs have suffer from drought / lack of rain,	58%
	% HHs have suffer from pests and diseases	46 %
D. Cultivated Lands and Irrigation Practices		
Agricultural water sources	% HHs have private wells	29.9%
	% HHs buy water	29.9 %
	% HHs don't have water source	11.9%
status of used water source	% Good	13.8%
	% medium	58.6%
	% Bad	27.6%
Irrigation system	Drip Irrigation	63%
	Traditional Surface Irrigation	37%
Quantity of water	Average quantity of water per dunum / month	136 (cup)
	average of total monthly water cost per dunum	32 $
E. Knowledge of treated wastewater		
Knowledge of treated wastewater and treatment methods		
Yes	Treated wastewater knowledge	78.5%
NO	Wastewater treatment methods	92.3%
Yes	Agricultural crops that are allowed to be irrigated with treated wastewater	93.7%
Yes	ready to use treated wastewater	100%

* = Indicators proposed to be calculated after the intervention and based on the results of the end-line survey or final evaluation.

The baseline survey results and indicators proved that the project objectives are closely related to the target group needs, and the project will remarkably be supporting them to bridge the gaps. The following are the key findings identification:
- The majority of HHs expenditures was on the seasonal items that include agricultural inputs.
- The expenses on preparing the lands for agriculture is the most critical item for the HHs.
- The main items of income sources are the income from temporary work.
- 11.9% of households do not have water source.
- 48% of households were unable to plant their lands because of their weak financial ability.
- The households are adopting several coping strategies in response to their gaps, these include reducing non-food and some food purchases, religion from relatives, and other strategies.
- Supporting the farmers is a very important intervention, it is highly appreciated by the targeted HHs and it is expected to improve their living conditions, and mainly food security.
- The farmers are interested to improve their lands, production and secure more sustainable water resources. The use of treated wastewater is highly welcomed as expected to introduce a remarkable improvement.
- In addition to provide or maintain water sources, other needs were requested by householders in FGDs such as learn the advanced techniques of planting, support them with fertilizers and how to deal with crops problems / diseases.
- Support the farmers with agricultural seedlings.
- Provide a permanent source of electricity and fences to protect agricultural land.

4.7.3 Baseline and Impact Assessment

The ESIA assembled, evaluated, and presented relevant baseline data on the environmental and social characteristics of the study area to cover the following.

- *Physical environment:* the physical environment to be treated is the entire service area, the site and the potential expansion site and neighbouring affected catchment area as well as those adjoining sites to be affected by adverse and/or beneficial effects.
- *Biological environment:* terrestrial communities in areas affected by construction, facility sitting, land application or disposal; aquatic, rare or endangered species, sensitive habitats, including parks or reserves, significant natural habitats, species of commercial importance inland application sites.

- *Social environment:* Present and projected populations; present land use and ownership; public health issues; cultural heritage sites, economic situations, employment, income, and current crisis and humanitarian conditions.

This ESIA Study evaluated the environmental impacts of the project during all development stages, design, construction and operation stages. The potential impacts of each component of the project are described and evaluated for the construction and post-construction stages of the project in order to identify the mitigation measures, which should be stated in the project contract documents and must be enforced by the responsible authorities.

An environmental impact matrix was used for comparison where environmental costs and benefits is quantified to the extent possible. The matrix identifies the impacts by systematically checking each development activity against each environmental component. Impacts assessment identified risks and impacts, assessed the significance, identified trends in impacts and presented the assessment criteria, significance, and weights.

4.7.4 Development of the Environmental and Social Management Plan (ESMP)

Based on the collected data, preliminary design, reports, site visits, interviews with involved staff and consultant's experience, an Environmental and Social Management Plan (ESMP) was developed for the project, which includes feasible and cost-effective measures to minimize or mitigate negative impacts and the actions to be adopted during the different phases of the project. Also, the ESMP is prepared to integrate environmental concerns into the design and implementation of the proposed projects. The ESMP includes three basic components: institutional component, environmental mitigation, and environmental monitoring.

The cumulative potential adverse environmental effects without these projects, however, can be substantial, particularly as they relate to sanitation, the ecology, and impact on the regional socio-economic and socio-cultural framework.

The projects' implementation and operation should mitigate the risks to humans, the impacts on ecology and natural resources. All potential environmental effects and measures to mitigate these effects must be adequately identified in a comprehensive environmental Management Plan as outlined in the subsequent sections.

4.7.5 General Findings and Impacts

The project of concern is of great direct impacts on water resources and agriculture in the Gaza Strip. During the operation phase, it is expected that significant benefits would occur to local labours, service providers and the communities in construction related fields. Direct, indirect or cumulative impacts may be produced during both construction and operations phases. These impacts either minor impacts with minimal effects or require monitoring and mitigation measures to minimize their effects.

The following sections detailed the project impacts considering two different scenarios. The first is to reveal the impacts of keeping the project components as is ("No Project" Scenario). The second is to investigate the potential impacts of carrying out the project components as proposed.

4.7.5.1 "No Project" Scenario

The "No Project" option considers the alternative of not conducting the project at all. It is normally evaluated to assess the impacts if the project does not go ahead.

If the present situation continues, "No project" Scenario, there will be an accelerating load and deterioration of the Rafah WWTP. Rafah WWTP will continue to receive the wastewater from the different neighbourhoods that may start to exceed treatment capacity (as per population increase).

Without the planned project activities, the negative impacts on the site components would follow the long-term impacts. However, this scenario requires mitigation measures and monitoring plan to minimize the impacts.

The environmental impacts would just follow the general impacts due to the increase of generated wastewater, bad odours, less quality of treated wastewater, impacts on underground water, and nuisance to the local surrounding communities. Numerous social negative impacts will occur, including degradation of agricultural practice and quality of life in the area.

A "No project" scenario would perpetuate the unsustainable scenario and deterioration levels, with long-term negative impacts on the site components, and would not provide much-needed socio-economic impetus in the proposed area and around. From a safeguarding perspective, certain potential impacts associated with wastewater collection, wastewater treatment, and monitoring of the underground water quality due to the additional generated quantities of wastewater would be continued and accelerated with time.

4.7.5.2 Environmental Benefits

Through the assessment process of the project, it is expected that significant benefits would accrue to the population. Significant environmental benefits are expected after the implementation of the project. The identified positive environmental impacts would include the following:

- The treated wastewater will be an important source of irrigation water, as water resources in the Gaza Strip are scarce.
- The implementation of the project will enhance the Municipality of Rafah in cooperation with the other involved entities to improve the infrastructure services in the in terms of installation of wastewater networks, which will lead to a healthy environment, and will enhance the quality of life.
- Securing a renewable energy source will reduce the dependency on generators and improve continuous operation with less costs and impacts.
- Conservation of land, water, and natural vegetation, through the sustainable utilization that ensures long-term agricultural production.
- Protecting the environment, the agro-biodiversity, and agricultural resources, to secure requirements for sustained development.
- Improvement of the technical and managerial capabilities of the agricultural sector to cope with probable climate and environmental changes and absorb their consequences.
- Halting unplanned expansion of urban areas on agricultural land that are violating current legislation of prohibiting building on agricultural land, through denial of services to these buildings.
- Improving water quality of effluent discharged and its compliance with the legal standards.
- Decreasing pollution of the final discharge point, especially in the sea.
- Increasing population wastewater treatment needs will be met.
- Possible overflows of untreated water will be avoided.
- Various capacity building, training, and research opportunities.

However, these impacts are positives and enhance the project idea, and the project partners and stakeholders, operators, contractors, and other parties are responsible to increase these positives as much as possible.

4.7.5.3 Socio-economic Benefits

Implementing the project components will contribute to achieving the following:

- The development of infrastructure facilities and improving the environmental conditions can contribute towards the well-being and quality of life of communities and can become an incentive for sustainable economic development.
- The Project will contribute to increasing energy security through reliance on an indigenous, inexhaustible and mostly import-independent energy resource.
- Increase revenues generation and greater cost recovery.
- Economic benefits are gained as short-term job opportunities for local skilled and unskilled laborers.
- Opportunities for local private sector participation and development through consulting, contracting, working, and manufacturing inputs throughout the project period.
- Employment generation will be elevated due to the engagement of many unemployed people in the project construction and operation. The project will be a great opportunity for local private sectors to participate in construction of such a project.
- The project will minimize the overload on RWWTP and then some nuisance from air pollutants and odours to surrounding communities.
- The project will enhance some farmers to rehabilitate their lands and plant new type of products.

4.7.5.4 Environmental Negative Impacts

The proposed construction activities are limited and there are no major negative environmental impacts envisaged since the project will comprise activities that support rehabilitation and improvements.

The following sections presents the key negative impacts and their significance and magnitude.

- **Air Quality**

The construction of various components of the project would generate dust, vehicular emissions, and noise. The amount of these impacts is largely a factor of the size of the facility, pressure lines, irrigation networks, and duration of construction. The short-term impacts on the local air quality from construction would be localized, and these impacts could be minimized to some extent using dust suppressants (such as water) or construction methods (such as covering storage piles, and removal of construction waste directly to dump sites). Emissions generated during the construction phase include:

- Vehicle and diesel emissions from large construction equipment and generators.
- Small amounts of air pollutants (carbon monoxide, nitrogen oxides, and particulates) from the different activities engaged in the construction phase. Fugitive dust from many sources such as disturbing and moving soils (clearing, grading, excavating, trenching, backfilling, dumping, and truck and equipment traffic), mixing concrete and drilling.

The emissions would present a short-term nuisance and will be limited to the project area and dispersed rapidly. The activities will be confined to project area which is away from the locality and sources of noise during the construction phase of the proposed project would primarily occur from the equipment used (bulldozers and diesel engines), installation of pipes, and the vehicular traffic. During the operation and maintenance phase, very limited emissions, dust, and noise are expected.

Failure of the treatment systems or pumping of low-quality treated wastewater may generate negative bad odours.

- **Land Use and Transportation**

The physical components of the proposed project include new structures and installations of infrastructure below ground such as the installation of footings and some in-site main lines that will dominate the project's physical activities. There will not be any physical displacement of people due to the project. The land is in rural area with limited population. Thus, the impact on land use will be inflatable.

Only minimal disturbances during construction could be occurred and could be mitigated efficiently by proper construction management.

Other components of the project are not anticipated to have as perceivable an impact on land use. Construction activities of the proposed project may result in short-term disruptions to the existing adjacent land uses. Construction vehicle emissions and dust would present a short-term nuisance.

Construction activities associated with the proposed project is relatively of small scale. Thus, it is not anticipated to generate unreasonable traffic. Construction of wastewater pipelines along the main roads may result in short-term disruptions to the existing traffic.

- **Agricultural resources and use**

The implementation of the various components of the project requires the construction of a few structures above and below ground. Vegetation within the immediate vicinity of the footprints of these facilities would be cleared. No unique vegetation of special concern is anticipated to be found in the vicinity of the proposed footprints. Thus, the project is not expected to result in a significant loss in vegetation and habitat. There are no old trees observed in the project area.

However, the project components will include very limited impacts on soil during construction due the activities and traffic. However, re-vegetation should be performed using local plants. All slopes and working surfaces should be returned to a stable condition. However, the project components will include very limited impacts on soil.
Using of the treated – filtered wastewater for other agricultural purposes is a critical challenge. Restrictions and penalties should be employed to avoid using the treated – filtered wastewater in irrigation of seasonal and vegetables.

- **Biological Habitat and Species**

Adverse impacts to biological or ecological resources (Fauna and Flora) could occur during the construction phase from fugitive dust, noise pollution, modification, fragmentation and reduction of ecological habitats and mortality of biota. Define the project area in order to create the least possible potential damage to vegetation and soil. Small numbers of natural birds, some reptiles and limited mammals have been observed in the vicinity. The baseline study within the project area did not show any endangered or significant flora or fauna within the project area therefore, any potential direct impact on biological environmental characteristics such as, loss of rare or endangered species, habitat fragmentation and wildlife migrations is not envisaged due to construction activities. During the project operation, some birds are expected to use the new metal structures of the project components we well as the trees to build their nests.

- **Water Resources**

No major negative impacts are expected on the water resources during construction phase. During operation, the failure of the filtration system or overflow will have negative impacts on the groundwater and will potentially increase the pollution of the final discharge point, sea.

- **Solid waste**

Solid waste during the construction phase will be minimal. Solid wastes resulting from the excavation, rejected components and materials, packing and shipping materials (pallets, crates, plastics, etc.), and human garbage will be disposed of properly to sanitary landfills as required by the Palestinian Environmental Law. The coordination with the municipality and JSC-KRM is recommended. Random disposal of such wastes may lead to soil pollution and will possess threat to public health safety.

4.7.5.5 Social Impacts

Most of the project components are not expected to have a major negative impact on the population and housing allocation. The impact will be mainly of a social nature. The project's positive impacts clearly overweigh its downsides. The following social aspects were examined: population and housing, employment, and income, Public and Worker's Health and Safety**.**

- **Population and Housing**

The project is not expected to incur social safeguard compliance issues. Implementation of the project activities will not have a direct impact on population and housing. There is no resettlement is expected, and a little of encroachment removal issue. Implementation of the project requires construction of new pipelines; those pipelines will be connected to Al-Mawasi neighbourhood. It is recommended to have deep consultation with stakeholders, key informant, such as CMWU, Rafah Municipality, during the different phase of the project.

- **Employment and Income**

A small number of workers may be required for the construction and operation of the proposed project. Overall, the implementation is not anticipated to significantly alter the employment structure and unemployment rate of the Gaza Strip. However, some short-term benefits may be realized during the construction and rehabilitation of these facilities, directly due to the employment of laborers and/or indirectly from the purchase of equipment and materials.

- **Public and Worker's Health and Safety**

During construction and operation activities, some impacts are expected on public health and safety. They will have major impacts if the contractors and responsible entities neglected the mitigation measures. The impacts will be minor or negligible if they are strictly mitigated. Risk of accidents and injuries that may occur during the loading up and loading down, trucks movement, using of sharp materials, falling, electricity shocks, high level of noise, generation of hazardous wastes, and dust generation are examples of potential impacts for public health and safety. Health and safety impacts of the project on workers and communities in influence of the project will be reasonably managed according to the National Occupational Health and Safety Regulation (Ministry of Labour) in order to reduce the likelihood of accidents and work-related illnesses on the job as well as accidents occurring between construction-related equipment and local vehicles. The entire workforce of the project items and components should be trained in the use of protective gear, emergency response and care procedures. Training given to the employees should be backed by regular on-site training in safety measures.

The key concern is to use the treated filtered wastewater for other purposes; drinking, washing, and cleaning. This will lead to major health impacts. Awareness campaigns should be arranged to the local community, farmers, and their households.

4.7.6 Environmental Management Plan (EMP)

The purpose of impact mitigation is to look for better ways of implementing the proposed project or associated activities so that the negative impacts are eliminated or minimized, while benefits are enhanced. Impact mitigation requires that the full extent of the anticipated environmental problems is understood. In view of this, this section of presents the mitigation measures resulting from the impacts identified.

Mitigation measures require a successful impact management plan implemented at the correct time and in a correct way. This usually requires a clearly written and agreed plan of action for managing impacts so that these are kept within the limits of acceptability. The monitoring plan describes how and who will carry out the monitoring activities for addressing the negative environmental issues.

This section aims to coordinate the environmental policies, plans, programs, and decisions of the various parties involved in the project, which exercise functions that affect the environment. Environmental monitoring is an important component of the ESMP. It provides the information for periodic review and refinement modification of the ESMP as necessary, ensuring that environmental protection is optimized at all project phases. Through monitoring, unwanted environmental impacts are detected early and remedied effectively. It will also validate the predicted impacts and the effectiveness of the proposed mitigation measures. Lastly, it will also demonstrate compliance with national regulatory requirements. The ESMP aims to minimize the duplication of procedures and provide consistency in the protection of the environment. In order to ensure smooth and uncomplicated achievement of the ESMP components, it would include the following basic components:

- Potential impacts and their mitigation measures
- Environmental monitoring and enforcement
- Institutional component.

4.7.7 Environmental Mitigation and Monitoring Plan

Environmental mitigation includes a matrix identifying the issues, mitigation measures, responsibility for carrying out the mitigation measures and the approximate cost estimates for the actions. Avoiding or minimizing the environmental impacts is by far preferable to compensation or rehabilitation measures after an impact has happened. It is the task of the ESIA and especially the ESMP to identify significant impacts, to define measures to avoid or at least to minimize these impacts and to take care that these measures are properly applied at all project phases. The following paragraphs describe the proposed mitigation measures and monitoring actions for each project phase in general before the most significant measures are defined in detail.

- As identified earlier, impacts during construction phase are primarily associated with the excavation, backfilling, levelling works, installation of pressure lines, concrete structures. The significant accompanying activities comprise earthworks, material transport and movement of heavy machinery. The use of heavy machinery and equipment at the site during construction (loading and unloading) is limited to the site boundaries. Such impacts are mostly short-term, local, and caused by the contractor activities at the construction sites and the access roads and can be mitigated through proper construction management in coordination with the contractor and the authorities concerned. The contractor in cooperation with the monitoring agency is responsible for implementing the mitigation measures during the construction phase.
- Impacts during the operation phase of the project are primarily associated with water resources, agriculture, public health, and land use.
- Environmental monitoring is the timely and proper survey of the significant environmental impacts of a project during all project phases. Monitoring results help judge the success of mitigation measures in protecting the environment. They are also used to ensure compliance with environmental standards, and to identify necessary changes in the project design or operation.
- In addition, the Project Management Unit (PMU), operator of the site, in coordination with other partners and stakeholders is responsible for monitoring and enforcing the various environmental issues as related to the project activities as outlined in Table 4-5. Also, the PMU is responsible for executing any necessary measure out of those highlighted in the table according to the prevailing conditions at the site. Environmental mitigation and monitoring actions are presented in a simple matrix format. They include identification of the problems, mitigation measures, monitoring responsibilities, and the responsibilities to carry out the mitigation and monitoring measures. All the mitigation measures should be incorporated into the construction and supervision contracts.

Table 4-6 summarizes the Potential Environmental Impacts, the Mitigation, and Monitoring Plan.

Table 4- 6_ Potential Environmental Impacts, Mitigation, and Monitoring Plan

Issue	Impact	Phase	Significance	Mitigation measures	Responsibility of Execution	Monitoring (Measure and Method)	Monitoring & enforcement Responsibility
Water resources	- Wastewater generated at the site during construction (generated from workers temporary facilities in the site).	Construction	Minor	- All water and liquid wastes arising from construction activities should be properly disposed off and will not be discharged into any water body/ stream without adequate treatment. - Sewage tanks should be periodically checked, emptied, and sewage should be taken to the WWTP.	Contractor	Supervision, and Site Monitoring	PMU, UAWC, EQA
	- Contamination and pollution of surface and groundwater may occur (risk of chemicals and fuel/oil/diesel spillage and/or leakage from vehicles and equipment that would be mixed with soil, and surface water).	Construction	Minor	- Ensure fuel storage, if any, are enclosed and placed in a secondary containment with sufficient capacity to be sized to contain at least 110% of the total volume of the primary containers. - Follow operation instructions.	Contractor, PMU	Inspection, and Site Monitoring	PMU, UAWC, EQA
	- Changing water drainage properties which could divert surface water drainage streams to un-preferred location during winter seasons. - Polluted storm water that accumulates in the winter season and could infiltrate to the groundwater.	Construction & Operation	Minor	- Engineering design, shaping of the land, and landscaping.	Consultant, contractor, PMU	Monitoring	Municipality, PWA, CMWU, EQA
	- Risk of system failure (in terms of functions, overflow, or breaks)	Operation	Minor	- Develop emergency response procedures to be revisited and refined if needed after initial operation.	UAWC	Inspection, tests and Monitoring	Municipality, UAWC PWA, CMWU, EQA, MOAg
	- Risk of water contamination through distribution system in case of breaks.	Operation	Moderate	- Survey of existing facilities during the design, monitor the excavation and immediate repair if happened, and check disposal plans. - Proper design and draw emergency plans	UAWC and MOAg	Monitoring, Periodic water sampling and quality testing	Municipality, UAWC, CMWU, EQA, MOAg

Issue	Impact	Phase	Significance	Mitigation measures	Responsibility of Execution	Monitoring (Measure and Method)	Monitoring & enforcement Responsibility
	- Contamination of groundwater from accidental spills, overflows and seepages (such as in the case of uncontrolled/ unplanned operation with surplus amount of filtered water to process or surplus treated water to handle.	Operation	Moderate	- Collect adequate groundwater quality baseline data - Carry out regular inspections and routine tests - Monitoring water quality using the nearby monitoring wells / agriculture wells.	UAWC and MOAg	Monitoring, Periodic water sampling and quality testing.	Municipality, UAWC PWA, CMWU, EQA, MOAg
Solid Wastes	- Removal of the old debris, removal of fences, levelling the areas, and construction activities would generate more solid wastes.	Construction	Minor	- Follow the instructions and prepare a plan for collection, storing and disposal of all materials. - Construction waste should be stored separately in a designate area. - The wastes should be removed / handed in coordination with authorized entities.	Contractor	Supervision	PMU, JSCKRM, UAWC, Municipality
	- Solid waste from trenches excavation and other domestic wastes may result in the impairment of the local traffic in the vicinity of the construction site; risk of traffic accidents.	Construction	Moderate	- All sorts of solid wastes should be collected systematically, and protected storage should be provided. - Solid wastes should be disposed to the transfer station and then to the sanitary landfill. - No burning of wastes will be permitted.	Contractor	Supervision	PMU, JSCKRM, UAWC, Municipality
	- Improper management of solid waste - Generated wastes by workers and visitors during construction. - Solid Wastes generation by levelling and construction activities.	Construction	Minor	- Prohibit fly-dumping of any solid waste to the land. - Domestic waste should be stored in containers and disposed when fill up. - Wastes should be stored in containers and disposed when fill up.	Contractor, Municipality, JSC-KRM	Mitigation, Supervision	PMU, Consultant, UAWC, JSC-KRM
Air Quality and Noise	- Dust generation, nuisance value that in extreme cases may affect health of population (due to trucks	Construction	Minor	- The activities should be confined to project area. - Dust suppressants, proper transporting, and storage of construction materials.	- Contractor	- Site monitoring - Complaint monitoring	PMU, Consultant, UAWC

Issue	Impact	Phase	Significance	Mitigation measures	Responsibility of Execution	Monitoring (Measure and Method)	Monitoring & enforcement Responsibility
	movement, cutting and backfilling, and removing scattered waste).			- Proper activity scheduling and working hours and days and limit the activities to day times and prevent any construction activities at weekends. - Using relatively new construction and transportation vehicles with lower emissions. - All the Construction vehicles and machineries should be regularly maintained to conform to the emission standards. - Watering the site and spraying of water before excavations during strong winds and dry periods, on regular basis. Using of treated water is highly recommended. - Issue site workers with appropriate dust masks and safety requirements. - Dust emission from stockpiles of excavated material will be controlled either by covering the stockpiled materials or water spraying over it. - As soon as construction is over all the surplus earth will be utilized properly all loose earth will be removed from the site.		- Site supervision - Public consultation	
	- Nuisance value that may in extreme cases affect health due to standby-generators and due to movement of trucks and construction activities (gas emissions from vehicles/ trucks movement)	Construction	Minor	- Avoid working at night as possible. - Use of mufflers and/or noise dampers. - Vehicles and equipment used should be fitted with silencer and maintained accordingly. - Regular maintenance of construction machines and trucks. - Fixed equipment and loading and unloading, stockpiling areas should be located far from sensitive receptor. - All the workers working very close to the noise generating machinery shall be provided earplugs to avoid any ill impacts on their health.	Contractor	Regular noise monitoring Complaint monitoring	PMU

Issue	Impact	Phase	Significance	Mitigation measures	Responsibility of Execution	Monitoring (Measure and Method)	Monitoring & enforcement Responsibility
				- An awareness program should be organized for drivers and equipment operators to make them aware of the consequences of noise and to act properly at site.			
	- Action of the wind on the structures and panels.	Construction & Operation	Minor	- Check the work, and does not leave the site without inspection, checking and fixing all items.	Contractor and PMU	Supervision, inspection, monitoring	PMU, UAWC, and Consultant
Land use, Topography and soil.	- Construction activities could reshape the actual land use in neighbour area. - Unplanned induced urbanization of neighbouring areas or areas facilitated by new infrastructure facilities, i.e. irrigation networks.	Construction	Moderate	- Consultations to be undertaken with local community. - Ensure that such assigned areas are reduced to the greatest extent possible. - Provide details on the grievance mechanism. - Provide construction schedule and duration for which such construction activities will take place. - Restrictions for buildings (and building licensing)	Consultant, Contractor, PMU, municipality, UAWC	- Proper design - Periodic checks - Supervision - Inspection and, - Monitoring	PMU, UAWC, municipality, and Consultant
	- Soil contamination, compaction, stability and erosion.	Construction	Minor	- The earth material generated due to excavation (usable materials) should be used to optimum quantity to reduce impact on land resources / soil. (to be re-used as fill materials and aggregates). - Proper stripping and stockpiling of soil layers to reduce dust pollution. - The excavation activities and vegetation clearance will strictly be limited to the pegged area, road and other construction area.	Contractor	Supervision, inspection and monitoring	PMU, UAWC, and Consultant
Transportation / infrastructure	- Impacts of heavy truck movement (importing sand, aggregates other materials).	Construction	Minor	- Develop a Traffic and Transport Management Plan (inside and outside) to ensure that the transportation process is properly and adequately managed and does not pose a risk of damage to the existing roads, highways, overpasses whilst ensuring public safety.	Contractor and PMU	Site monitoring and Complaint monitoring	PMU

Issue	Impact	Phase	Significance	Mitigation measures	Responsibility of Execution	Monitoring (Measure and Method)	Monitoring & enforcement Responsibility
				- Traffic signs to ensure proper routing and distribution of traffic. - Provision of adequate notification procedures for any road closures.			
	- Damage to the access road infrastructure from excavations, construction traffic and heavy machineries.	Construction	Moderate	- Proper planning of construction activities. - Traffic management (signs, traffic flow) - Speed limits for construction vehicles. - Fixing any damage caused by the contractor.	Designer, PMU, Contractor	Design documents Site monitoring Complaint monitoring	PMU, municipality
	- Potential accidental break of existing water, wastewater and irrigation network.	Construction & Operation	Moderate	- Consideration in the detailed design, construction supervision, in case of damage immediate repair.	Contractor Municipality, CMWU	Report about compliance with the as-built drawings	Municipality, CMWU, PMU, UAWC
	- Risk of accidents	Construction	Minor	- Provide insurance for all vehicles inside the site and updated compliance certificates (mandatory periodical verifications). - Document and report about the accidents and injuries.	Contractor and PMU	Site monitoring	PMU
Aesthetics	- Impact to landscape and disturbance of aesthetic feature.	Construction and operation	Minor	- Landscaping (esp. screening by planting of trees, substitution of cut-down trees) - Proper operations and maintenance management and reshaping of construction sites.	Consultant, Contractor and PMU	Site monitoring	PMU, UAWC
	- Improper disposal and pile up of construction materials	Construction	Minor	- Cleaning and removal of wastes or deposits to landfills or designated areas.	Contactor	Construction supervision, Complaint monitoring	Municipality / CMWU
	- Improper collection of sand and wastes if the roads will not be paved after construction	Operation	Minor	- Periodic cleaning waste collection and management plan	Municipality	Complaint monitoring	Municipality
	- Construction activities would create a temporary effect on the visual quality of the site	Construction	Minor	- The site will be cleaned immediately after the construction activity is over.	Contractor and PMU	Site monitoring	PMU, municipality

Issue	Impact	Phase	Significance	Mitigation measures	Responsibility of Execution	Monitoring (Measure and Method)	Monitoring & enforcement Responsibility
	and its surroundings from presence of elements typical of a construction site such as equipment and machinery.			- The debris materials will be disposed of only at identified area for disposal and proper levelling will be done after disposing the materials and shall be covered with top soil and some landscaping will be done at the disposal site. - Ensure proper storage, collection, and disposal of waste streams generated			
Agriculture activities, vegetation	- Potential accidental break of the existing local water networks/old irrigation networks.	Construction	Moderate	Consideration in the detailed design, construction supervision, in case of damage immediate repair.	Consultant, Contractor, PMU	Investigation of the existing farms	PMU, Municipality, CMWU
	- Loss of older or historic trees and shrubs along the roadsides and in the project areas	Design & Construction	Negligible	- Minor modifications of the pipeline route in order to avoid tree felling or uprooting. - Replanting of similar trees and shrubs.	Contractor Municipality MOAg	Construction supervision	Municipality
	- Damage of agricultural area	Construction & Operation	Minor	- Check proper implementation before hand over process - Compensation	PMU, UAWC	Coordination with authorities and residents	PMU, UAWC, MOAg
	- Dust generated from construction activities cause impairment of agricultural activities especially during the flowering period from October until April or May (for the nearby citrus, olive, and vegetables). - Dust resulting from construction activities lowers the photosynthetic rate of neighbouring vegetation and agricultural crops.	Construction	Minor	- Minimizing the release of dust by using appropriate technology and tools. - Dust generating activities should be avoided during the flowering period as much as possible.	Contractor	Construction supervision	PMU, EQA, MOAg

Issue	Impact	Phase	Significance	Mitigation measures	Responsibility of Execution	Monitoring (Measure and Method)	Monitoring & enforcement Responsibility
	- The quality of treated wastewater is not meeting the standards. - Contamination to or groundwater (heavy metals, NO_3, salinity/TDS, pathogens, etc) from treated wastewater discharge. - high salinity or heavy metals) or crop contamination (pathogens, etc.) due to extensive wastewater reuse activities in irrigation. - High salinity of treated wastewater may harm citrus trees & other types of plants.	Operation	Moderate	- Pollution prevention and resource efficiency. - Ensure strict compliance with the Laws, policies, and standards. - Design and put in place appropriate irrigation management systems and scheduling along with soil and treated wastewater quality monitoring. - Monitoring tests at RWWTP, filtration system, and irrigation network.	UAWC and MOAg	Periodic monitoring Periodic water sampling and quality testing.	UAWC CMWU, EQA, MOAg
	- Irrigation for crops that are not allowed or restricted (vegetables and field crops).	Operation	Major	- Ensure strict compliance with the Laws, policies, standards, and instruction. - Awareness campaigns - Issue agreements with the beneficiary farmers.	PMU, UAWC and MOAg	Periodic monitoring	UAWC and MOAg
Flora and Fauna	- Dust generated during construction would cause loss of lower vegetation forms (grasses and herbs) in the project areas (indigenous species).	Construction	Minor	- These plant forms have a fast regeneration time. They are found elsewhere. No action is needed here.	--	--	--
	- Using of pests to fight rodents and other mammals.	Construction	Moderate	- Apply pesticides as needed through an application plan that would give preference to biological pesticides, then to other pesticides with negligible impact on humans and minimum impact on untargeted species and the environment.	PMU	Good planning, Site investigation, Pest control	PMU, EQA, municipality

Issue	Impact	Phase	Significance	Mitigation measures	Responsibility of Execution	Monitoring (Measure and Method)	Monitoring & enforcement Responsibility
	- Spread of rodents and insects in the vicinity.	Construction & Operation	Minor	- Sanitation and appropriate pest control methods.	PMU	Good planning Site investigation - Pest control	PMU, EQA, UAWC, MOAg
	- Habitat loss / escape of some sensitive bird species from the site.	Construction	Minor	- Monitoring and avoidance of noise-generating machines and disturbances. - The contractor shall ensure adequate measures to ensure that no illegal poaching of wild animals is being done by construction workers.	PMU	- Good planning for activities, Site investigatio n	EQA, MOAg
	- The activities will impact on the presence of some fauna in the area such as birds, mammals and reptiles.	Construction	Minor	- Monitoring especially for rare or threatened bird species. - Construction works should be limited to targeted areas only.	PMU	Monitoring	EQA
	- The implementation of the project (mainly PV system) may constitute a motive for some of the bird flocks, and thus the accumulation of (the bird droppings) on the panels and reducing their efficiency.	Operation	Minor	- Use agricultural scarecrows to scare away the birds. - Installation of some mechanical items such as panels washing tools.	Designer, Contractor, PMU	Monitoring	UAWC
Marine Life	- Pollution of the sea due to additional quantities of wastewater and potential disposal of untreated wastewater to the sea (as a result of the new facilities and structures and any potential drop of the system)	Operation	Minor	- The generated wastewater should be connected to the treatment facility - Follow effluent disposal regulations regarding quality and distance offshore	Monitor long-term changes in marine life	Monitoring	EQA
Sharing Information with the community.	- Different concerns and Negative publicity and misconceptions of neighbours /farmers / local community. - Lack of acceptance and people rejecting the use of treated	Construction	Minor	- Public information campaigns before the project is executed. - Information sharing with the community and forming a committee from the local residents to monitor the construction.	UAWC	Public consultation	UAWC

Issue	Impact	Phase	Significance	Mitigation measures	Responsibility of Execution	Monitoring (Measure and Method)	Monitoring & enforcement Responsibility
	wastewater for irrigation due to cultural beliefs. - Lack of hygiene conscious by farm workers.			- Conduct regular consultation sessions with the stakeholders and neighbours. - Grievance uptake channels to be created in the site for any coming complaints during construction by ensuring significant number of indicative signs around the project site (including contact information, project description, etc.) and using the complaint box located at PMU. - Sort and process the received complaints. - Acknowledge and follow up the complaints. - Verify, investigate, and act to determine the validity of received grievance.			
	- High unemployability and willingness to work. This will lead some unemployed persons to request temporary jobs during construction and permanent jobs during operation as guards.	Construction & Operation	Moderate	- The Contractor is to hire workers from local community.	Contractor	Project document (labour sheets), site visits	UAWC
Community Health & safety	- Visiting the construction site by any un-authorized persons.	Construction & Operation	Moderate	- Coordination is required - Restrict the access of unauthorized people.	Contractor, PMU	Site control, monitoring	UAWC
Occupational and Public Health / Safety	- There will be some risks to workers health and safety during the construction activities of the Project.	Construction	Major	- The project must comply with the requirements of the local EHS guidelines. - Prepare an Occupational Health and Safety Plan for the construction works. - Prepare a project and site-specific Emergency Preparedness and Response Plan. - Provisioning adequate arrangements of drinking water, lighting, ventilation, bedding, bathing; sanitation facilities and other basic facilities in the labour camps.	PMU, contractor	Project documents, site control, and monitoring	UAWC, MOL

Issue	Impact	Phase	Significance	Mitigation measures	Responsibility of Execution	Monitoring (Measure and Method)	Monitoring & enforcement Responsibility
	Risk of accidents and injuries that may occur during the following activities: - Loading up and loading down (lifting) - Trucks movement - Using of sharp materials - Falling - Reshaping activities (cut and backfill) - Construction activities - Electricity chocks	Construction	Major	- Follow safety instructions, and worker should wear proper clothing; Personal Protective Equipment (PPE) - Ensure that all the workers (direct and indirect workers) are included in the insurance. - A first aid station with trained staff, which is able to coordinate with local hospitals in case of emergencies - Personnel will be trained in Occupational and EHS matters including accident prevention, safe lifting practices, safe chemical handling, proper control and maintenance of equipment and facilities. - Adequate sanitary facilities, potable water, and garbage bins should be provided. - Security of the project site should be always imposed. - The site must have access control. - The public will not be allowed near the working areas. - On site vehicles will be fitted with reversing horn. - Open excavations will be marked with danger tape. - Warning signs and instructions in case of emergencies should be properly displayed, workers must be informed about these precautions. - Requirements of Palestinian Labour Law should be applied. - Documenting and Reporting about all accidents and injuries.	Contractor, PMU	Training program, Site supervision, Public consultation.	UAWC, MOL

Issue	Impact	Phase	Significance	Mitigation measures	Responsibility of Execution	Monitoring (Measure and Method)	Monitoring & enforcement Responsibility
	- Communication with local community, and bad behaviour of workers	Construction	Moderate	- Restrict the communication between workers and the surrounding local community. - No camp for accommodation at the night except for the camp guard. - A code of conduct of the workers should be prepared and implemented for all workers in the construction camp.	Contractor, PMU	Site control and monitoring	UAWC, MOL
	- Working conditions	Construction	Major	- Provide a suitable rest place for all workers in the site. - Give the workers an hour for rest and taking their meal (lunch hour). - Provide hygiene tools for the workers in the site. - Secure good transportation means for the workers to reach the site safely specially it locates near the border line.	Contractor, PMU	Site control and monitoring	UAWC, MOL

4.7.8 Conclusions and Recommendations

No major negative environmental impacts are expected for the construction and implementation of the project, as the project invested in activities that support the rehabilitation and improvement of basic infrastructure.

Potential negative impacts that are localized and limited in nature will be avoided through the recommended instructions and mitigation measures. The planned project activities are expected to improve environmental conditions, improve wastewater treatment, minimise pollution and contamination of seawater and the beach from poor quality treated wastewater and maximize agricultural benefits. Despite the negative environmental impacts that could result from the implementation of the project, the project is essential for the facilities and services. Should the monitoring phases of the full-scale plant show that the environmental quality is deteriorating to an unacceptable level, PSC and PMU will correct the operational procedures contributing to the problem and/or make the necessary technical installations.

4.8 Technical Training Programme

In order to also achieve the third objective of the project, a technical training programme and the production of a technical manual for the management and maintenance of the wastewater treatment plant were carried out.

Technical training programmes are activities that support the development of people's skills and knowledge, in this case in area of wastewater management and its use for agricultural purposes, to facilitate the transition to innovative agricultural water management systems. The main objectives of the trainings were to increase public acceptance and social awareness of the reuse of treated wastewater.

The Training of Trainers (ToT) was carried out by DICAM for UCAS and UAWC staff and included the provision of skills and knowledge on wastewater use in agriculture. Training was conducted remotely by DICAM in several sessions during the second and third years of the project (as it was not possible to conduct an on-site outreach due to the Covid 19 pandemic). The beneficiaries of this ToT training were UAWC staff, UCAS university students, and local water and agriculture experts (MoA, PWA and CMWU).

In turn, UAWC will transfer skills and knowledge to local farmer committees through on-site trainings, tailored to the needs of individual beneficiaries. These trainings will focus on providing innovative tools to change beneficiaries' perceptions on the use of wastewater in agriculture and the suitability of the new technologies. The method used is to identify the change agents (in the local committees and among the selected beneficiaries) and sensitise them on the possible changes in the population regarding wastewater management so that they are able to promote this change.

The remote training sessions were very well attended and saw numerous questions from participants, both from members of the agricultural committees with less technical, scientific and academic knowledge and from the more knowledgeable MoA and UCAS staff. During the meetings, it was also possible to present the whole design, planning, study and monitoring phase of the pilot model and share the final results collected, receiving questions and positive feedback from the participants about the experience.

At the end of the first and the last training sessions, we asked the participants to answer questionnaires (see Appendix C) to assess their personal knowledge and attitude towards the water issue in Gaza Strip and wastewater use and recycling, and to assess the level of basic knowledge and improvement of information on the same topics after the ToT training.

The results of the questionnaires showed that: - regarding water resources management, there was an improvement in knowledge, which can be quantified at around 50%, compared to the initial very low and/or non-existent knowledge about the global distribution of water, household consumption, the situation in Gaza Strip, and the impact of individual behaviour on water conservation. In relation to wastewater management, treatment and recycling, an improvement of about 55% was observed in knowledge about treatment methods, the hazardousness of wastewater and the importance of recycling. In relation to the specific case study project, planned activities and attitude towards using treated water according to the techniques described an improvement of about 85% was quantified in knowledge and willingness to use treated water in their fields.

Fig.4- 20(A) Training for Technicians, Experts of Water Sector and Ministry of Agriculture; (B) Training for students of UCAS University.
(Photo credit by Authors)

4.9 Conclusions

This chapter presents the international cooperation project developed in Rafah Governorate, Gaza Strip, entitled "Reuse of Treated Wastewater in the Agricultural Sector in Al-Masawi District - Rafah, Gaza Strip", established by the Italian Agency for Cooperation and Development.

The study shows how the project has contributed to the economic development of the agricultural sector in the Gaza Strip, Palestine. Through new synergies between the research system and the Civil Society Organizations a wastewater finishing treatment plant was built to implement the Rafah wastewater treatment plant and reuse the treated wastewater for agricultural purposes.

The following highlights summarise the main results of the cooperation project:

➢ Realization of the real wastewater treatment plant in Rafah Governorate, Gaza Strip. The realization of the real plant has led to the first outcome of the project, which is to improve the availability of water for agriculture. The technologies selected for this case study, consisting of phytoremediation followed by natural disinfection, aim to optimize the Rafah wastewater treatment plant and ensure the quality of the effluent for reuse in agriculture. The implemented treatment system represents an appropriate technology for the study area and requires affordable and simple operation and maintenance.

- Improving agricultural productivity in Al-Mawasi District - Rafah, Gaza Strip.

Reuse of treated wastewater for agricultural purposes conserves water resources and enables better availability of and access to water resources. It provides a new and sustainable source of water for irrigating the crops of beneficiary farmers. The realization of the irrigation network linking the treatment plant to the agricultural fields allows farmers, the beneficiaries of the project, to use this "new" resource.

- Improving knowledge and raising awareness among local stakeholders on the use of treated wastewater in agriculture. The training programme implemented under the project included activities to transfer know-how and applied research components to local authorities and partners. Through the ToT activities, we were also able to increase the acceptance and social awareness for the reuse of treated wastewater. This aspect is very important as wastewater reuse plans can fail if planners do not consider the dynamics of social acceptance.
- The presence of strong local partners (such as NGOs and universities) has proven to be as a key factor for the successful implementation of the cooperation project. The partnership with the UAWC Association and UCAS University enable the various activities of the project to be implemented smoothly and probably gained the trust of local farmers in the project. It has also created a strong partnership between the local stakeholders that can guarantee the continuation of the project after its "official" end.

CHAPTER 5.

Case study II: Natural wetland for wastewater treatment in Cape Coast, Ghana

The case study presented in this Chapter was aimed investigating the importance of natural wetlands for domestic wastewater treatment in Cape Coast, Ghana. It has been performed during my Ph.D. period abroad that I spent at the Department of Water and Sanitation, University of Cape Coast (UCC), Ghana.

5.1 Scope of the Case Study

Many countries in the developing world, including Ghana, face the enormous challenge with an effective manner of handling large quantities of wastewater generated in the rural area and urban centers (Nikiema et al., 2011 ; Awuah et al., 2014). Domestic wastewater management is a challenge and remains one of Ghana's most neglected sanitation components (Appiah-Effah et al., 2019).

Sanitation infrastructure in most areas in Ghana is deplorable. Most times, domestic wastewater go untreated, ending up in drains and nearby water bodies, especially domestic wastewater. In fact, domestic wastewater in Ghana does not receive any adequate treatment before it is discharged into drains, streams, and wetlands (Envasan Consultant, 2014-2015).

In this scenario, we want to focus on the importance and function of natural wetland as domestic wastewater treatment, as described in Chapter 3. Many studies show the function in the use of wetlands as wastewater treatment (Gopal ,1999; Mander, 2002; Vymazal, 2018).

The value of wetlands for fish and wildlife protection has been known for several decades; in more recent years, wetlands have been valuable as resources, sinks, and transformers of a multitude of chemicals, as well as biological and genetic materials. They (Wetlands) are sometimes described as “the kidneys of the landscape because they serve as the downstream receivers of water and waste from both natural and human sources".

Even in Ghana, the importance of wetland is well recognized. Ghana as a country has been a signatory to the Ramsar Convention, described in paragraph 3.1.2, since 1988 and in June 1999 the then Ministry of Lands and Forestry (now Ministry of Lands and Natural Resources)

launched the National Land Policy to further recognize wetlands as environmental conservation areas (Ministry of Lands and Forestry, 1999).
The Wetland ecosystems constitute about 10% of the Ghana's total land surface, comprising marine/coastal, inland, and man-made systems. In order to protect and drive the sustainable use of these resources, Ghana instituted a National Wetlands Conservation Strategy in 1999 (Everard, 2018; Xu et al., 2019).
In particular, there is no conventional wastewater treatment plant for domestic wastewater treatment for the entire Metropolis of Cape Coast. Much of the domestic wastewater generated in metropolis is discharged onto the wetland analysed without measuring the quality and quantity of the influent and the effluent.
The case study focuses on the threats to natural wetlands in Cape Coast by first looking at their potential in domestic wastewater treatment by analysing data gathered and drawing conclusions and identifying why the wetland in Cape Coast is under threat.
The goal of the project is to investigate the function and the performance of the natural wetland of Cape Coast for domestic wastewater treatment using water quality indicators.
This study, therefore, assesses the water quality to establish the performance of the natural wetland in Cape Coast using Nemerow's pollution Index (NPI) and Water Quality Index (WQI). The findings will inform the decision-makers about the importance of natural wetlands as an alternative economic approach to wastewater treatment, the implications of the threat to national development, and recommendations on its proper use and limitation.

5.3 Description of the Study Area

5.3.1 Study area

The study was conducted on the natural wetland located in Cape Coast, along the Takoradi highway road (Iture-Abakam**).** It has a longitudinal location of 1˚ 18' 48.3" W and 1˚ 19' 19.9" W and a latitudinal location of 5˚ 05' 01.4'' N and 5˚ 033' 56.3'' N (Amadu, 2021). The wetland is closer to the University of Cape Coast (UCC) campus in the Cape Coast metropolis, Central Region, Ghana (see Fig. 5-1).
The total wetland area has been approximately 1.1871 km^2 since 1991, and this land cover has changed a lot during the last 30 years (Amadu, 2021).
The communities near the natural wetland, which directly and indirectly impact on the wetland involved in the present study, are Amamoma, Apewosika, Kwaprow, and Duakro. These communities surround the University of Cape Coast. The campus community is considered the

main residential facilities for students (residence halls, and hostels) and staff (bungalows, chalets, and quarters). These are traditional communities, and each of them has specific characteristics.

Apewosika is a small Fante village situated in the southern section of the UCC University. The community is poorly serviced in terms of water distribution and road network. It has been provided with one public toilet facility (Ventilated Improved Pit, VIP) and with one skip container at a central collection point to collect solid waste. There are three main socio-economic activities carried out by the people in the community: fishing, trading, and public service work (e.g. laborers and janitors in UCC), and other minor occupations include taxi drivers and those who work outside the community. The community is also supplied with water from Ghana Water Company Limited (GWCL) through pipe networks and electricity by the Electricity Company of Ghana (ECG). It has an information center and a primary school. Specifically, they have an inadequate drainage system, and the grey and waste water are not properly channelled into the existing main drain (Envasan Consultant, 2014-2015).

Amamoma community is located near Apewosika village, and locals, as well as students, occupy it. Also, this community is poorly serviced in terms of water distribution and road network, and it presents the high state of disrepair and dirty surroundings. The major socio-economic activities in the community are fishing, trading, and public service work. The community is also supplied with water from GWC through pipe networks and the provision of electricity by the ECG. Still, it cannot boast of amenities such information center and a primary school. Then the drainage system is inefficient, and some community section does not have drains of any type; and usually, the wastewater flows on the ground and end up at the back of other houses, walk paths, and unattended bushes (Envasan Consultant, 2014-2015).

Kwaprow community shares boundary with the University of Cape Coast on its eastern side. It has students at the University residing there and commuting daily for campus activities. It has an estimated population of about 3,000. The predominant occupation in the community is farming. Other notable activities include petty trading, artisanry, transport services, and charcoal burning (Tham-Agyekuma , Okorley & Amamoo, 2019).

The case of poverty pervades the communities in various forms: vulnerability to shocks and disaster, low level of education, material deprivation, powerlessness, isolation, physical weakness, low financial status, susceptibility to violence, and also lack of access to clean water and sanitation (Envasan Consultant, 2014-2015; Tham-Agyekuma, Okorley & Amamoo, 2019).

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Another similar characteristic of these communities surrounding the University is the increased generation of waste because they are heavily populated with student hostels and rate of waste generation is high with little rules governing its disposal.

In the Duakro community, majority of the household solid wastes, and human excreta are connected into bigger drain or gutters that are channelled into the wetland. The people living in this community are farmers.

The rivers involved in the study area are Kakumdo river and Kakum River, the largest ones. The Kakum River drains the western part of the township of Cape Coast and flows into the Gulf of Guinea with other minor streams flowing into wetlands.

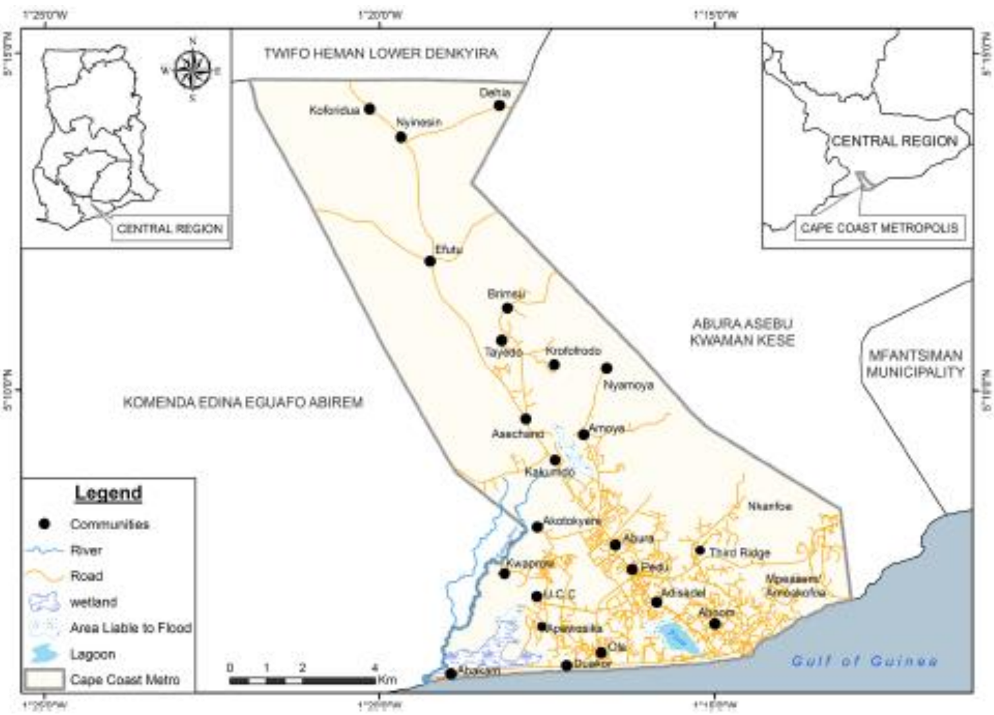

Fig. 5- 1_Map of metropolis of Cape Coast.

Source: Department of geography and Regional Planning, UCC (2019)

5.3.2 Description of Natural Wetlands in Cape Coast

The natural wetland under study, called Iture-Abakam, was in existence before the realization of the University of Cape Coast (UCC). It receives wastewater from some students' halls inside the UCC University and some communities around the University (Duncan et al., 2010).

The wetland area has reduced drastically by about 83% from 1991 to 2020 (Amadu, 2021). The total wetland area has been approximately 1.1871 km^2 since 1991 and has been reduced to 0.1989 km^2 in 2020 (Amadu, 2021).

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The natural wetland in Cape Coast is under serious threat resulting from indiscriminate disposal of waste, leaching from waste dumps, flooding, changing in land cover, sand mining, improper use of agrochemicals, overharvesting of mangroves, effluent discharge, residential development, and domestic wastewater. These activities are accelerating the degradation and threat to the biodiversity conservation and sustainable ecosystem services that the wetlands provide.

Some people live along the river, fish in it whilst children swim in the swash downstream. Also, some habitants use the stream for domestic purposes, while some cultivators use it to irrigate their crops. Meanwhile, the safety of the communities around the University of Cape Coast that still use this water for many activities and domestic activities is compromised.

The findings from this case study will inform the decision-makers about the importance of natural wetlands as an alternative economic approach to wastewater treatment, the implications of the threat to national development, and recommendations on its proper use and limitation.

Fig. 5- 2_Pictures of the natural wetland in Cape Coast.
(Photo credit: Authors)

5.4 Methodology

5.4.1 Sampling site

The performance of this natural wetland system has been assessed by evaluation of influent and effluent parameters at 12 sampling points, with their positions being recorded with a Ghana Post GPS visible in Fig. 5-3 and described in Table 5-1 below.

The sampling points named A, B, C, D, E identify the Campus Community and Apewosika community that go directly to the Cape Coast Natural Wetland (point F). The points H, Hi, I, J denote the points near Kakumdo River going directly in Fi, located in Amamona Community, represented the influent in the wetland (point F). Point G identifies the effluent from the wetland, entry point in the Gulf of Guinea.

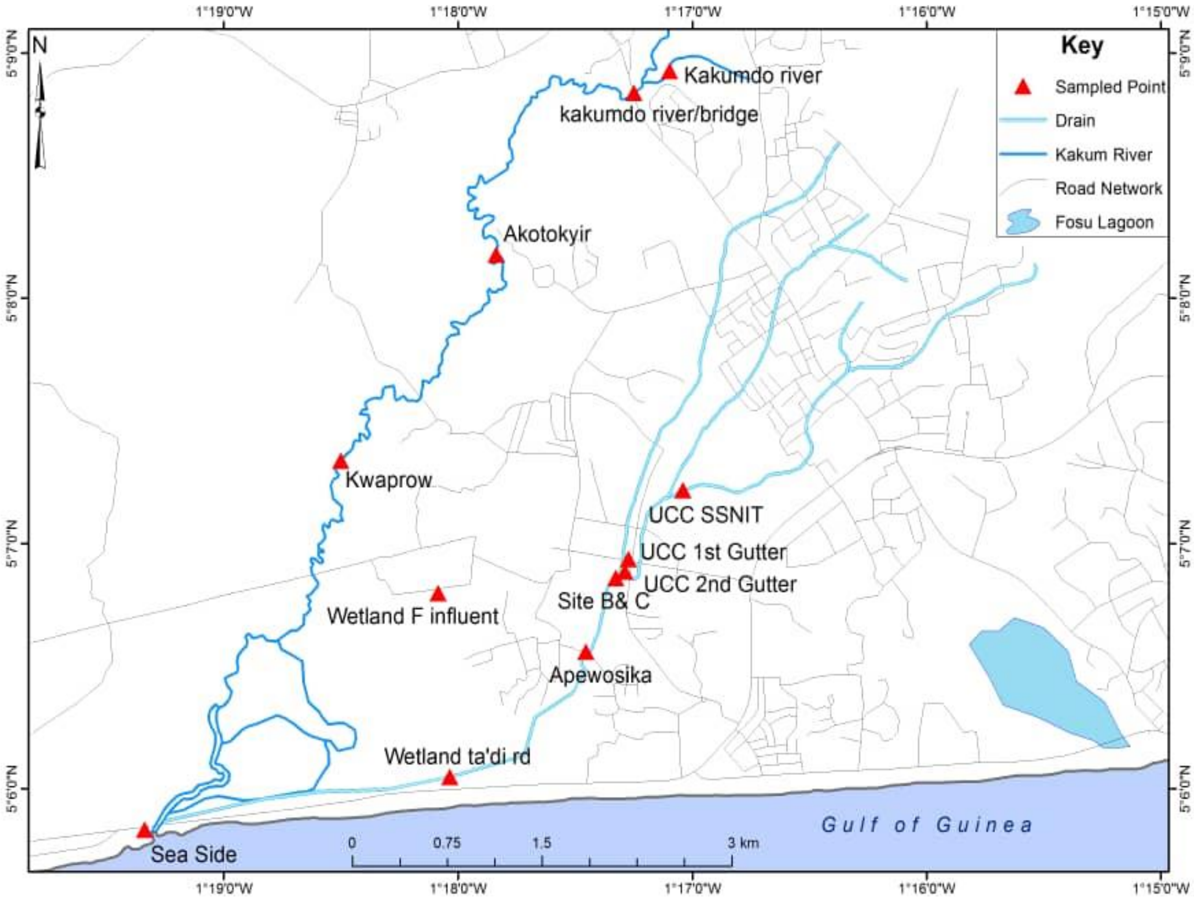

Fig. 5- 3_Area selected for the case study: communities and sampling points location.

Source: Self-designed

Table 5- 1_Location of the various sampling sites

IDENTIFICATION	LOCATION
A	UCC SSNIT
B	UCC East Gate – 1st Gutter
C	UCC Central Gate – 2nd Gutter
D	Meeting point of site B& C
E	Apewosika Community
F	Wetland ta-di road
F_I	Wetland F influent
G	Near Sea Side (Gulf of Guinea)
H	Kakumdo River
H_I	Kakumdo River to the bridge
I	Amamoma Community - Akotokyir
J	Kakumdo River- Kwaprow Community

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Fig. 5- 4_(A) Sampling site J; (B) sampling site I; (C) sampling site E;
(D) sampling site (Fi); (E) sampling site G.
(Photo credit: Authors)

5.4.1 Data collection and analysis

In order to determine the pollutants in the natural wetland, samples of the river, channel and stream water were taken at 12 different points within three communities and the University community.

Different samples of domestic wastewater have been collected and analysed. Influent and effluent wastewater samples have been collected monthly during 3 months in the wet season, from June to August 2021.

All wastewater samples have been collected using sterilized polyethylene plastic containers. Samples were used to rinse containers before collection, after collection they were preserved in ice (4^{o}C) and transported to the Laboratory of the "Department of water and sanitation – University of Cape Coast, Ghana" for further analysis, that have been performed according to standard methods for the examination of water and wastewater tests (APHA, AWWA, 2017,23rd edition) and analysed using Excel software.

For this study, influent and effluent wastewater samples were analysed in order to test the following parameters: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Temperature, pH, Turbidity, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Suspended Solid (TSS), Total Alkalinity (TA), Total Hardness (TH), Calcium, Magnesium, Total Phosphorus, Orthophosphate, Ammonia (NH_4), Nitrate (NO_3), Sulphate, and Iron, shown in Table 5-2 with the respective limits of the standard of Ghana Environmental Protection Agency (GEPA) and of WHO.

Table 5- 2_Parameters analysed with their corresponding GEPA and WHO standards

Parameter	Unit	Standard Limits
Temperature	(°C)	< 30[a]
pH		6 - 9 [a]
Turbidity	(NTU)	75 [a]
Electrical Conductivity	(µS/cm)	1000[b]
Total Dissolved Solids	(mg/L)	1000 [a]
Total Suspended Solids	(mg/L)	50 [a]
Dissolved Oxygen	(mg/L)	1 [a]
BOD	(mg/L)	50 [a]
COD	(mg/L)	250 [a]
Total Alkalinity	(mg $CaCO_3$/L)	200 [b]
Total Hardness	(mg/L)	500 [b]
Calcium Hardness	(mg/L)	200 [b]
Magnesium Hardness	(mg/L)	150 [b]
Phosphorus, Total	(mg/L)	5 [b]
Phosphorus, Ortho Phosphate	(mg/L)	5 [b]
Nitrate	(mg/L)	50 [b]
Ammonia	(mg/L)	0.5 [b]
Sulphate	(mg/L)	250 - 300 [a]
Iron	(mg/L)	0.3 [b]

Note: a= GEPA Standard, source: (Owusu-Ansah et al., 2015; Dwumfour-Asare et al., 2020); b= WHO Standard, source: (WHO and UNEP, 2006; Duncan, Oti, and Potakey, 2019)

5.4.2 Laboratory analysis procedures

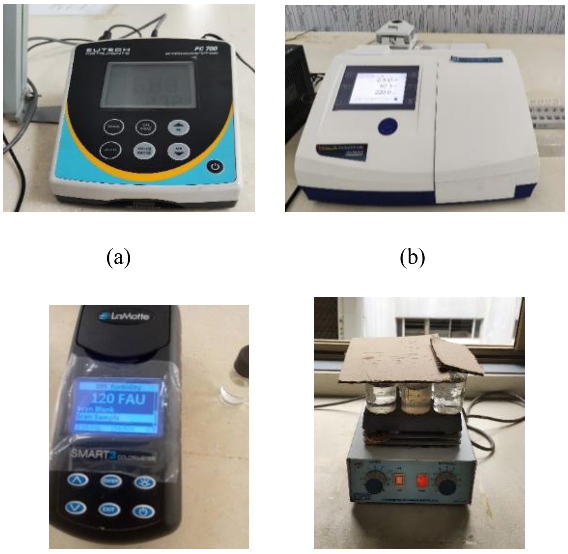
The analyses were carried out according to standard methods for the examination of water and wastewater tests (APHA, AWWA ,2017, 23rd edition) and then analysed using Excel software. Temperature, pH, Electrical Conductivity (EC) were calculated using a multi-parameter checker (mod. No. PC700 EUTECH) (see Fig.5-5a). Turbidity, TDS were measured with the colorimeter (mod. Smart3-LaMotte) (see Fig.5-5c). Before taking readings, all the equipment was adequately calibrated.

The Biochemical Oxygen Demand (BOD) test need 5 days to obtain the results (BOD_5); it is used to measure waste loads to treatment plants, determine plant efficiency (in terms of BOD removal), and control plant processes. It is also used to determine the effects of discharges on receiving waters. Two BOD bottles were completely fill with dilution water. Additional BOD bottles were partially filled with dilution water, and a measured volume of samples was then added to the partially filled bottles. Dilution water was added until the bottles were completely filled. Because the meter method was used for DO measurements, the initial and final DO determinations were performed on the same bottle.

Principle of Chemical Oxygen Demand (COD) using Open Reflux Method. Most types of organic matter are oxidized by a boiling mixture of chromic and sulfuric acids. A sample is refluxed in a strongly acid solution with a known excess of potassium dichromate ($K_2Cr_2O_7$). After digestion, the remaining unreduced $K_2Cr_2O_7$ is titrated with ferrous ammonium sulphate to determine the amount of $K_2Cr_2O_7$ consumed and the oxidizable matter is calculated in terms of oxygen equivalent.

To calculate Total Phosphorus using the Digestion and ascorbic acid Spectrophotometric Method. The TP sample added phenolphthalein indicator aqueous solution, sulphuric acid, and persulphate and boiling. After the digestion was put again, the phenolphthalein indicator was added to the reagent and mixed. In the end, measure the absorbance of each sample with the Spectrophotometer (see in Fig. 5-5b) and calculate, plot, and compare with the calibration curve prepared with standard sample blank.

To calculate Nitrogen, Nitrate we used the UV spectrophotometric Method. The titrimetric method was employed to determine Total Alkalinity and Total Hardness. To calculate the Sulphate, we used the Turbidimetric method. Iron was measured using a spectrophotometer.



(a) (b)

(c) (d)

Fig. 5- 5_Some instrument used in the Laboratory analysis: (a) multi-parameter; (b) Spectrophotometer, (c) Colorimeter ; (d) Magnetic stirrer hot plat

5.4.3 Method of Assessing Water Quality

In this case study, two index namely the Weighted Arithmetic Water Quality Index (WAWQI) and Nemerow's Pollution Index (NPI) would be applied in the quality assessment. These indices use the permissible levels of the parameters concerned as a reference point for assessment.

5.4.3.1 Water Quality Index (WQI)

A Water Quality Index is a classification tool used to establish the state of a water source for a specific period. It summarizes sets of water quality data for a certain period into a single number and gives it a standing base on the type of the indicator (Boah, Twum & Pelig-Ba, 2015; Duncan, De Vries & Nyarko, 2016; Duncan, Peprah & Marfo, 2020). Among the different form of this Index, the Weighted Arithmetic Index (WAI) (Brown et al., 1972) method was utilized in this study.

The WAWQI uses a rating scale from 0 to 100, which each range of value classifies the water quality into one of the following categories: excellent, slightly polluted (good), moderately polluted (poor), polluted (very poor), and excessively polluted (unsuitable) (see Table 5-3). The index thus suggests the degree to which the water quality is affected by human activities and can be used to describe the state of water quality as a whole in a body of water (Brown et al., 1972; Boah, Twum & Pelig-Ba, 2015).

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Water Quality Index (WQI) is calculated as:

$$WQI = \sum Q_i W_i \qquad (1)$$

where, W_i is the relative weight of i[th] parameter and Q_i is the sub-index of i[th] parameter.
The relative weight (Wi) is computed with the following equation:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad (2)$$

where w_i is the Unit weightage, which is calculated as follow:

$$w_i = \frac{k}{S_i} \qquad (3)$$

where and S_i the recommended standard for i[th] parameter; and the value of k is calculated as this:

$$k = 1 \,/\, \sum(1 \,/ S_i) \qquad (4)$$

And the sub-index of i[th] parameter is calculated as below:

$$Q_{i=} 100 * \frac{V_i}{S_i} \qquad (5)$$

Where V_i is the monitored value of the i[th] parameter.

Table 5- 3_Water Quality Index Status

WQI Index	Water quality status
0-25	Excellent
25-50	Slightly polluted (good)
50-75	Moderately polluted (poor)
75-100	Polluted (very poor)
>100	Excessively polluted (unsuitable)

Source: Brown et al. (1972)

5.4.3.2 Nemerow's Pollution Index (NPI)

Nemerow's Pollution Index (NPI) measures the pollution potential of individual pollutants in a sampled area referred to the standard limits value (Rathod , Mohsin & Farooqui, 2011; Duncan, Peprah & Marfo, 2020). NPI identifies and establishes the extent of pollution of individual parameters at each sampling point.

The Nemerow's Pollution Index (NPI) is calculated with the following equation (Swati and Umesh, 2015; Dawood, 2017; Duncan, Oti & Potakey, 2019):

$$NPI = \frac{C_i}{L_i} \qquad (6)$$

Where, C_i is the observed concentration of i^{th} parameter; L_i is the permissible limit of i^{th} parameter.

Each value of NPI shows the relative pollution contributed by single parameter. It should be less than or equal to 1. NPI values exceeding 1 indicate the presence of pollution in water.

The quality of the effluent has been compared to the limit of the standard of Ghana Environmental Protection Agency (GEPA) and WHO standards.

5.5 Results and Discussions

5.5.1 Results of the analysis

Tables 5-4 and 5-5 present the results of the average values of the nineteen (19) physico-chemical parameters analysed in each sampling site for the three months of study.

Table 5- 4_Mean values of physical parameters in each sampling site

Parameter and Unit	SAMPLING SITE											
	A	B	C	D	E	F	G	H	Hi	I	J	Fi
Temp. (°C)	24.2	22.3	22.4	23.9	23.9	26.55	26.7	25.35	25.9	24.9	26.1	25.6
pH	7.73	7.29	7.21	7.17	7.04	6.91	7.2	6.11	6.5	6.8	6.4	7.2
Turb. (NTU)	56	22	22	52	58	31	**118.5**	34.5	38.5	47.5	43	12.5
EC (µS/cm)	**1719**	**1133**	**1504**	**1309**	**1398**	**1396**	**2810**	152.1	194.2	68.6	205.4	**4210.5**
TDS (mg/L)	859	569	751	655	699	695	**1420**	75.9	97.4	851	102.9	**3435**
TSS (mg/L)	47	15	16	50	**56**	28.5	**100.5**	28.5	28	42	34	11

Note: values highlighted in bold are outside the standard limits

All of the mean values of the sampling sites in terms of temperature presented in Table 5-4 are below the maximum allowable value for discharge into water bodies Ghana EPA and WHO.
The pH of the aquatic system is an important water quality parameter as it is closely related to biological productivity (Carr and Neary, 2008). It is a measure of the concentration of hydrogen ions in the water. The solubility and bioavailability of chemical constituents such as nutrients and heavy metals depend on the pH of the water (Duncan, De Vries & Nyarko, 2018). Mean pH values determined for all sampling sites fluctuated a bit during the monitoring period, but where within the recommended range of GEPA standard. Turbidity in water is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted without changing in direction or flow level through a sample (APHA/AWWA/WEF, 2012). It is also a measure of how cloudy water is and can be caused by clay, organic matter, and other tiny inorganic particles (Environmental F. Inc., 2014). High turbidity reduces the light available to submerged aquatic vegetation and ceases their photosynthesis activities, reducing the amount of dissolved oxygen available in the water (Zheng et al., 2015). A mean Turbidity value of 12.5 to 118.5 NTU was measured for all the sampling sites. At all the sampling sites besides point G, Turbidity is within the permissible level for GEPA.
The measure of conductivity is the waters' ability to conduct electric current. It is related to the ionic content of dissolved ions in the water. The Electrical Conductivity of water estimates the total amount of dissolved solids in water: water bodies have fairly constant conductivity; hence a sharp change in conductivity could be a sign of possible pollution (Duncan, De Vries & Nyarko, 2018). The EC of the sampling sites range from 68.6 to 4210.5 µS/cm. The main EC of 8 of the 12 sampling sites were above the limits of WHO.
According to the GEPA standard, water with a TDS less than 1000 mg/L is considered good. The mean TDS value ranged from 75.9 to 3435 mg/L. Almost all sampling points, with the exception of points G and Fi, had a TDS value that was above the allowable concentration for the GEPA limits.
Variations may be influenced by the intensity of the agricultural, domestic and sand mining activities (Carr and Neary, 2008) that occurred in the study area during this period. Concentration exceeding the recommended level have a high potential to affect the health of those who directly consume the water if the ions are toxic or carcinogenic. This could also affect aquatic life and the water treatment costs. Sample G is an estuary of the Gulf of Guinea and a high TDS could be attributed to the sea's salty nature.
The mean TSS range of 11 to 100.5 mg/L was recorded. Except for points G and E, almost all the sampling points recorded TSS below the allowable concentration for GEPA limits. The

TSS, when present in a water body, can affect it in terms of physical, chemical, and biological characteristics (Bilotta and Brazier, 2008).

Table 5- 5_Mean values of chemical parameters in each sampling site

Parameter and Unit	SAMPLING SITE											
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**Hi**	**I**	**J**	**Fi**
DO (mg/L)	**2.5**	**6**	**3.9**	**5.2**	**3**	**4.4**	**6.2**	**8**	**7.9**	**7.45**	**7.9**	**7.5**
BOD_5 (mg/L)	35	**175**	**130**	**165**	**65**	**140**	**170**	**257.5**	**262.5**	**232**	**260**	**250**
COD (mg/L)	163.6	127.2	18	218.1	181.8	**660.9**	**463.9**	63.44	**350.3**	51.2	74.3	**1591**
TA (mg/L)	**484**	**232**	**284**	**260**	**272**	**268**	79	43	74	84	74	**233**
TH (mg/L)	**520.5**	110.1	450.41	**610.55**	470.42	315.3	**1729.1**	79.07	59	79.1	87.6	**1887.7**
Calc.H. (mg/L)	**448.9**	**278.3**	**422**	**341.2**	**386.1**	**209.2**	**574.6**	90.2	87.9	127.9	115.3	**816.1**
Mag.H. (mg/L)	17.4	40.9	6.91	65.5	20.5	3.9	**294.8**	2.7	75	12.9	7.8	**723.3**
TPO_4 (mg/L)	**29.2**	1.2	**6.5**	**10.1**	**8.4**	**11.9**	2.3	1.9	1.9	2.9	2.3	1.5
Orth. (mg/L)	**20.8**	1.3	4.2	**6.1**	1.5	**6.8**	0.9	0.7	0.7	0.5	0.67	1
Nitr. (mg/L)	7.6	9.25	17	17.1	15.5	8.3	10.7	5.4	5	5.1	5.3	16
Amm. (mg/L)	**226.6**	**53.9**	**56.3**	**53.9**	**70**	**166.6**	**126.7**	**99.1**	**96.9**	**82.4**	**281.9**	**141**
Sulp. (mg/L)	16.7	106.9	186	73.5	92.8	31.2	122.1	2.5	7.2	15.5	2.8	186.6
Iron (mg/L)	0.02	0.01	0.03	0.1	0.1	0.03	0.1	0.1	0.1	0.1	0.1	0.1

Note: TA: Total Alkalinity; TH: Total Hardness; Calc.H.: Calcium Hardness; Mag.H.: Magnesium Hardness; TPO_4: Total Phosphorus; Orth.: Ortho Phosphate; Nitr.: Nitrate. Values highlighted in bold are outside the standard limits.

The DO in water is a water quality parameter used to evaluate biological changes in the water body due to aerobic and anaerobic (Davis, 1975) and the driving force for metabolic activities of aerobic organisms in the water. The level of DO in water was influenced by many factors such as the temperature, the level of organic matter, and the wind blowing on the water surface or the river's flow (Davis, 1975; Englande Jr, Krenkel & Shamas, 2015).

The mean DO range of 2.5 to 8 mg/L was recorded. All the sampling points recorded DO above the allowable concentration.

One reason for the low removal efficiency of the natural wetland in the wet season may also be due to the high precipitation that occurred during the sampling period, thereby causing surface run-off in the wetland, reducing the settling velocity of the suspended solids. Thus, the particles remain in suspension and ultimately are discharged as effluent. Also, in the wet season, the temperature is colder, and the metabolism and bio-activity of microbes are low compared with the rest of the year, which slows down the BOD_5 and COD removal (Steinmann, Weinhart, and Melzer, 2003; Denisi et al., 2021).

The BOD5 is the mass of the oxygen required by bacteria in decomposing an organic matter under aerobic conditions. Low BOD_5 in a water body indicates the good quality of the water because it implies less decomposable organic matter in the water and less oxygen needed to break it down. The analysis results show the mean BOD_5 range of 35 to 262.5 mg/L. All the sampling points recorded BOD_5 above the allowable concentration, except point A, showing an excess of the permissible limit and the influence of the high levels of the suspended solids in the aquatic system under study. When BOD_5 increases and nothing is done to restore the oxygen levels, many aerobic aquatic species can be lost through death as anaerobic conditions set in.

The mean COD range of 18 to 1591 mg/L was recorded. Four sampling points (F, G, Hi, Fi) recorded COD above the allowable concentration.

Alkalinity for aquatic life is important because it buffers the pH of water within the system: resisting changes in pH after the small addition of acid or base.

The mean Total Alkalinity range of 43 to 484 mg CaCO3/L was recorded. Seven sampling points (A, B, C, D, E, F, Fi) are above the WHO standards.

Exceeding the recommended alkalinity will affect aquatic plant growth and raise water treatment costs. Urbanization within the wetland could be a reason for the increase in alkalinity as cement, and other urban construction materials may wash into the river during rain runoffs. Wastewater discharges from surrounding homes also contribute to the increase in alkalinity.

Water hardness in this study is defined as the measure of the amount of calcium and magnesium in water. The mean Total Hardness range of 59 to 1887.7 mg/L was recorded. Four sampling points (A, D, G, Fi) are above the WHO acceptable limit.

The mean Calcium Hardness range of 87.9 to 816.1 mg/L was recorded. There is no standard for Calcium for GEPA Standards. Eight sampling points (A, B, C, D, E, F, G, Fi) are above the WHO standards.

The mean Magnesium Hardness range of 2.7 to 723.3 mg/L was recorded. There is no standard for Magnesium for GEPA Standards. Only 2 points (G, Fi) are above the standard limits.

Phosphorus as nitrate is a nutrient that could result in eutrophication in a river or lake when present in high concentrations. Phosphorus can appear in the dissolved or particulate form because particulate phosphorus can change to a soluble form under some environmental conditions. Heavy phosphate-containing water bodies favor the growth of aquatic plants and negatively affect water quality and deplete oxygen by accelerating the growth of algal clump, resulting in anoxic conditions, bad odor, and decoloration, such conditions not only make the water aesthetically unattractive but reduce its recreational potential and may cause the death of many sensitive aquatic organisms (Carr and Neary, 2008).

The mean Total Phosphorus concentration in the water range of 1.2 to 29.2 mg/L was recorded. Five sampling points are above the WHO standards.

The mean Orthophosphate range of 0.5 to 20.8 mg/L was recorded. Only 3 points (A, D, F) are above the limits for WHO standards.

An excess of phosphate and nitrate will cause algae and aquatic plants to grow wildly, choke up the waterway and use up large amounts of the oxygen (Brian Oram, 2014), creating eutrophic conditions.

The concentration of Nitrate increases when nitrate-rich aquifers and pollutants feed the river. Agricultural activities and waste disposal are other ways through which nitrate reach the water bodies (WRC, 2012). Though Nitrate, when present in normal levels, usually does not directly affect human and aquatic lives, they do when in excess. In the area under study, all the concentration values of Nitrates are below WHO's standard limits.

The mean Ammonia range of 53.90 to 281.9 mg/L was recorded. All the values are far above the limits of the standard for WHO. Ammonia concentrations provide information on the contamination of water by urban wastewater or leaching from agricultural areas. Ammonia, if present in water, has a direct toxic action on fish.

The mean Sulphate range of 2.5 to 186.6 mg/L was recorded. All the values are below the maximum permissible for GEPA.

The mean concentration range of Iron was recorded 0.01 to 0.1 mg/L. All the values of this metal are below the maximum permissible for WHO standard.

5.5.2 Results of Water Quality Index

The results of the various water quality parameters used to understand the water quality of the water bodies and the pollution caused by each parameter are presented in Tables 5-7, 5-8 and 5-9.

Table 5-6 shows the relative Weightage factors of selected parameters used to compute the WAWQI for individual sampling site. The summary of the calculation of WAWQI is presented in Table 5-7.

Table 5- 6_The Standard value and the relative Weightage factors of selected parameters

Parameters	Standard Value considered	Relative Weightage (Wi)
Temp. (°C)	< 30	0.0056
pH	6 - 9	0.0215
Turb. (NTU)	75	0.0022
EC (µS/cm)	1000	0.0002
TDS (mg/L)	1000	0.0002
TSS (mg/L)	50	0.0033
DO (mg/L)	1	0.1667
BOD_5 (mg/L)	50	0.0033
COD (mg/L)	250	0.0007
TA (mg/L)	200	0.0008
TH (mg/L)	500	0.0003
Calc. (mg/L)	100-300	0.0008
Mag. (mg/L)	150	0.0011
TPO_4 (mg/L)	5	0.0333
Orth. (mg/L)	5	0.0333
Nitr. (mg/L)	50	0.0033
Amm. (mg/L)	1	0.1667
Iron (mg/L)	0.3	0.5558
Sulp. (mg/L)	250-300	0.0006
		$\sum$ Wi= 1

Table 5- 7_WAWQI in each sampling site

Sampling site	A	B	C	D	E	H	Hi	I	J	Fi	F	G
WAWQI	3861	1007	1021	1015	1242	1810	1765	1523	4857	2488	2874	2242

The WAWQI of the sites are classified using the water quality status (Tab.5-3). The WAWQI values ranged from 1007 to 4857 classifying all the sampling sites excessively polluted.

The NPI values shown in Table 5-8 and 5-9 confirm the polluting effect of parameters whose mean values are above the standard limits. The NPI values ranged from 0.1 to 453.2 for the sampling sites studied, confirming that some of the parameters that have a high mean value contribute to the overall pollution of the aquatic environment studied.

The major parameters affecting the water quality are DO, BOD, Ammonia which are far above the permissible limits. EC and TA are the other parameters that contribute the most to water pollution in the studied sites.

As far as the overall pollution of the wetland area is concerned, the NPI results indicate that 6 of the sites were polluted by 8-11 physico-chemical parameters, while 2 sampling sites were polluted by 6-7 physico-chemical parameters and 4 sites were polluted by 3-4 physico-chemical parameters during the rainy season studied.

Table 5- 8_Mean value of physical parameters and NPI in each sampling site

	PARAMETERS AND UNITS					
SITE	**Temp. (°C)**	**pH**	**Turb. (NTU)**	**EC (µS/cm)**	**TDS (mg/L)**	**TSS (mg/L)**
A	24.20	7.73	56.00	1719.00	859.00	47.00
NPI	0.81	1.00	0.75	1.72	0.86	0.94
B	22.30	7.29	22.00	1133.00	569.00	15.00
NPI	0.74	0.94	0.29	1.13	0.57	0.30
C	22.40	7.21	22.00	1504.00	751.00	16.00
NPI	0.75	0.93	0.29	1.50	0.75	0.32
D	23.90	7.17	52.00	1309.00	655.00	50.00
NPI	0.80	0.93	0.69	1.31	0.66	1.00
E	23.90	7.04	58.00	1398.00	699.00	56.00
NPI	0.80	0.91	0.77	1.40	0.70	1.12
F	26.55	6.91	31.00	1396.00	695.00	28.50
NPI	0.89	0.89	0.41	1.40	0.70	0.57
G	26.75	7.22	118.50	2810.00	1420.00	100.50
NPI	0.89	0.93	1.58	2.81	1.42	2.01
H	25.35	6.11	34.50	152.15	75.90	28.50
NPI	0.85	0.79	0.46	0.15	0.08	0.57
Hi	25.95	6.47	38.50	194.25	97.40	28.00
NPI	0.87	0.83	0.51	0.19	0.10	0.56
I	24.90	6.78	47.50	68.60	851.00	42.00
NPI	0.83	0.87	0.63	0.07	0.85	0.84
J	26.10	6.41	43.00	205.35	102.85	34.00
NPI	0.87	0.83	0.57	0.21	0.10	0.68
Fi	25.65	7.18	12.50	4210.50	3435.00	11.00
NPI	0.86	0.93	0.17	4.21	3.44	0.22

Note: The results highlighted in red indicate the NPI values exceeding 1

Table 5- 9_Mean value of chemical parameters and NPI in each sampling site

	PARAMETERS AND UNITS												
SITE	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	TA (mg/L)	TH (mg/L)	Calc. (mg/L)	Mag. (mg/L)	TPO_4 (mg/L)	Orth. (mg/L)	Nitr. (mg/L)	Amm. (mg/L)	Iron (mg/L)	Sulp. (mg/L)
A	2.50	35.00	163.58	484.00	520.47	448.90	17.39	29.16	20.77	7.62	226.59	0.02	16.74
NPI	2.50	0.70	0.65	2.42	1.04	2.24	0.12	5.83	4.15	0.15	453.18	0.07	0.06
B	6.00	175.00	127.23	232.00	110.10	278.32	40.88	1.19	1.30	9.25	53.89	0.01	106.95
NPI	6.00	3.50	0.51	1.16	0.22	1.39	0.27	0.24	0.26	0.18	107.78	0.04	0.39
C	3.90	130.00	18.00	284.00	450.41	421.96	6.91	6.49	4.20	16.99	56.35	0.03	186.01
NPI	3.90	2.60	0.07	1.42	0.90	2.11	0.05	1.30	0.84	0.34	112.70	0.09	0.68
D	5.20	165.00	218.10	260.00	610.55	341.16	65.46	10.07	6.14	17.10	53.89	0.08	73.50
NPI	5.20	3.30	0.87	1.30	1.22	1.71	0.44	2.01	1.23	0.34	107.78	0.26	0.27
E	3.00	65.00	181.80	272.00	470.42	386.05	20.50	8.43	1.50	15.53	70.00	0.08	92.76
NPI	3.00	1.30	0.73	1.36	0.94	1.93	0.14	1.69	0.30	0.31	140.00	0.26	0.34
F	4.40	140.00	660.90	268.00	315.30	209.19	3.91	11.92	6.76	8.35	166.63	0.03	31.24
NPI	4.40	2.80	2.64	1.34	0.63	1.05	0.03	2.38	1.35	0.17	333.25	0.10	0.11
G	6.20	170.00	463.90	79.00	1729.06	574.56	294.84	2.32	0.87	10.68	126.71	0.06	122.06
NPI	6.20	3.40	1.86	0.40	3.46	2.87	1.97	0.46	0.17	0.21	253.42	0.20	0.44
H	8.00	257.50	63.44	43.00	79.07	90.23	2.71	1.88	0.72	5.38	99.05	0.06	2.55
NPI	8.00	5.15	0.25	0.22	0.16	0.45	0.02	0.38	0.14	0.11	198.09	0.20	0.01
Hi	7.90	262.50	350.27	74.00	59.05	87.90	7.46	1.86	0.72	5.00	96.90	0.06	7.22
NPI	7.90	5.25	1.40	0.37	0.12	0.44	0.05	0.37	0.14	0.10	193.80	0.20	0.03
I	7.45	232.00	51.18	84.00	79.07	127.94	12.89	2.92	0.48	5.06	82.42	0.05	15.49
NPI	7.45	4.64	0.20	0.42	0.16	0.64	0.09	0.58	0.10	0.10	164.84	0.15	0.06
J	7.95	260.00	74.35	74.00	87.58	115.32	7.83	2.30	0.67	5.36	281.95	0.06	2.83
NPI	7.95	5.20	0.30	0.37	0.18	0.58	0.05	0.46	0.13	0.11	563.89	0.20	0.01
Fi	7.55	250.00	1591.00	233.00	1887.70	816.10	723.34	1.54	1.00	15.97	140.99	0.02	186.57
NPI	7.55	5.00	6.36	1.17	3.78	4.08	4.82	0.31	0.20	0.32	281.98	0.07	0.68

Note: TA: Total Alkalinity; TH: Total Hardness; Calc. H.: Calcium Hardness; Mag. H.: Magnesium Hardness; TPO_4: Total Phosphorus; Orth.: Ortho Phosphate; Nitr.: Nitrate. The results highlighted in red indicate the NPI values exceeding 1

The observed water quality index selected for the study confirms the polluting effects of the parameters which are purely introduced by anthropogenic activities occurring around the wetland, that degrade the wetland and affect his potential and performance.

To support this argument, in research conducted by Amadu, 2021 on this wetland reveal that. The land cover map of the wetland from 1991 to 2020 shows how the wetland has reduced in size as a result of indiscriminate building in and round the wetland, cutting down of mangroves in the wetland and dumping of refuse in and around the wetland. The land cover class reveal that the wetland in the year 1991 was about 1.187 km^2**,** in 2001, the wetland had reduced to **0.**2988 km^2 owing to these factors mentioned earlier. In the year 2015, the wetland had reduced to 0.2405 km^2 and in 2020, 0.1989 km^2**.** These acts underpin the effectiveness of the wetland to provide its quota to wastewater treatment**.** Below are shown the pictures of the land cover map.

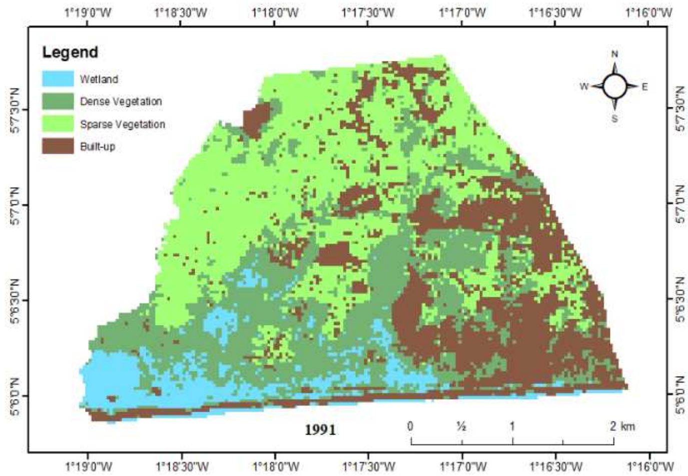

Fig. 5- 6 _Land civer map for 1991.

Source: Amadu (2021)

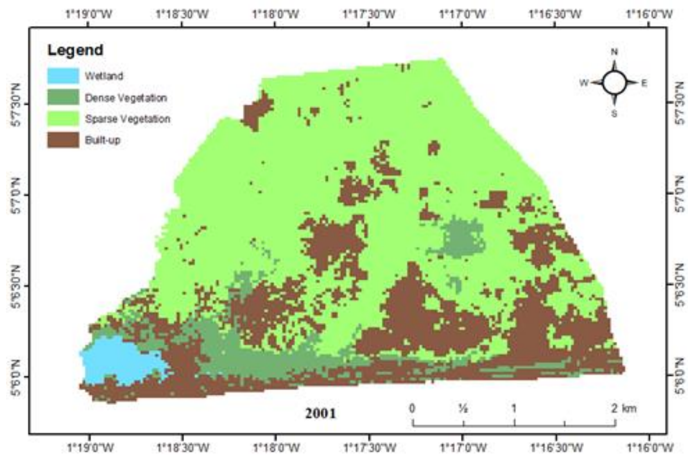

Fig. 5- 7_ Land cover map for 2001.

Source: Amadu (2021)

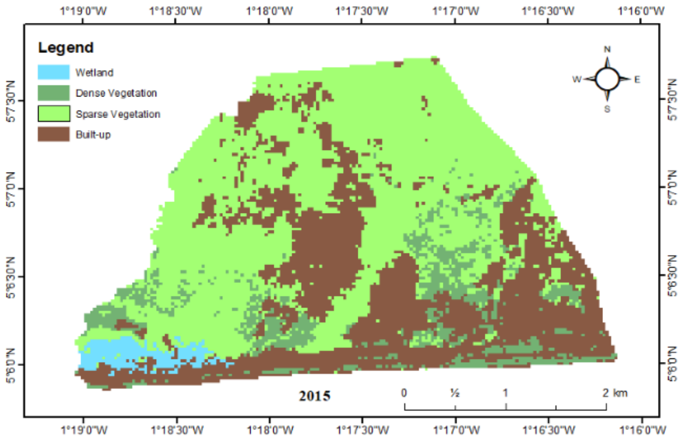

Fig. 5- 8_Land cover map for 2015.

Source: Amadu (2021)

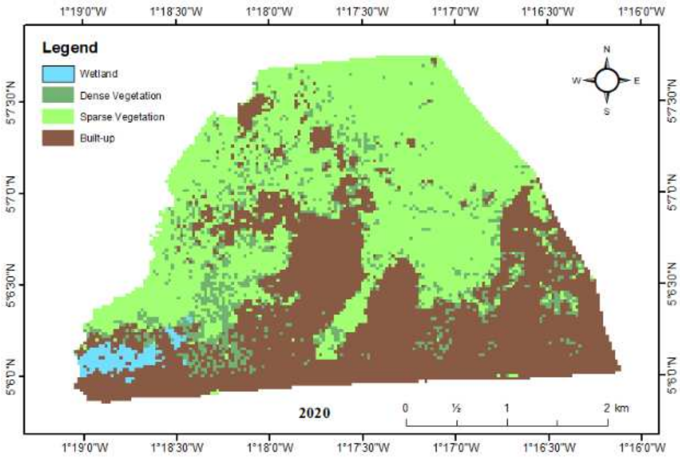

Fig. 5- 9_ Land cover map for 2020.

Source: Amadu (2021)

5. 6 Conclusions

This study shows that the water quality of the aquatic environment studied and Iture-Abakam wetland in Cape Coast is excessively polluted. The parameters DO, BOD, and Ammonia pose a significant problem to the natural wetland in Cape Coast.

The results of the current study show that Iture-Abakam wetland in Cape Coast is threatened. Degradation and pollution are greatly influenced by improper waste disposal, sand mining, agriculture runoffs, overharvesting of mangroves, increase in population and residential facilities developments in and around the natural wetland, which also directly affect the land cover by the wetland, loss of habitat, hydrological changes, and alter the water quality. The Iture-Abakam wetland in Cape Coast results over-exploited and is not efficient of removing pollutants from incoming domestic wastewater. The main problems are the absence of any conventional primary wastewater treatment plant in Cape Coast; therefore, the wetland must perform the primary treatment and not the secondary one for which it should be designated.

Therefore, the study suggests that human activities contributing heavily to wetland degradation should be monitored and regulated. Good wetland management requires understanding basic ecosystem processes, animal and plant life strategies, and wildlife management principles.

Therefore, some recommendations should be made to improve the use and efficiency of natural wetland:

- It is important to put a primary treatment facility for domestic wastewater (i.e., septic tank) to improve water quality discharged to the wetland.
- The amount of wastewater flowing into the wetland must be controlled.
- Plants in the natural wetland must be harvested regularly to ensure that removed pollutants do not re-enter the wetland as the plants die and decompose.
- Raise awareness among the farmers who use the water on the working mechanism of the wetland.
- The systems will undoubtedly pique the interest of the farmers and encourage their participation in the maintenance.
- Education and public outreach about the environmental and economic importance of the wetland should be realized.
- Relevant environmental laws on the proper use and management of the natural wetland should be enforced.
- Implement the cooperative efforts of various social and political stakeholders in formulating, implementing, and monitoring successful measures for sustainable wetland management.

6. Conclusions

The main goal of the research activities was to investigate the valorization of wastewater resources through the application of appropriate natural wastewater treatment processes in two different Low-and Middle-Income Countries, specifically the Palestinian Territories and Sub-Saharan Africa.

The major challenge of exploring the utilization of facilities that can be adapted to each context, is sustainable and have low social and environmental impacts on the local population.

The first study has been developed in the southern part of Gaza Strip, in the frame of an international cooperation project carried out by the Italian NGO Overseas-Onlus, in collaboration with the University of Bologna (Italy), the Palestinian NGO UAWC, and the University of Applied Sciences (Palestine), to promote the agricultural sector by using treated wastewater for irrigation purpose. This area is characterised by geographical isolation, high population density, unreliable electricity supply, water scarcity and pollution, and quite complex wastewater treatment facilities and management.

The second study has been developed in Ghana, during my Ph.D. period abroad, thanks to the collaboration with UCC University, Ghana, in the Cape Coast metropolis, to assess the feasibility of using the Natural Wetland in Cape Coast for domestic wastewater treatment. This area is characterised by the absence of primary and conventional infrastructures for wastewater treatment, the lack of data on the quantity and quality of wastewater generated, and the deficiency of laws or guidelines for wetland protection and management.

The first experimental research carried out in Rafah, Gaza Strip showed that the implementation of the existing primary treatment plant with a natural finishing treatment plant properly optimized the wastewater quality for reuse in agriculture and was appropriate for the study area. The construction and implementation of the project have supported the rehabilitation and improved the already existing basic infrastructures. Beneficiary farmers from the project shall use this “new” resource to irrigate their fields.

Furthermore, thanks to an effective training programme, a fruitful transfer of knowledge to the local population and water and agriculture experts, and the actual achievement of a technical manual for the management and maintenance of the plant, we have also been able to increase the acceptance and social awareness of the reuse of treated wastewater.

The presence of strong local partners, such as the Farmers Association and local University, was one of the key factors for the successful implementation of the cooperation project, which

ensured the success of the ongoing project and guaranteed the continuation of the project also after its “official” conclusions.
Further studies have finally been planned to improve the efficiency of the system, increase the amount of treated wastewater and expand the number of beneficiary farmers.
The second experimental research, which was conducted in Cape Coast, Ghana, shows that the natural wetland studied is currently overly polluted and threatened. This is mainly because there are no primary treatment plants for domestic wastewater. In addition, several anthropogenic factors, such as improper waste disposal, sand mining, agriculture runoffs, over-harvesting of mangroves, increase in population and in built-up area, directly affect the wetland land cover, habitat loss, hydrological changes, and alter the water quality.
The natural wetland in Cape Coast is over-exploited and no longer able to remove pollutants from incoming domestic wastewater.
Based on the findings of the study, some recommendations can be made to improve the efficiency of natural wetland. I) Introduce primary wastewater treatment plants (i.e., septic tanks) to use the wetland as a secondary treatment plant. II) Control the amount of wastewater produced. III) Relevant environmental laws should be enforced for proper use and management of the natural wetland. IV) Public awareness programmes on the environmental, economic, and social importance of the wetland should be conducted.
In addition, further studies should be carried out in order to analyse how the potential of the wetland varies according to the season and to better inform decision-makers about the importance of natural wetlands as an alternative economic approach to wastewater treatment, the impact of the threat on national development and recommendations on its proper use and limitation.

On balance, this research study shows the importance of using natural wastewater treatment systems for domestic wastewater in two different developing countries.
It shows how the efficiency of these wastewater treatment systems can be achieved if they are properly utilized, managed, monitored, and accepted by the local population and stakeholders.

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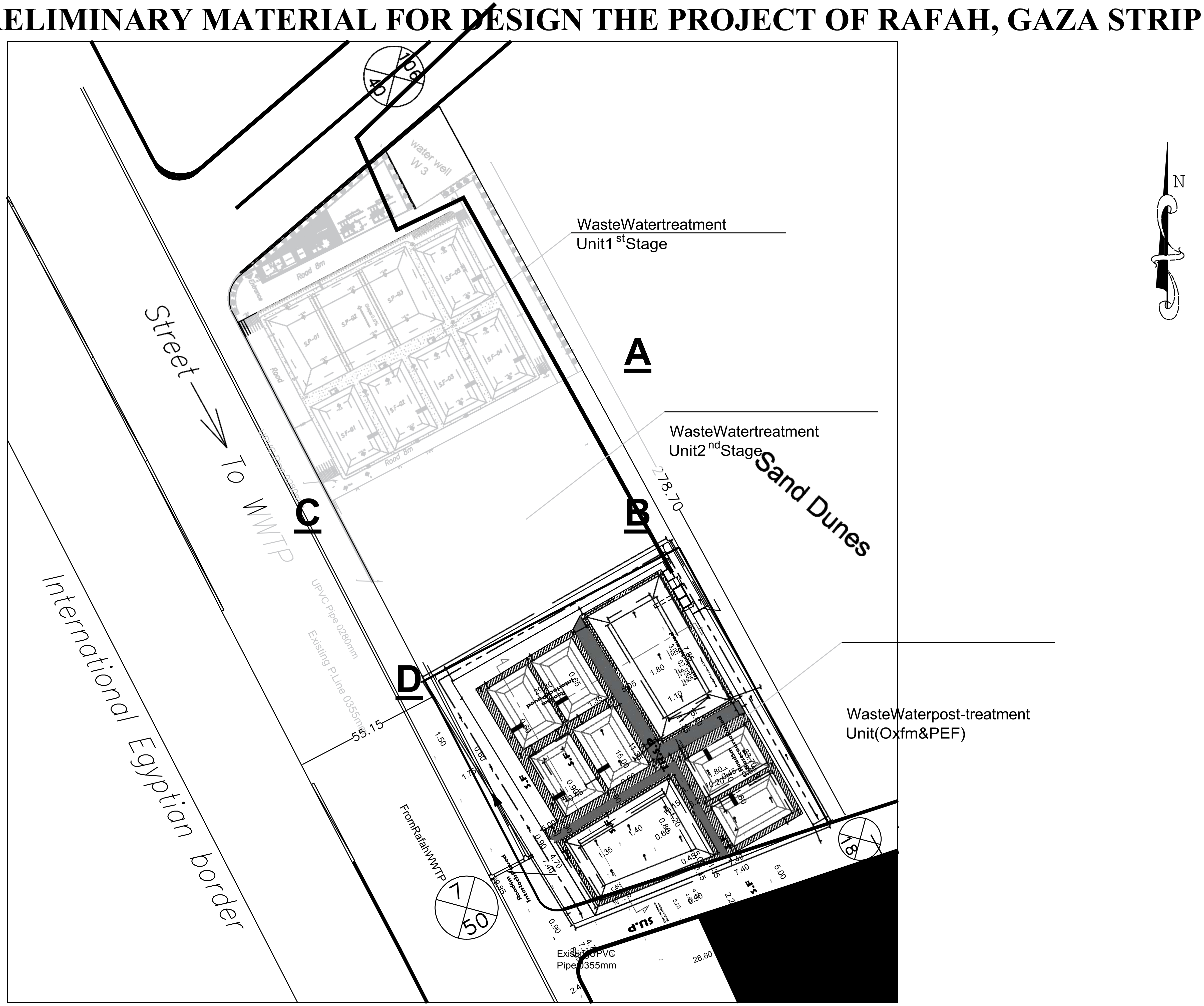
APPENDIX A - PRELIMINARY MATERIAL FOR DESIGN THE PROJECT OF RAFAH, GAZA STRIP



Waste water Treatment Unit

General Plan

APPENDIX A

A **B**

N ↑

Pecdar

level=+14 m
from the means sea level

15.77	15.65	15.65	16.15	16	15.55	hole	hole	hole
15.88	16.05	16.15	16.88	16.7	17.94	18.46	18.9	19.46
16.05	16.33	16.73	17.31	17.5	18.12	18.9	19.4	20.52
16.15	16.49	16.87	17.45	17.75	18.36	19.03	19.55	21
16.23	16.57	17.06	17.56	17.93	18.6	19.26	19.82	21.2
16.2	16.75	17.25	17.8	18.05	18.89	19.47	20.04	21.3
16.73	18.85	17.38	17.93	18.32	19.05	19.73	20.25	21.22
16.36	16.85	17.43	18.07	18.6	19.22	19.88	20.47	21.15
16.39	16.78	17.48	18.07	18.75	19.25	19.82	20.5	21.1
16.31	16.75	17.35	17.87	18.45	19.1	19.65	20.3	21.05

hole between our land and Oxfam its resulted from the excavation works
of Oxfam

Oxfam

+18.5
+16
level

C D

State of Palestine
Coastal Municipalities Water Utility
Central lab
Tel : 082632060 Fax : 082632020

دولـــــة فلسطيـــــن
مصلحـة ميـاه بلديـات السـاحل
المختبر المركزي
ت : 082632060 - ف : 082632020

Registry No. 563101633 — مشتغل مرخص 563101633

Laboratory Results' Sheet - Chemical

General Information :-

Test No. \	2301	/ رقم الفحص
Facility Name \	عينة خارجية	/ اسم المنشأة
Collected by \	المختبر	/ اسم آخذ العينة
Collect Date \	05/02/2019	/ تاريخ أخذ العينة
Sample Owner \	الكلية الجامعية - د. تامر اشتيوي	/ مالك العينة
Sample Location \	مخرج محطة معالجة المياه العادمه رفح	/ موقع العينة

Field Measurements :-

#	Test		Unit	Result	Max Value
1	COLOR	اللون	Cobalt Platine		15
2	PH	رقم الحموضة	---	**7.98**	6.5 - 8.5
3	TEMPERATURE	درجة الحرارة	C	18.9	25
4	TURBIDITY	العكارة	NTU		5
5	EC / Electrical Conductivity	التوصيل الكهربائي	Micro mho/cm		1500
6	DO	الأكسجين الذائب	ppm	**0.22**	6 - 8.5
7	EH	------	mV		---
8	ALKAKINITY	القلوية	ppm as CaCO3		200

Chemical Tests :-

#	Test		Unit	Result	Max Value
1	T.D.S Total Dissolved Salt	الأملاح الذائبة الكلية	ppm	**2820**	1000
2	CHLORIDE	الكلورايد	ppm as CL		250
3	NITRATE	النترات	ppm as NO3	**67**	50
4	NITRITE	النيتريت	ppm as NO2		0.2
5	AMMONIA	الأمونيا	ppm as NH3		1.5
6	TOTAL HARDNESS	العسر الكلي(الصلابة)	ppm as CaCO3		300
7	SULFATE	الكبريتات	ppm as So4		250
8	CALCIUM	الكالسيوم	ppm as Ca		200
9	MAGNISUM	المغنيسيوم	ppm as Mg		50
10	SODIUM	الصوديوم	ppm as Na		200
11	POTASSIUM	البوتاسيوم	ppm as K		12
12	FLOURIDE	الفلورايد	ppm as F		1.5
13	PHOSPHATE	الفوسفات	ppm as Po4		6.7
14	FREE CHLORINE	الكلور الحر	ppm		0.8
15	DETERGENTS	المنظفات	ppm as MBAS		0.5
16	TOTAL PHOSPHORUS		ppm		
17	BOD		ppm	**135**	
18	COD		ppm	**310**	
19	T.S.S		ppm	**100**	
20	T.N		ppm as N	**115.22**	

* MDL Minimum Detection Limit.

Test Date :- 12/02/2019

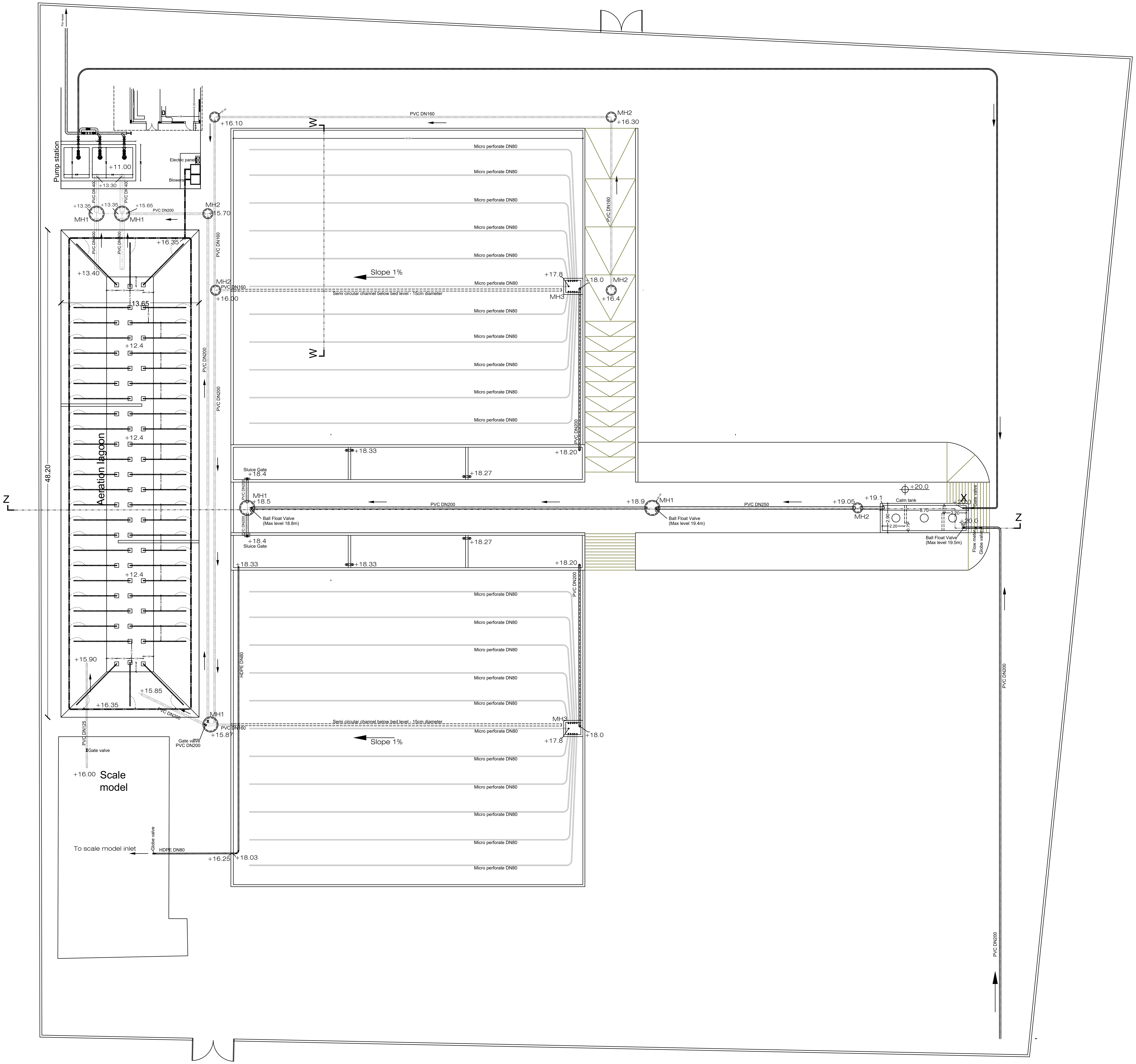
Tested by :-

Remarks :- ملاحظات

مصلحة مياه بلديات الساحل CMWU المختبر المركزي

POSTED - مرحلة

APPENDIX B1_DRAWING OF REAL PLANT OF RAFAH, GAZA STRIP



Notes:

FUNDED BY

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY

OVERSEAS

الكلية الجامعية للعلوم التطبيقية
University College of Applied Sciences

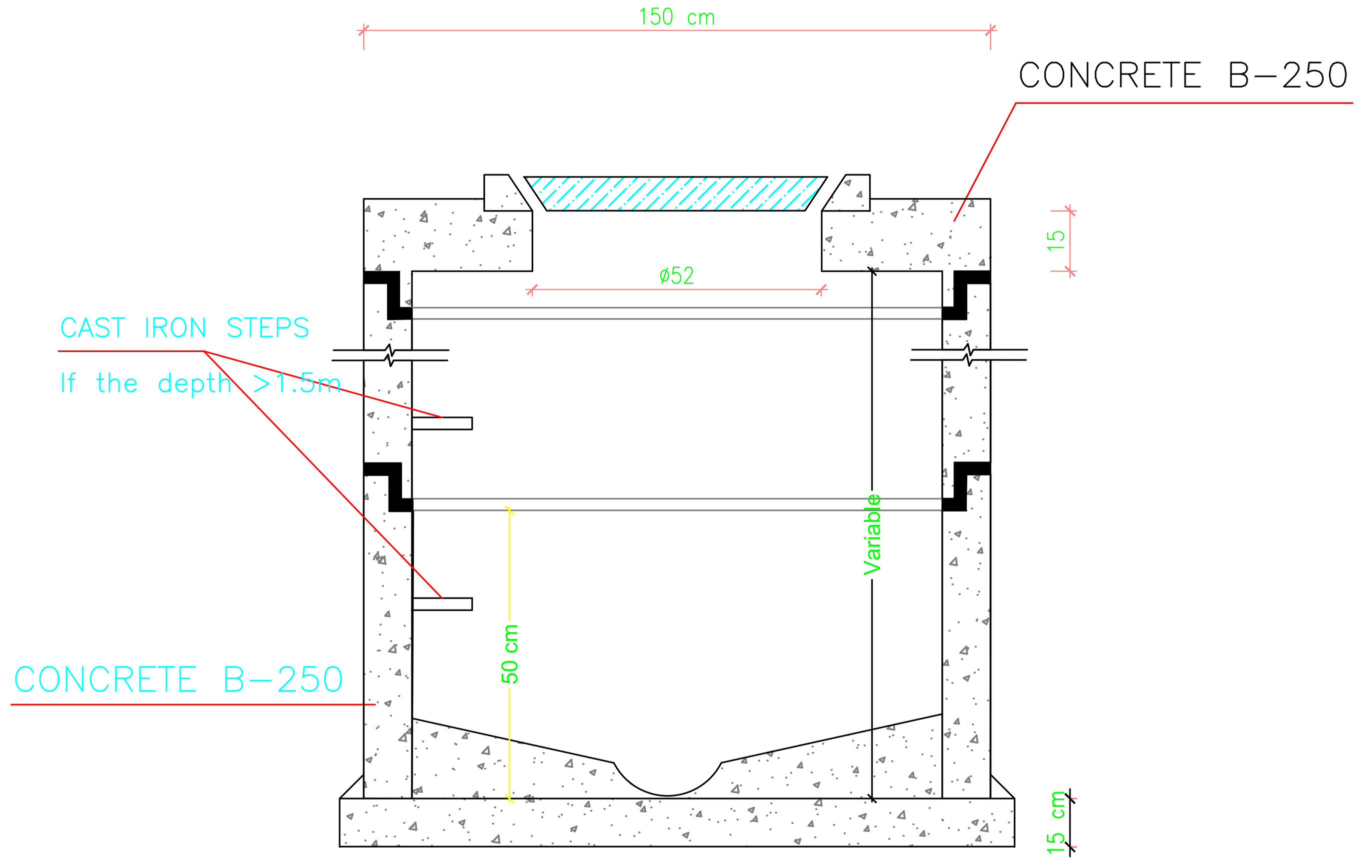
UAWC
إتحاد لجان العمل الزراعي

Project Name:
Reuse of treated wastewater for agricultural use in Al-Mawasi district – Rafah Governorate – Gaza Strip

Project No :
11473/OVERSEAS/TOC

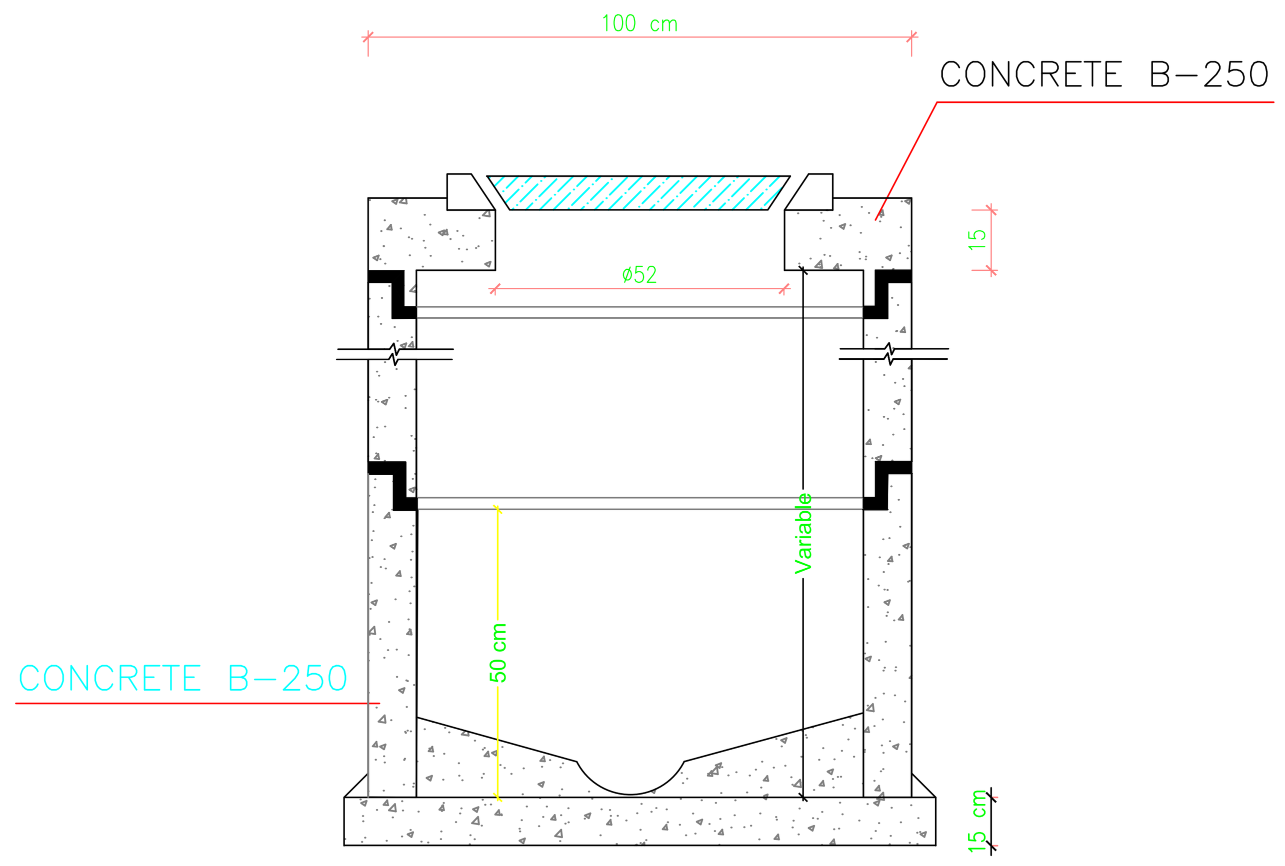
Drawing Title:
Mechanical / Hydraulic plan

Design	
Checked	
Drawing NO.	M1
Scale:	As Shown
Date:	October 2020



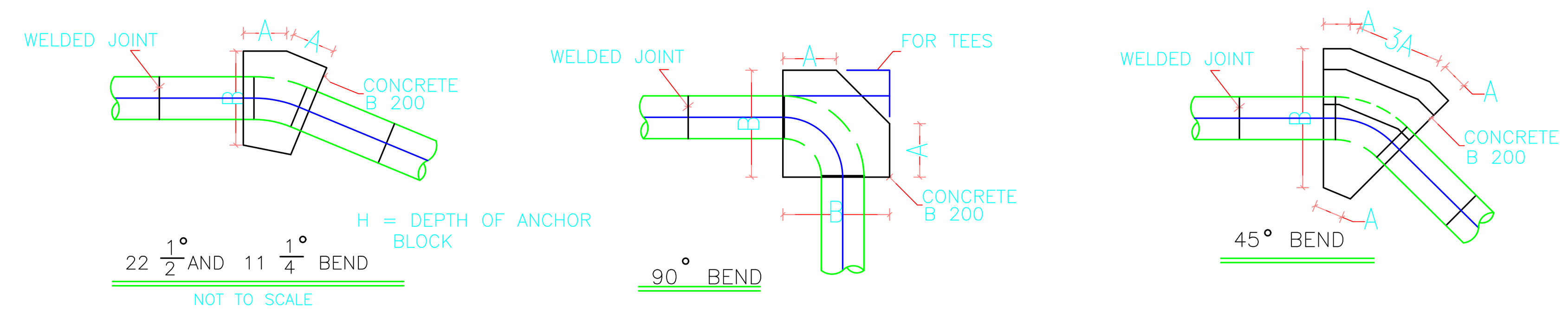
MANHOLE (MH1)

NOT TO SCALE



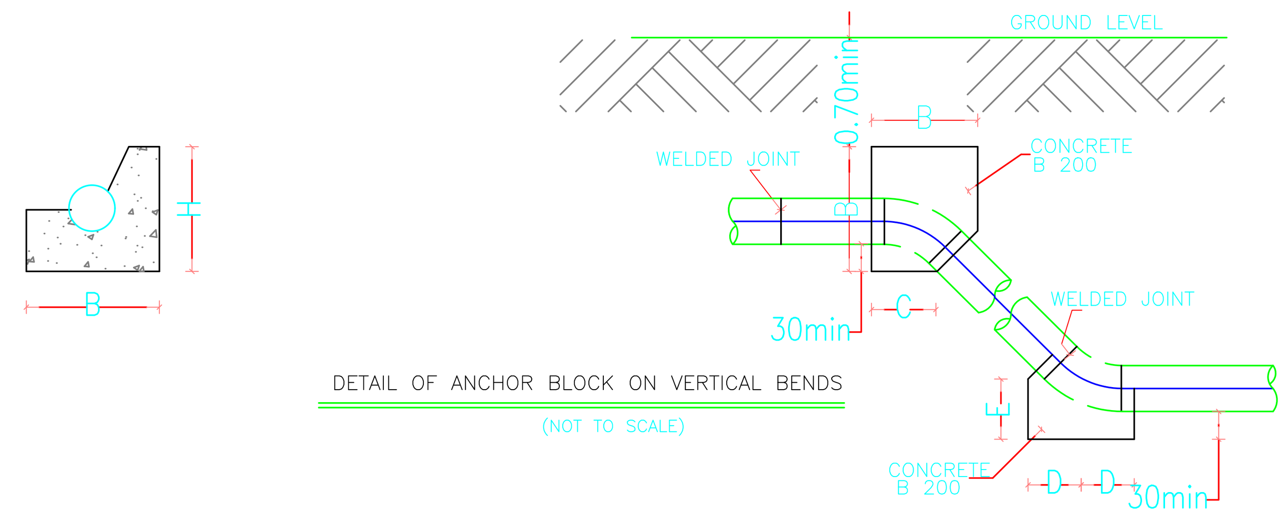
MANHOLE (MH2)

NOT TO SCALE



DETAILS OF ANCHOR BLOCK ON HORIZONTAL BENDS

(NOT TO SCALE)



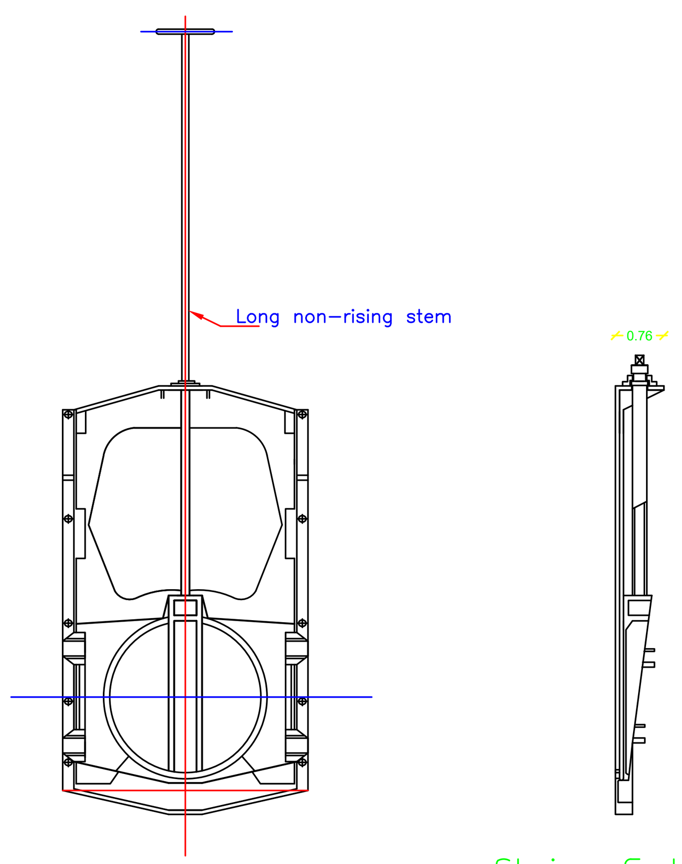
DETAIL OF ANCHOR BLOCK ON VERTICAL BENDS

(NOT TO SCALE)

DIMENSIONS OF ANCHOR BLOCKS IN CMS.

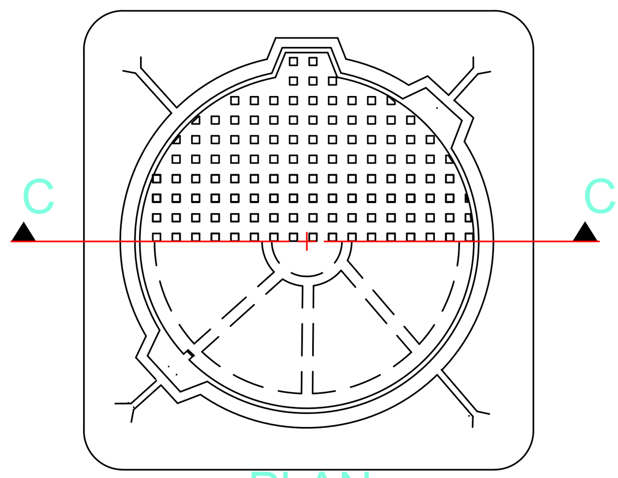
DIAMETER OF PIPES (mm.)	HORIZONTAL BENDS									VERTICAL BENDS									
	90 BEND AND TEE			45° BEND			22 1/4° AND 11 1/4°			45° BEND					22 1/2° AND 11 1/4° BEND				
	A	B	H	A	B	H	A	B	H	B	C	D	E	H	B	C	D	E	H
350 300	70	170	150	30	150	150	50	125	100	120	60	30	50	100	100	25	20	50	100
250 200 150 100	40	95	100	20	100	80	30	80	60	80	30	15	40	60	80	10	10	40	80

SEWER GENERAL DETAILS

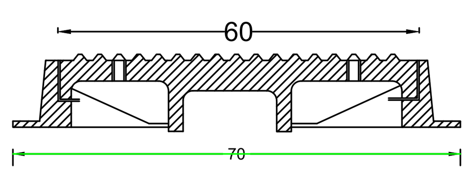


Sluice Gate Front View

Sluice Gate Side View



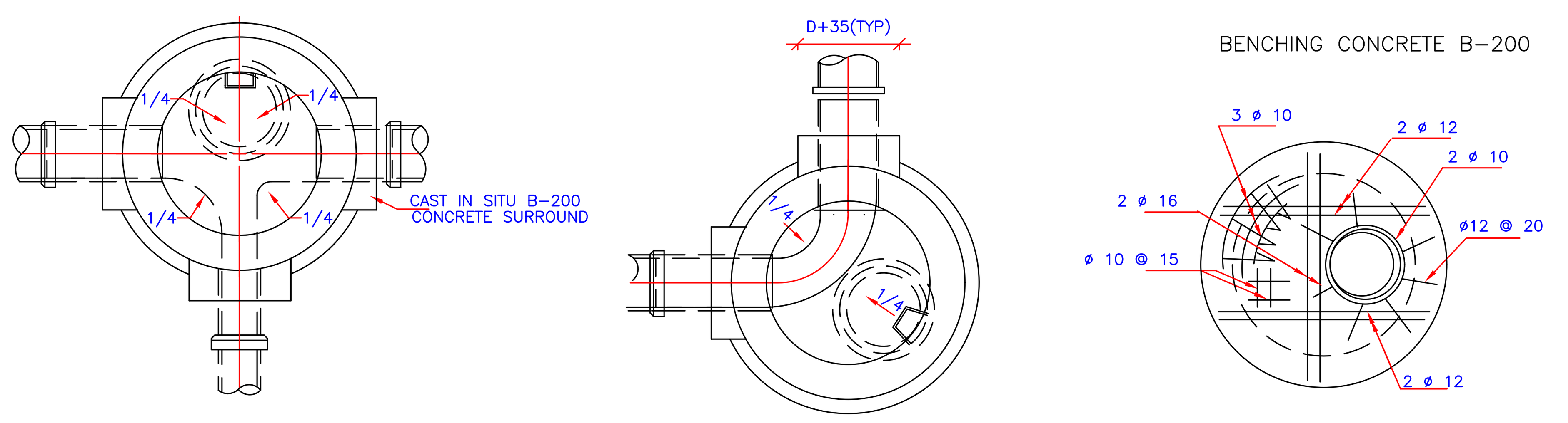
PLAN



SECTION C-C

TYPICAL HEAVY DUTY CAST IRON MANHOLE COVER AND FRAME

Do Not Measure from Drawings



TYPICAL PLANS M.H. BENCHING

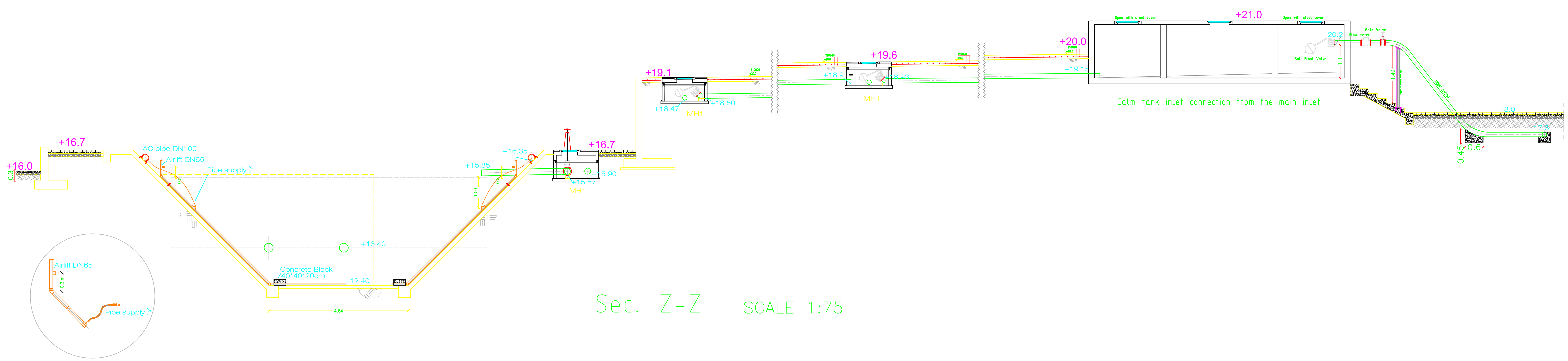
NOT TO SCALE

TYPICAL PLANS M.H. BENCHING

NOT TO SCALE

CEILING REINFORCEMENT DETAIL

NOT TO SCALE



Sec. Z-Z SCALE 1:75

Notes:

FUNDED BY

IMPLEMENTED BY

Project Name:

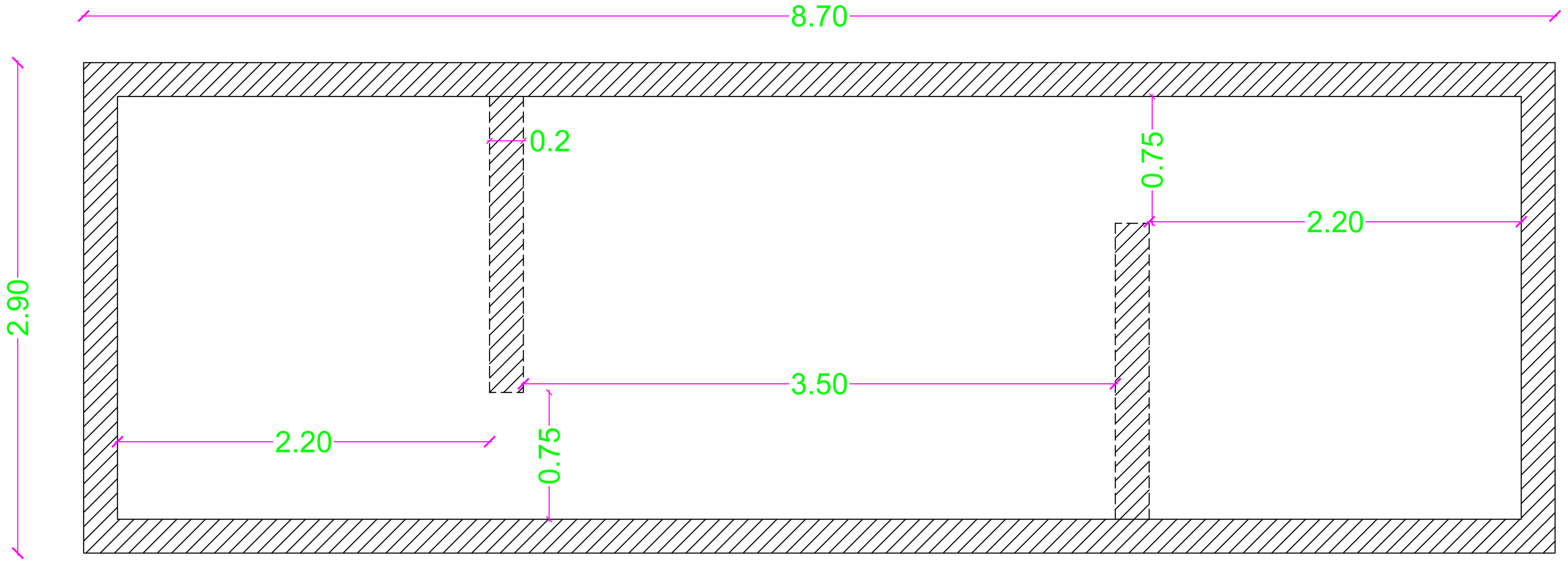
Reuse of treated wastewater for agricultural use in Al-Mawasi district – Rafah Governorate – Gaza Strip

Project No :

Drawing Title:

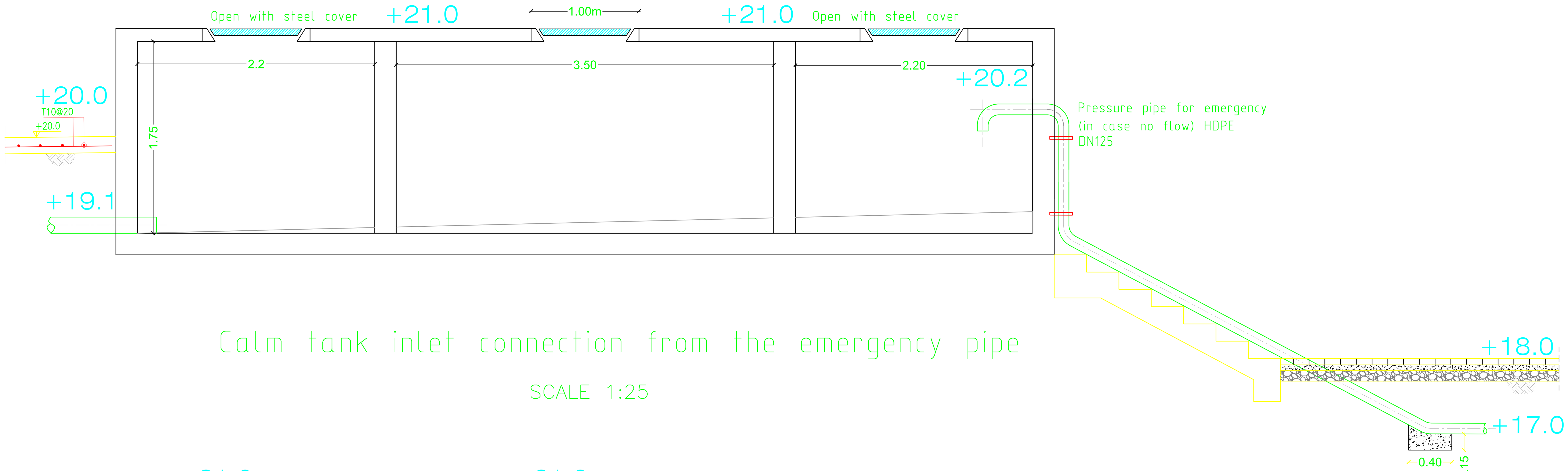
Mechanical/hydraulic details I

Design	
Checked	
Drawing NO.	M2
Scale:	As Shown
Date:	July 2020



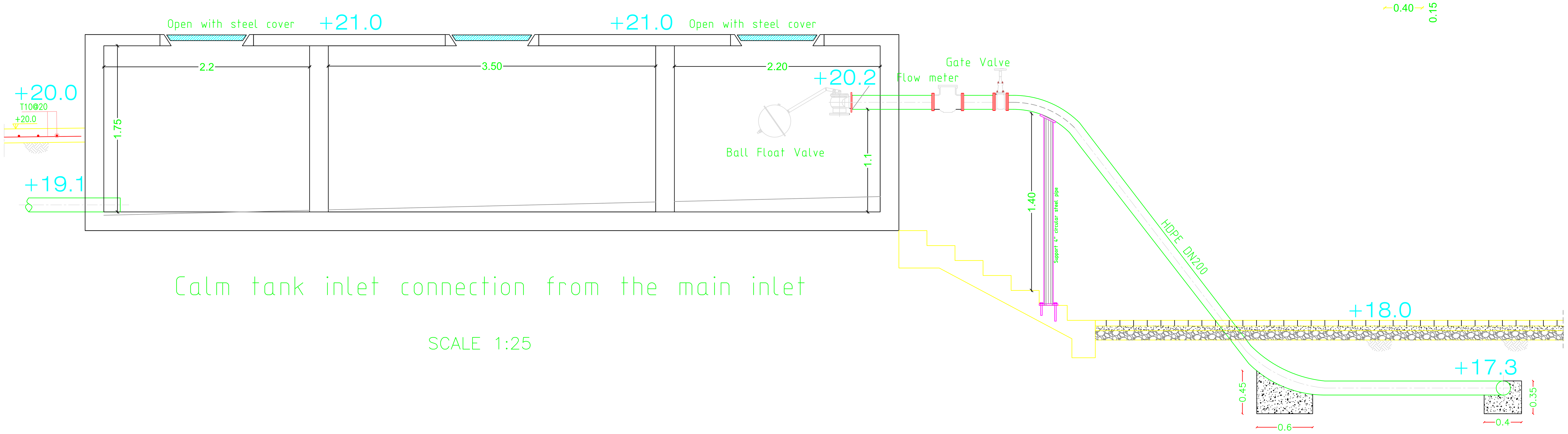
Calm tank top view (main dimensions)

SCALE 1:25



Calm tank inlet connection from the emergency pipe

SCALE 1:25



Calm tank inlet connection from the main inlet

SCALE 1:25

Notes:

FUNDED BY

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY

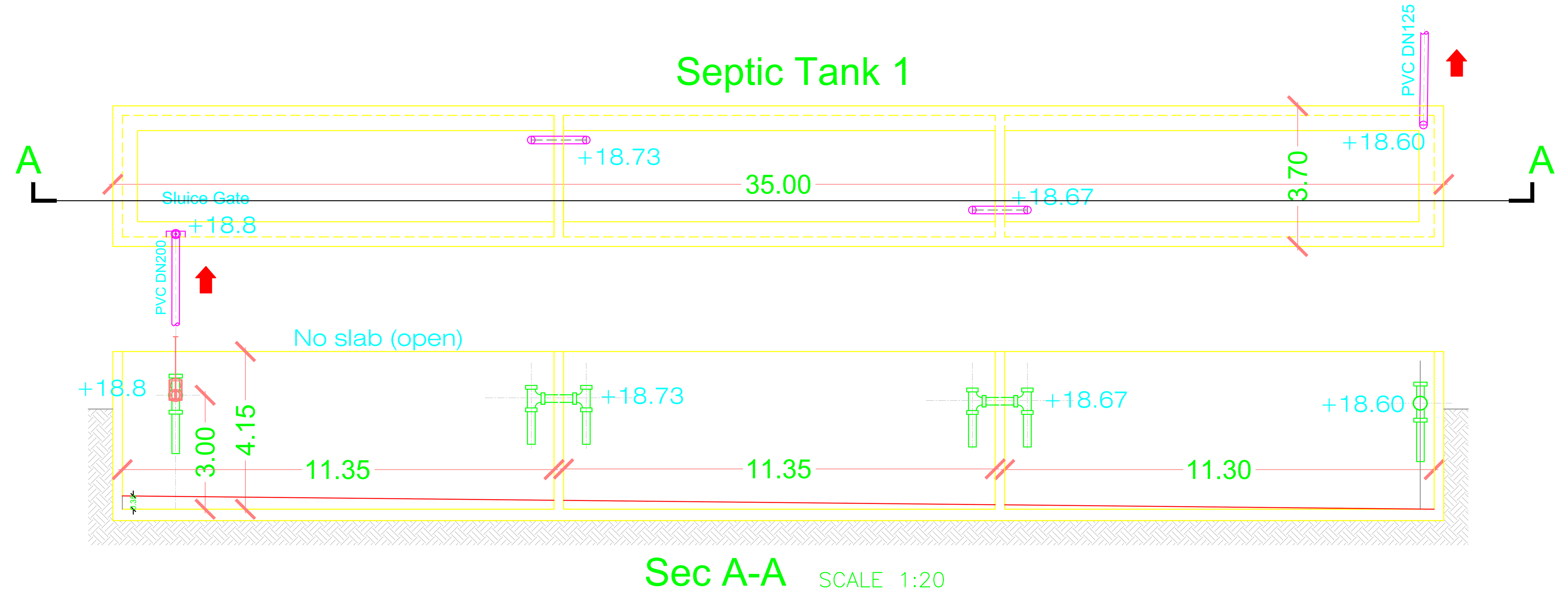
OVERSEAS

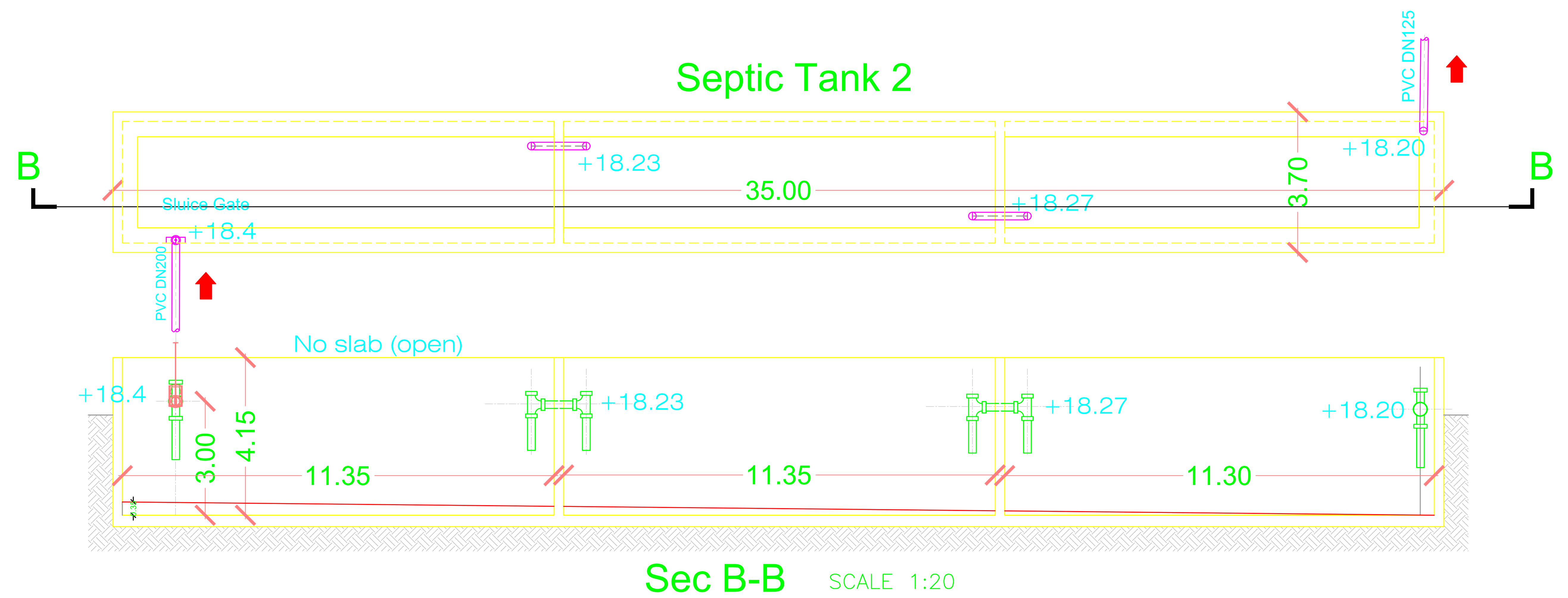
الكلية الجامعية للعلوم التطبيقية
University College of Applied Sciences

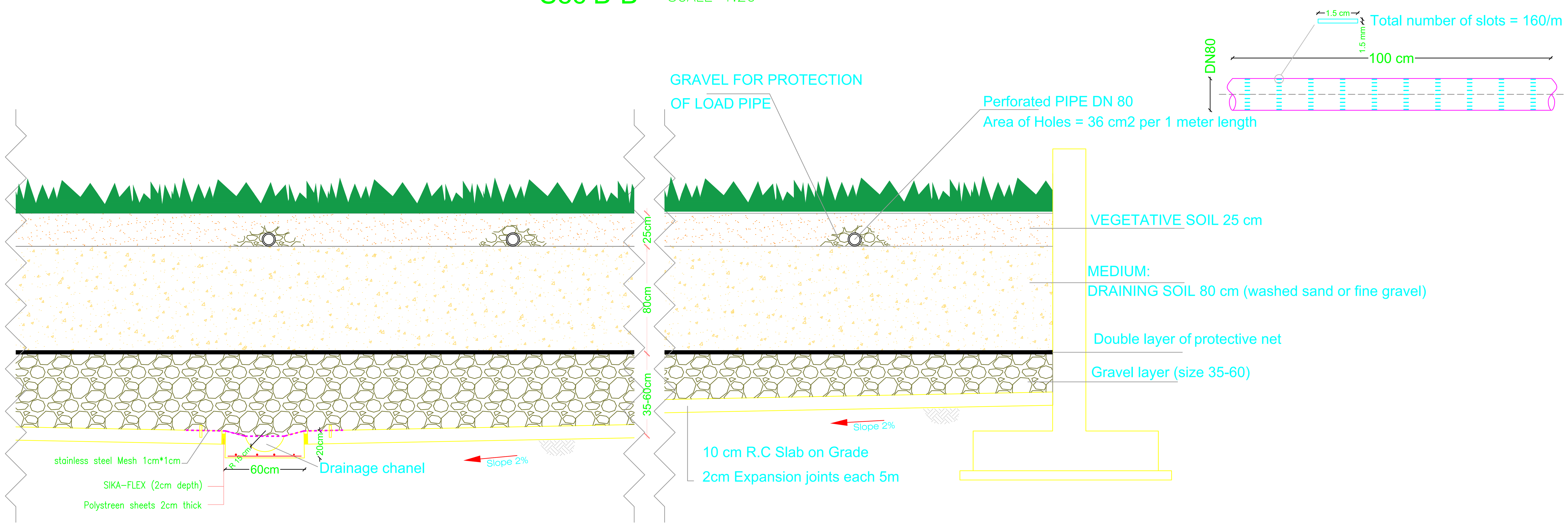
UAWC

Project Name:	Reuse of treated wastewater for agricultural use in Al-Mawasi district – Rafah Governorate – Gaza Strip
Project No :	11473/OVERSEAS/TOC
Drawing Title:	Mechanical/hydraulic details II
Design	
Checked	
Drawing NO.	M3
Scale:	As Shown
Date:	July 2020

REALIZZATO CON UN PRODOTTO AUTODESK VERSIONE PER STUDENTI







Sec. W-W in the Phytoremediation Lagoon

SCALE 1:20

Notes:

FUNDED BY

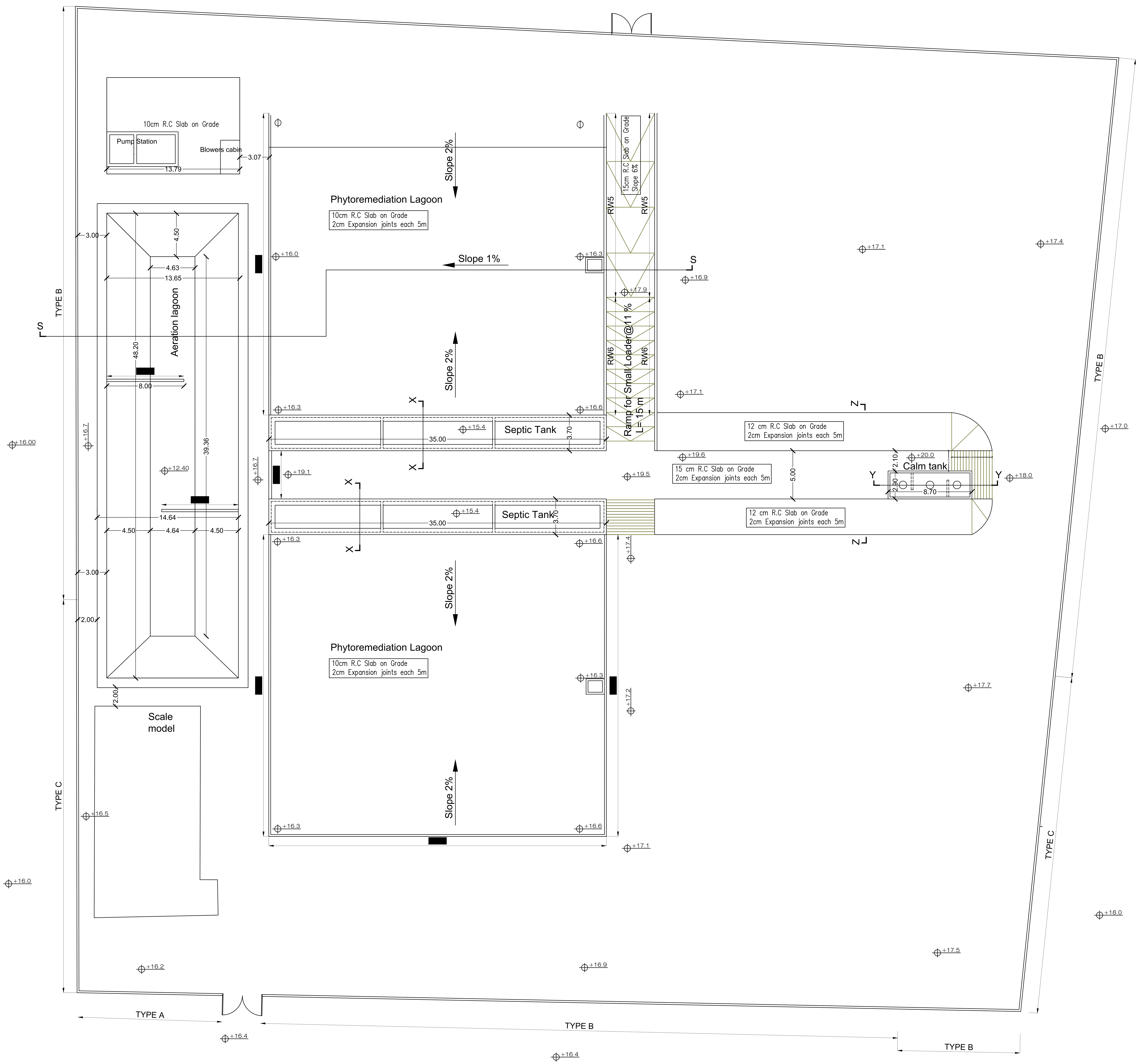
IMPLEMENTED BY

Project Name:
Reuse of treated wastewater for agricultural use in Al-Mawasi district – Rafah Governorate – Gaza Strip

Project No :
11473/OVERSEAS/TOC

Drawing Title:
Mechanical/hydraulic details III

Design	
Checked	
Drawing NO.	M4
Scale:	As Shown
Date:	July 2020



Notes:

FUNDED BY

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY

OVERSEAS

الكلية الجامعية للعلوم التطبيقية
University College of Applied Sciences

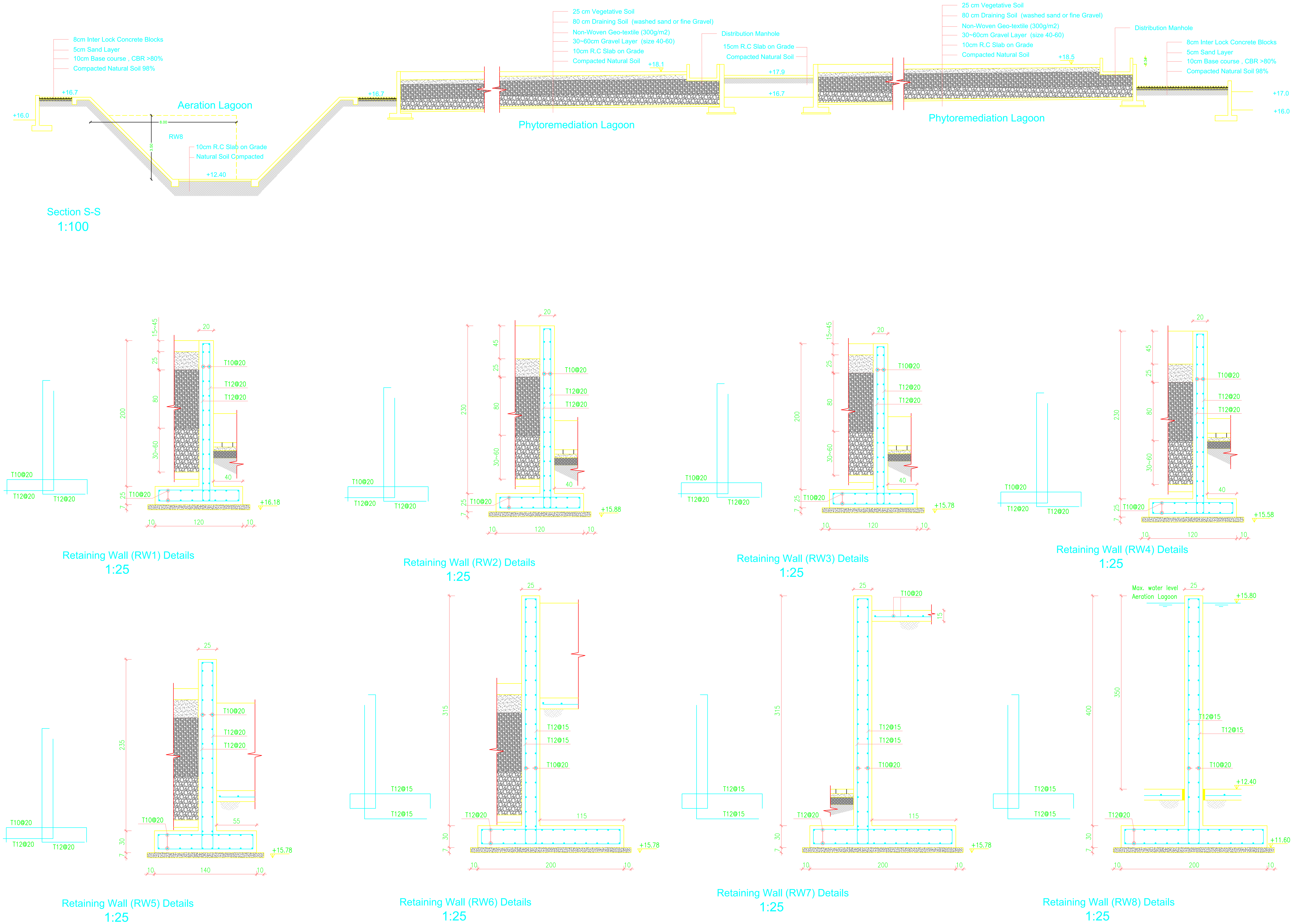
UAWC

Project Name:
Reuse of treated wastewater for agricultural use in Al-Mawasi district – Rafah Governorate – Gaza Strip

Project No :
11473/OVERSEAS/TOC

Drawing Title:
Arc. and Civil Plan

Design	
Checked	
Drawing NO.	C1
Scale:	As Shown
Date:	October 2020



Notes:

FUNDED BY

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY

OVERSEAS

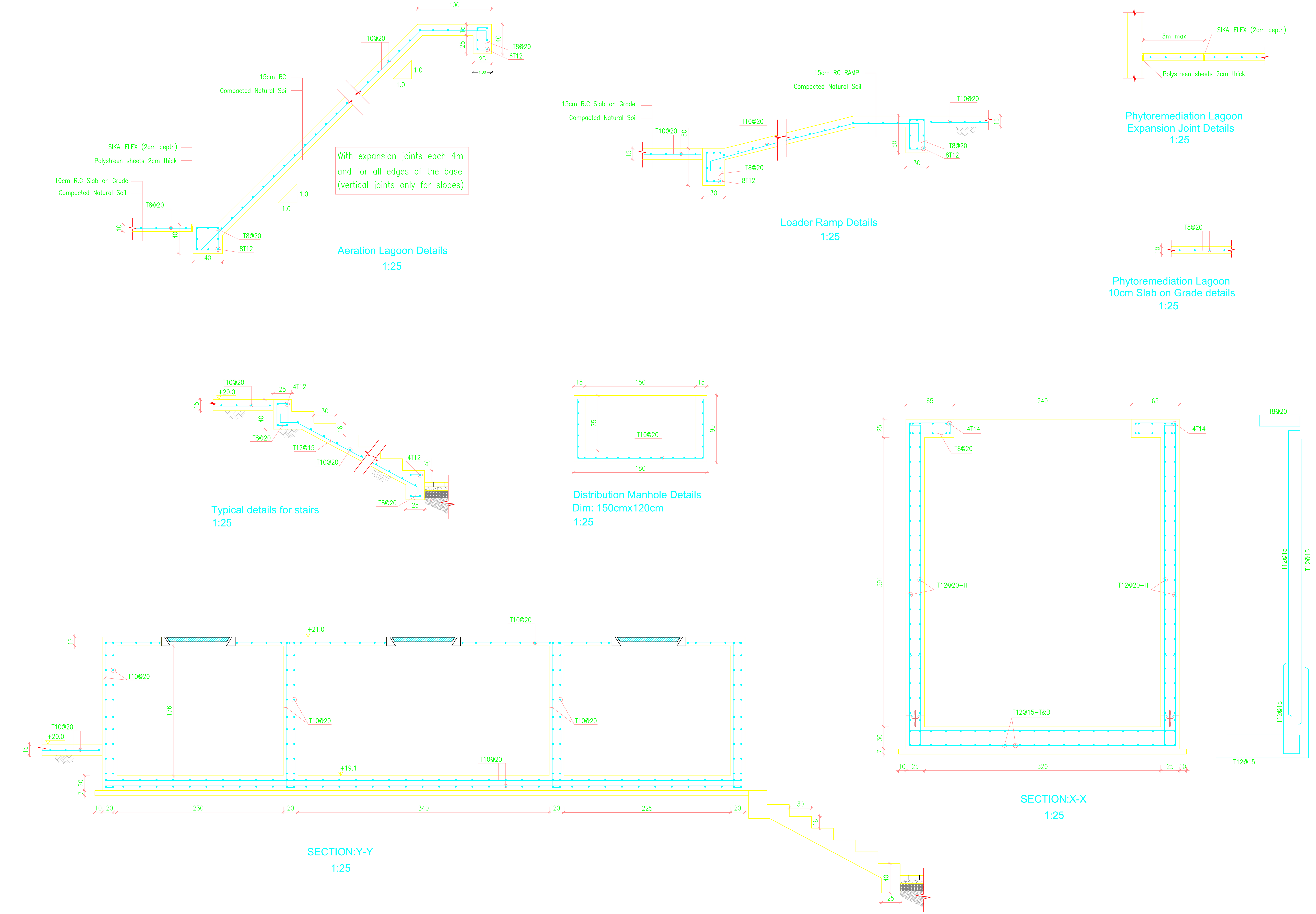
UAWC

Project Name:
Reuse of treated wastewater for agricultural use in Al-Mawasi district – Rafah Governorate – Gaza Strip

Project No :
11473/OVERSEAS/TOC

Drawing Title:
Civil Details I

Design	
Checked	
Drawing NO.	C2
Scale:	As Shown
Date:	July 2020



Notes:

FUNDED BY

IMPLEMENTED BY

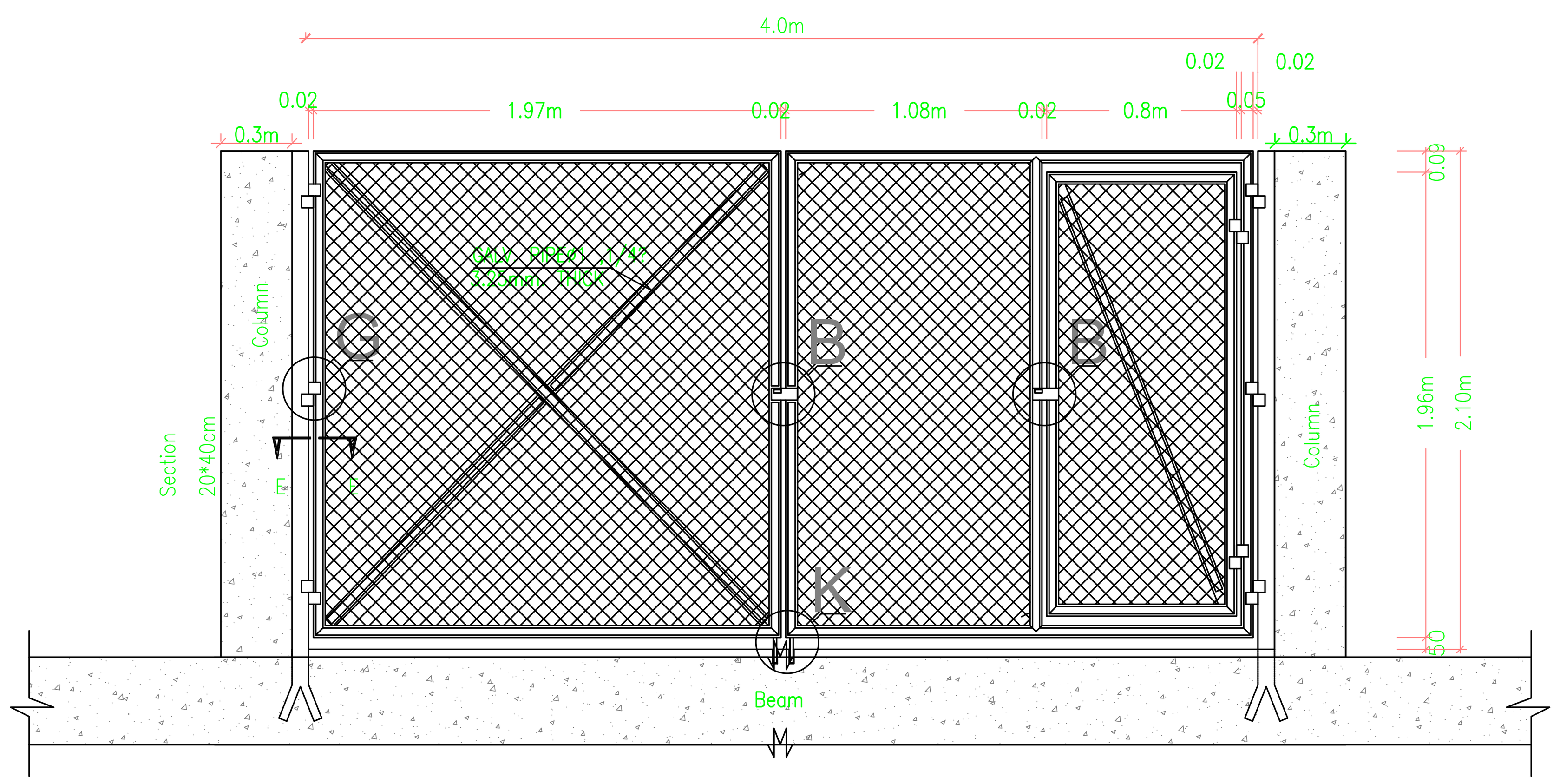
Project Name:
Reuse of treated wastewater for agricultural use in Al-Mawasi district – Rafah Governorate – Gaza Strip

Project No :
11473/OVERSEAS/TOC

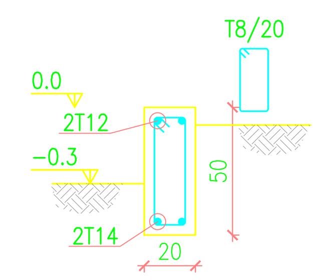
Drawing Title:
Civil Details II

Design	
Checked	
Drawing NO.	C3
Scale:	As Shown
Date:	July 2020

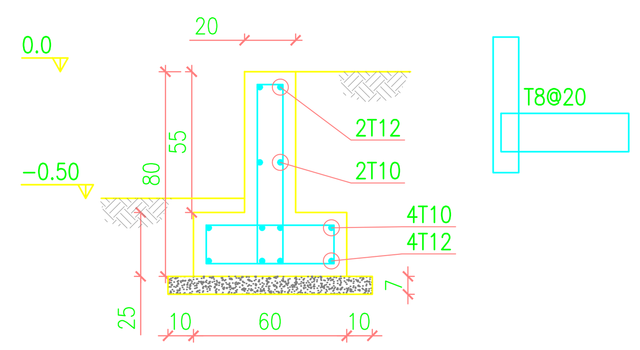
REALIZZATO CON UN PRODOTTO AUTODESK VERSIONE PER STUDENTI



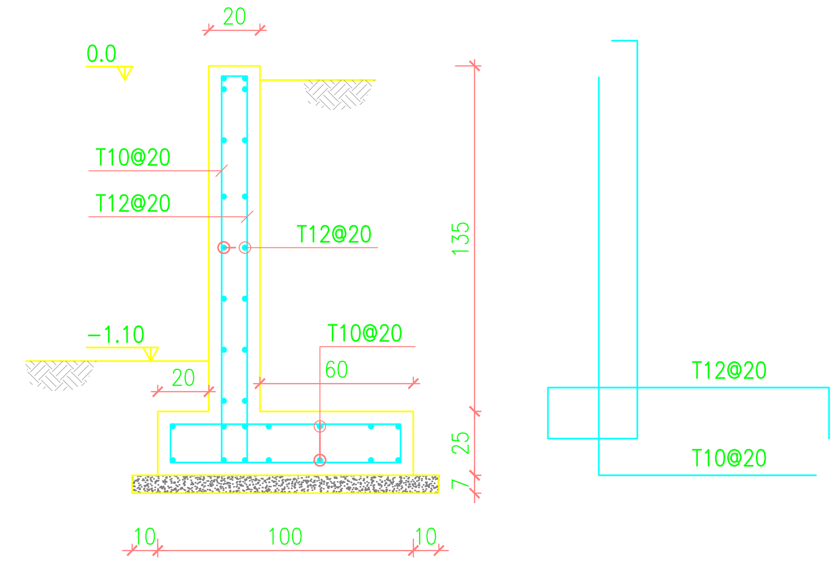
SECTION A-A
SCALE 1:20



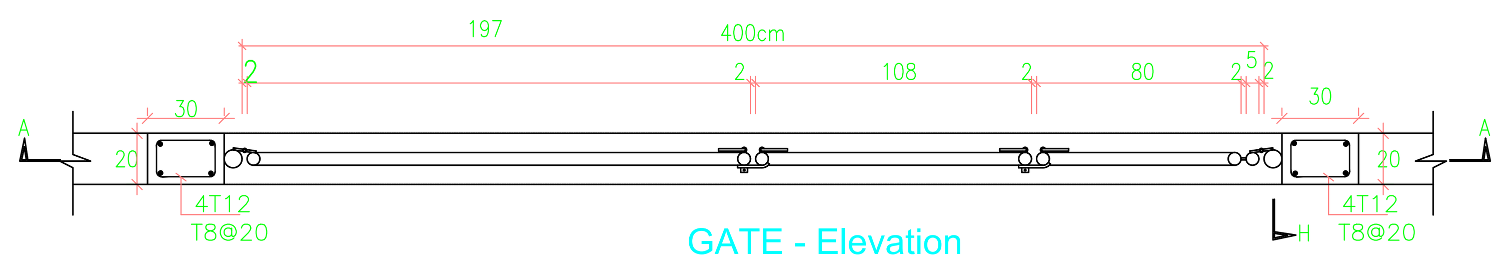
BOUNDARY WALL TYPE A DETAILS
1:25



BOUNDARY WALL TYPE C DETAILS
1:25

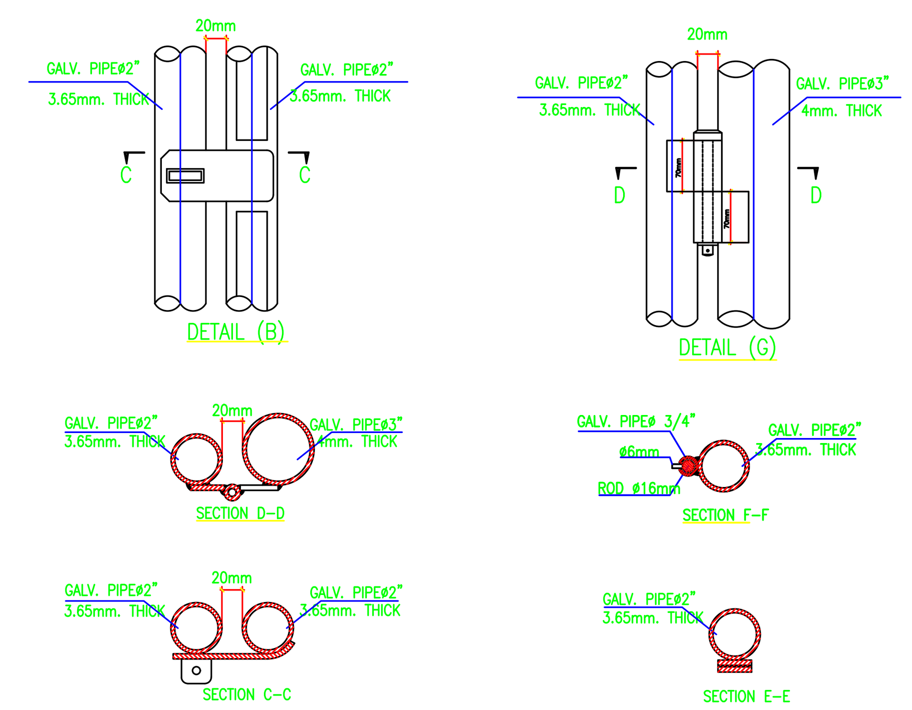


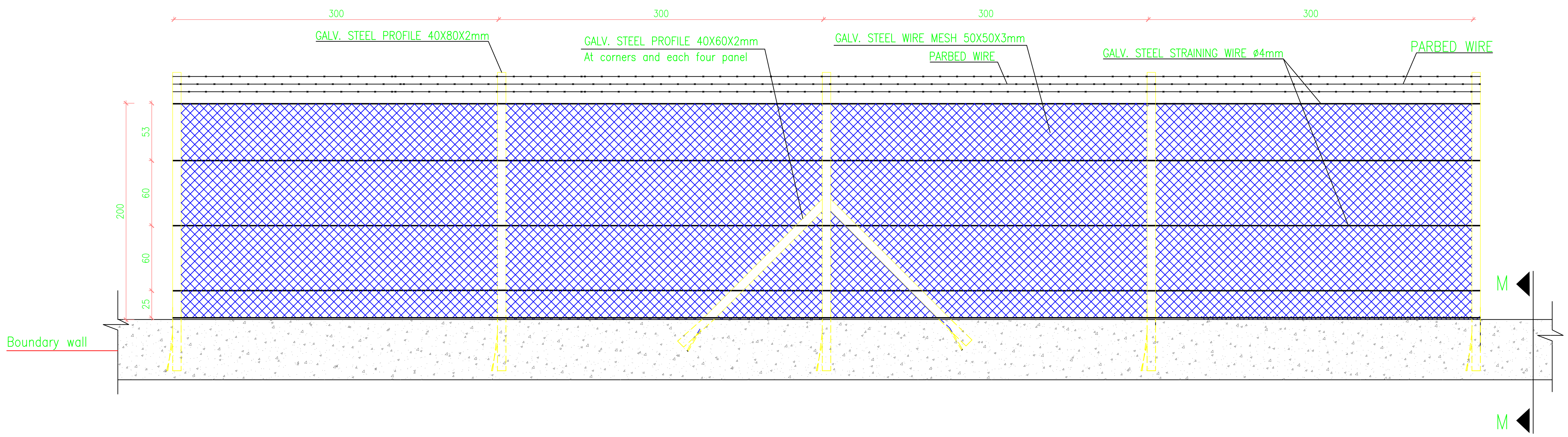
BOUNDARY WALL TYPE B DETAILS
1:25



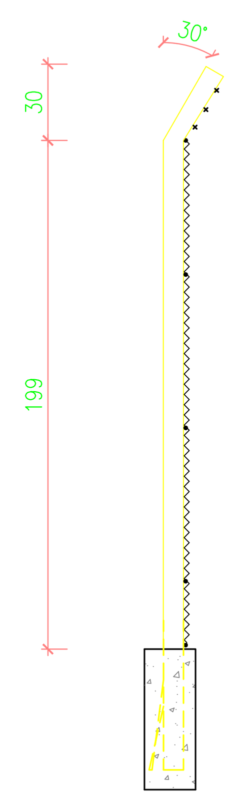
GATE - Elevation

Gate Fence & Details
NTS





Fence Elevation Detail
Scale 1:25



Section M-M
1:25

Notes:

FUNDED BY

IMPLEMENTED BY

Project Name:
Reuse of treated wastewater for agricultural use in Al-Mawasi district – Rafah Governorate – Gaza Strip

Project No :
11473/OVERSEAS/TOC

Drawing Title:
Civil Details III

Design	
Checked	
Drawing NO.	C4
Scale:	As Shown
Date:	July 2020

APPENDIX B1_DRAWING OF IRRIGATION NETWORK OF RAFAH, GAZA STRIP

FUNDED BY

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY

OVERSEAS

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

UAWC

CONSULTANT

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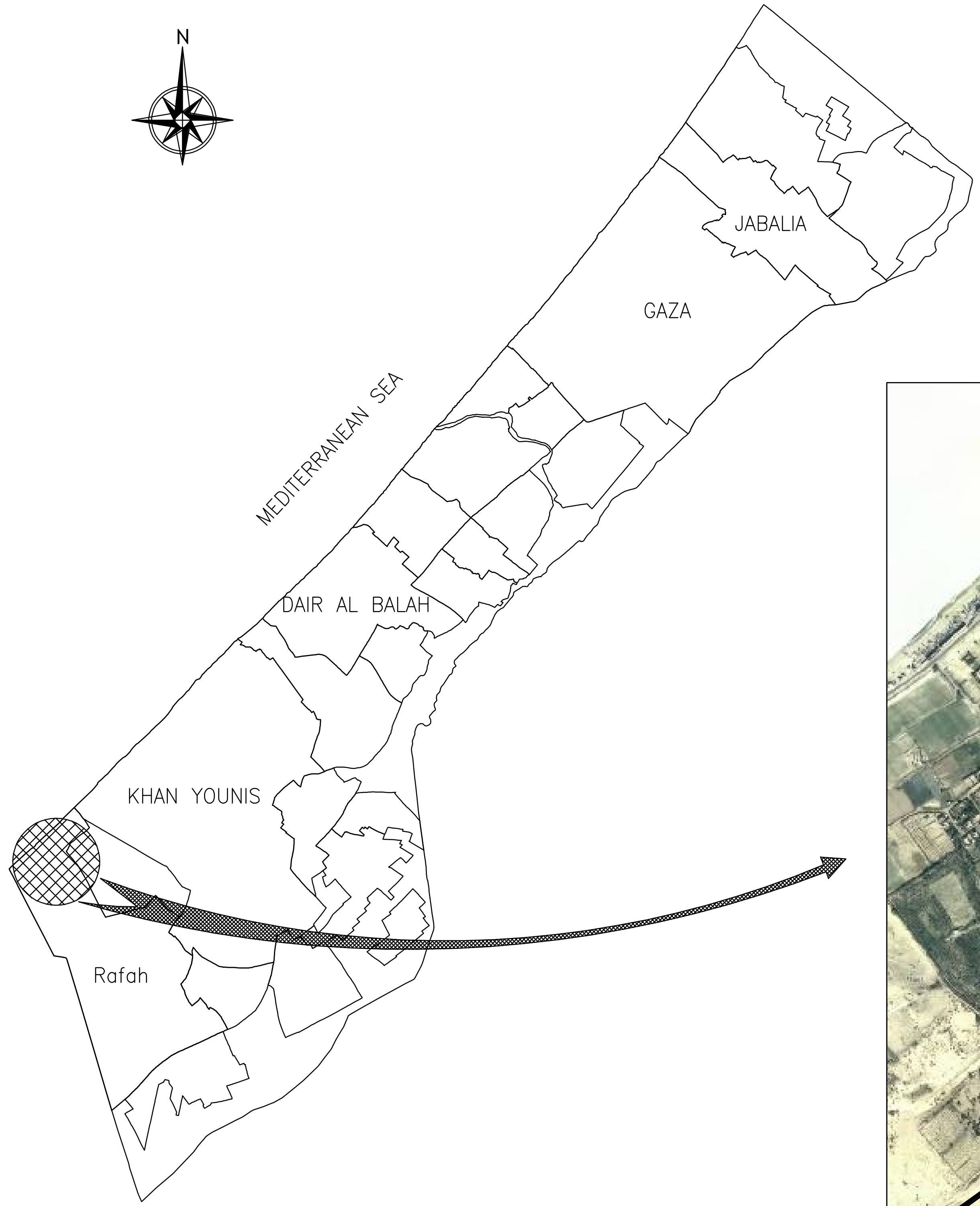
center for engineering and planning

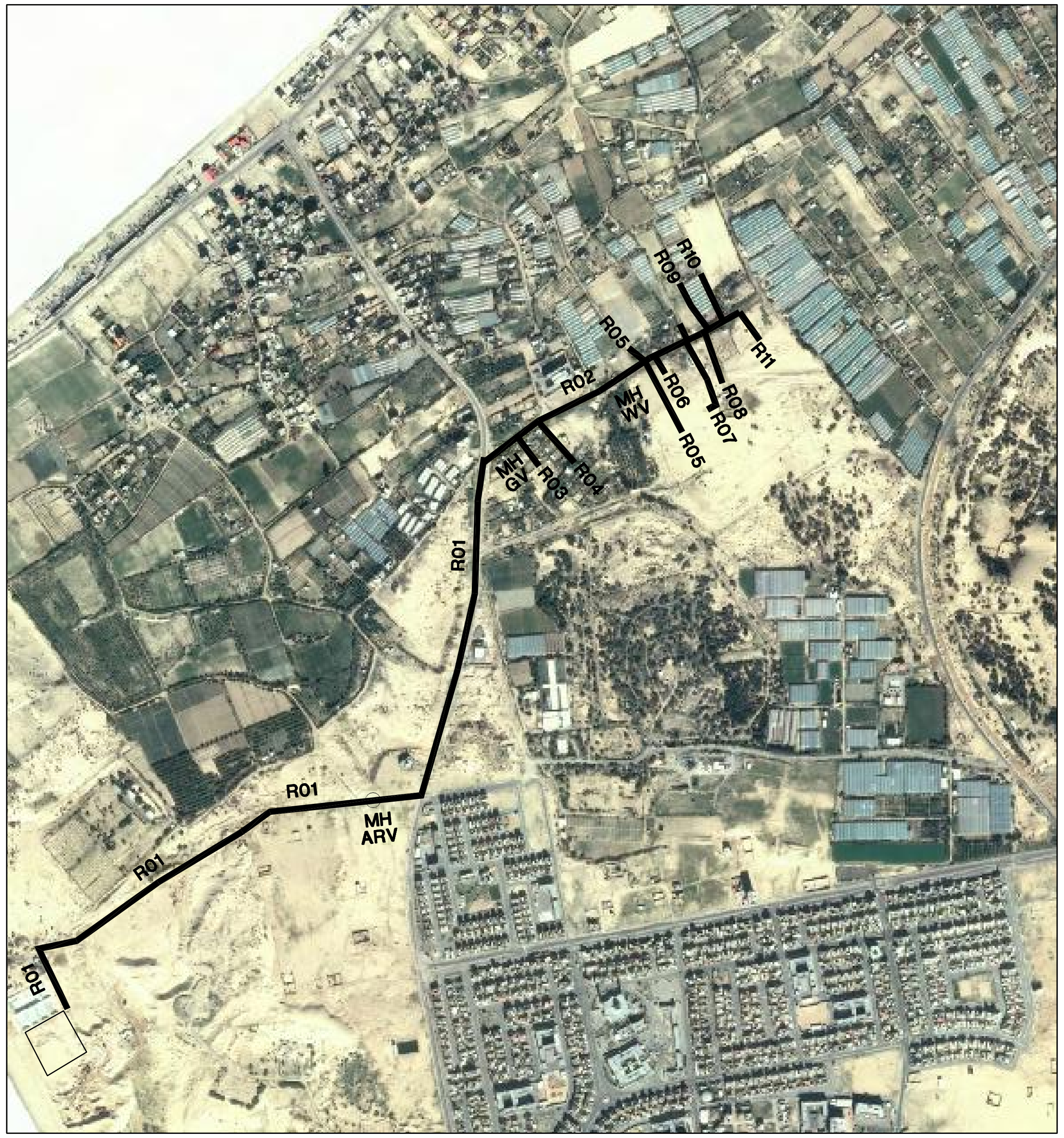
LIST OF DRAWINGS FOR CARRIER LINE

NO.	DRAWING NAME	DWG NO.
01	LOCATION MAPS FOR AL-MAWASI PROPOSED PIPES	CL-01
02	PLAN & PROFILE FOR ROAD R01 FROM St. 0 to St. 50	CL-02
03	PLAN & PROFILE FOR ROAD R01 FROM St. 50 to St. 100	CL-03
04	PLAN & PROFILE FOR ROAD R01 FROM St. 100 to St. 150	CL-04
05	PLAN & PROFILE FOR ROAD R01 FROM St. 150 to St. 163	CL-05
06	PLAN & PROFILE FOR ROAD R02 FROM St. 0 to St. 37	CL-06
07	PLAN & PROFILE FOR ROAD R02 FROM St. 37 to St. 64	CL-07
08	PLAN & PROFILE FOR ROAD R03 AND R04	CL-08
09	PLAN & PROFILE FOR ROAD R05 AND R06	CL-09
10	PLAN & PROFILE FOR ROAD R07 AND R08	CL-10
11	PLAN & PROFILE FOR ROAD R09 AND R10	CL-11
12	PLAN & PROFILE FOR ROAD R11	CL-12
13	GENERAL DETAILS (1/2)	CL-13
14	GENERAL DETAILS (2/2)	CL-14



GAZA STRIP VICINITY MAP

SCALE 1:1,000



AL-MAWASI LOCATION MAP

SCALE 1:1,000

NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS	
	GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
	ALL FLANGED TEE (T3)
	DOUBLE FLANGED TEE (T2)
	DOUBLE SOCKET TEE (T1)
	ALL SOCKET TEE (T)
	FLANGED COUPLING (FC)
	FLANGED SOCKET (FS)
	STRAIGHT COUPLING (SC)
	FLANGE REDUCER (FR)
	REDUCER (R)
	END CAP (C)
	BEND (B)
	AIR RELEASE VALVE (ARV)
	WASH VALVE (WV)
	FIRE HYDRANT (FH)

FOR TENDER ONLY

FUNDED BY:

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY:

OVERSEAS — ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA — UAWC

CONSULTANT:

مركز الهندسة والتخطيط
center for engineering and planning

PROJECT TITLE:

REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP

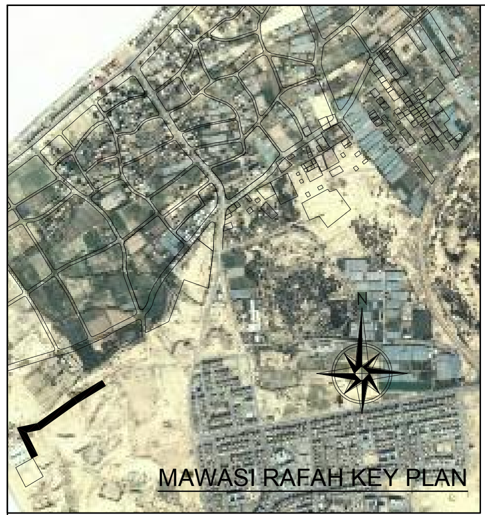
Project Code.: 11473/OVERSEAS

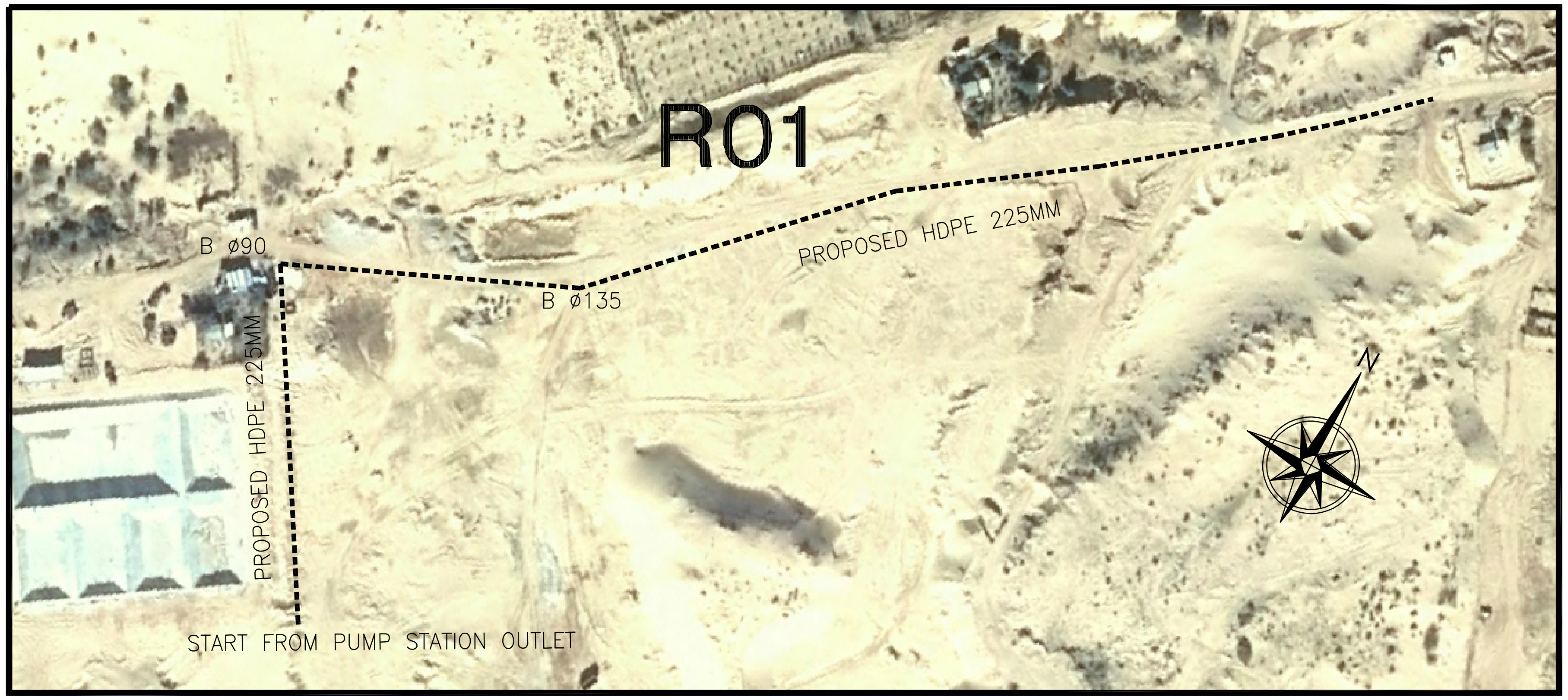
DRAWING TITLE:

LOCATION MAPS FOR AL-MAWASI PROPOSED PIPES

DRAWING NO.: CL-01

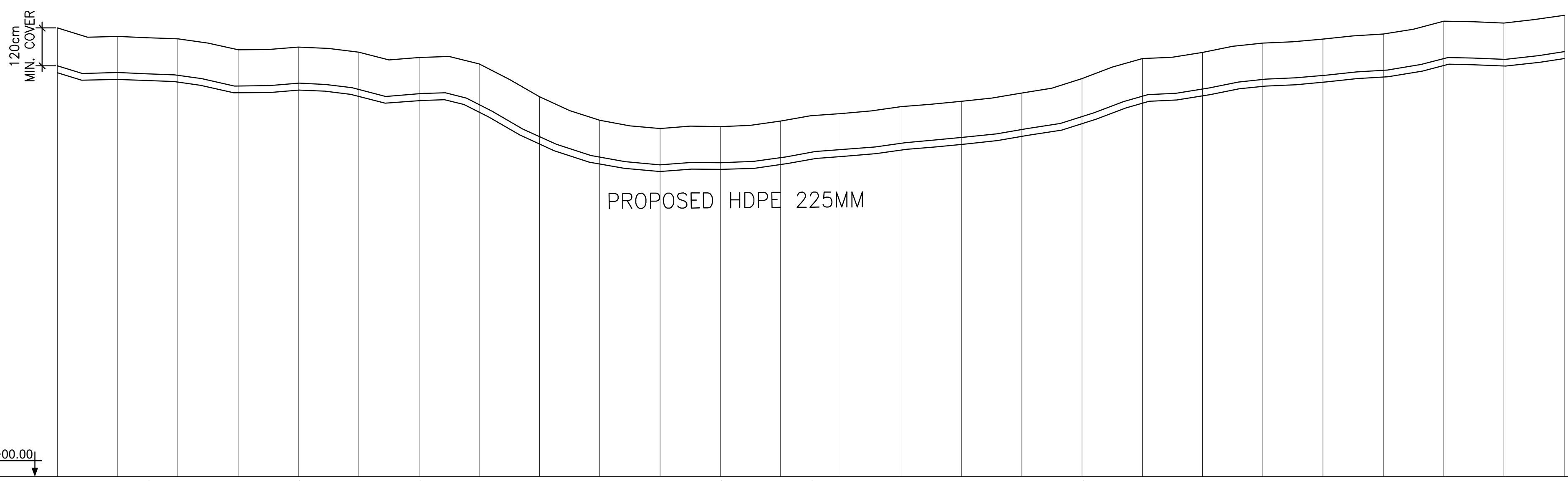
DATE:JULY 2020	SCALE: AS SHOWN





PLAN FOR R01 FROM St. 0 to St. 50

SCALE: 1:1000



EXISTING GROUND LEVEL	14.897	14.59	14.617	14.574	14.539	14.395	14.171	14.181	14.264	14.218	14.091	13.837	13.914
CUMULATIVE DISTANCE	0	10	20	30	40	50	60	70	80	90	100	110	120
STATION No.	ST.000	ST.001	ST.002	ST.003	ST.004	ST.005	ST.006	ST.007	ST.008	ST.009	ST.010	ST.011	ST.012

EXISTING GROUND LEVEL	13.951	13.699	13.19	12.61	12.151	11.829	11.646	11.557	11.635	11.624	11.662	11.803	11.984
CUMULATIVE DISTANCE	130	140	150	160	170	180	190	200	210	220	230	240	250
STATION No.	ST.013	ST.014	ST.015	ST.016	ST.017	ST.018	ST.019	ST.020	ST.021	ST.022	ST.023	ST.024	ST.025

EXISTING GROUND LEVEL	12.058	12.14	12.283	12.368	12.465	12.572	12.739	12.898	13.214	13.595	13.878	13.922	14.082
CUMULATIVE DISTANCE	260	270	280	290	300	310	320	330	340	350	360	370	380
STATION No.	ST.026	ST.027	ST.028	ST.029	ST.030	ST.031	ST.032	ST.033	ST.034	ST.035	ST.036	ST.037	ST.038

EXISTING GROUND LEVEL	14.291	14.391	14.436	14.529	14.633	14.697	14.858	15.12	15.102	15.06	15.171	15.32
CUMULATIVE DISTANCE	390	400	410	420	430	440	450	460	470	480	490	500
STATION No.	ST.039	ST.040	ST.041	ST.042	ST.043	ST.044	ST.045	ST.046	ST.047	ST.048	ST.049	ST.050

PROFILE FOR ROAD R01

NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS
GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
ALL FLANGED TEE (T3)
DOUBLE FLANGED TEE (T2)
DOUBLE SOCKET TEE (T1)
ALL SOCKET TEE (T)
FLANGED COUPLING (FC)
FLANGED SOCKET (FS)
STRAIGHT COUPLING (SC)
FLANGE REDUCER (FR)
REDUCER (R)
END CAP (C)
BEND (B)
AIR RELEASE VALVE (ARV)
WASH VALVE (WV)
FIRE HYDRANT (FH)

FOR TENDER ONLY

FUNDED BY:
ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY:
OVERSEAS
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA
UAWC

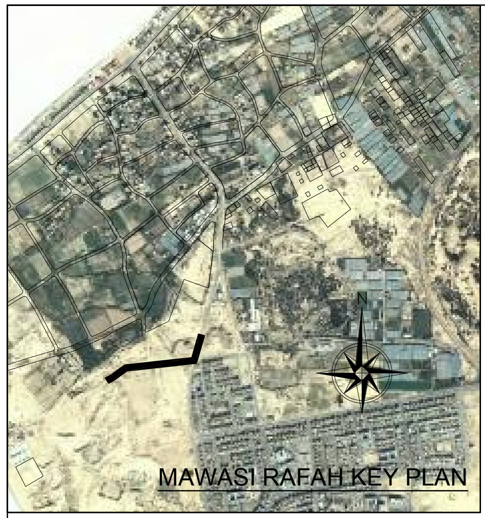
CONSULTANT:
مركز الهندسة والتخطيط
center for engineering and planning

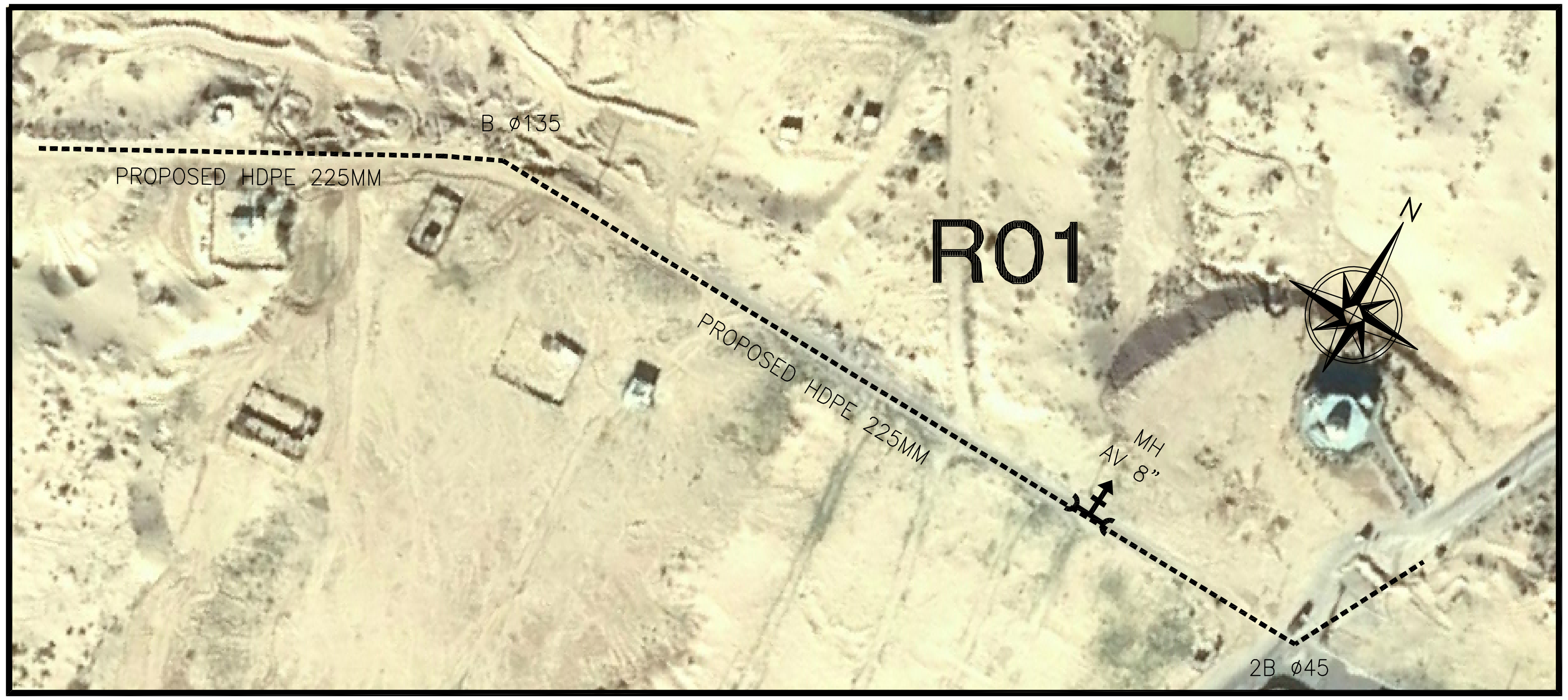
PROJECT TITLE:
REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP
Project Code.: 11473/OVERSEAS

DRAWING TITLE:
PLAN & PROFILE FOR ROAD R01 FROM St. 0 to St. 50

DRAWING NO.: CL-02

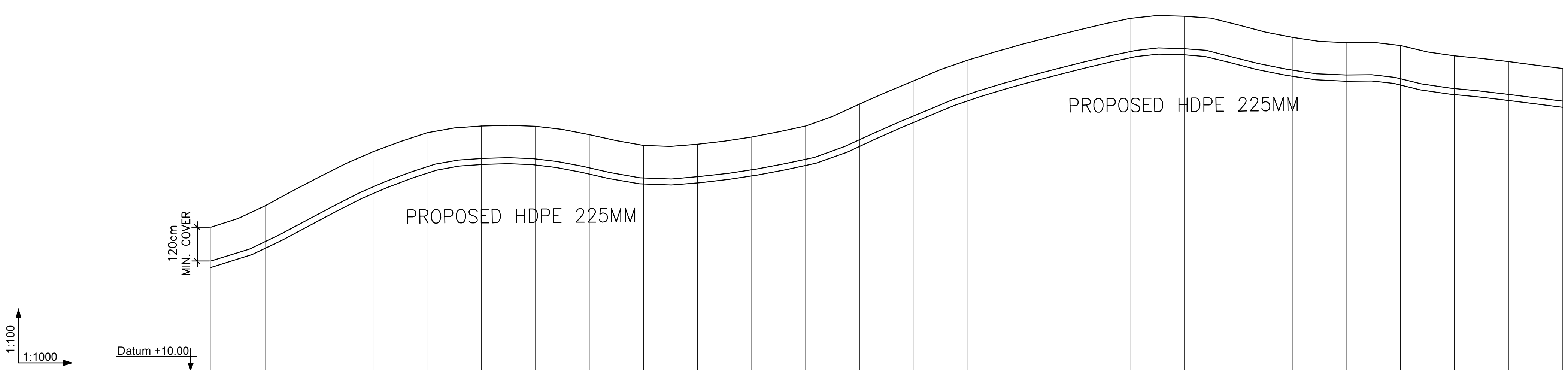
DATE: JULY 2020 | SCALE: AS SHOWN





PLAN FOR R01 FROM St. 50 to St. 100

SCALE: 1:1000



STATION No.	ST.050	ST.051	ST.052	ST.053	ST.054	ST.055	ST.056	ST.057	ST.058	ST.059	ST.060	ST.061	ST.062	ST.063	ST.064	ST.065	ST.066
EXISTING GROUND LEVEL	15.32	15.632	16.109	16.644	17.174	17.678	18.114	18.486	18.813	18.991	19.06	19.089	19.053	18.934	18.74	18.515	18.338
CUMULATIVE DISTANCE	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660

STATION No.	ST.067	ST.068	ST.069	ST.070	ST.071	ST.072	ST.073	ST.074	ST.075	ST.076	ST.077	ST.078	ST.079	ST.080	ST.081	ST.082	ST.083
EXISTING GROUND LEVEL	18.304	18.388	18.5	18.654	18.846	19.056	19.413	19.873	20.32	20.738	21.151	21.497	21.801	22.079	22.338	22.591	22.824
CUMULATIVE DISTANCE	670	680	690	700	710	720	730	740	750	760	770	780	790	800	810	820	830

STATION No.	ST.084	ST.085	ST.086	ST.087	ST.088	ST.089	ST.090	ST.091	ST.092	ST.093	ST.094	ST.095	ST.096	ST.097	ST.098	ST.099	ST.100
EXISTING GROUND LEVEL	23.041	23.148	23.122	23.045	22.797	22.538	22.338	22.191	22.145	22.152	22.039	21.801	21.652	21.557	21.44	21.31	21.186
CUMULATIVE DISTANCE	840	850	860	870	880	890	900	910	920	930	940	950	960	970	980	990	1000

PROFILE FOR ROAD R01

NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS
GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
ALL FLANGED TEE (T3)
DOUBLE FLANGED TEE (T2)
DOUBLE SOCKET TEE (T1)
ALL SOCKET TEE (T)
FLANGED COUPLING (FC)
FLANGED SOCKET (FS)
STRAIGHT COUPLING (SC)
FLANGE REDUCER (FR)
REDUCER (R)
END CAP (C)
BEND (B)
AIR RELEASE VALVE (ARV)
WASH VALVE (WV)
FIRE HYDRANT (FH)

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FUNDED BY:

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY:

OVERSEAS — ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA — UAWC

CONSULTANT:

مركز الهندسة والتخطيط
center for engineering and planning

PROJECT TITLE:

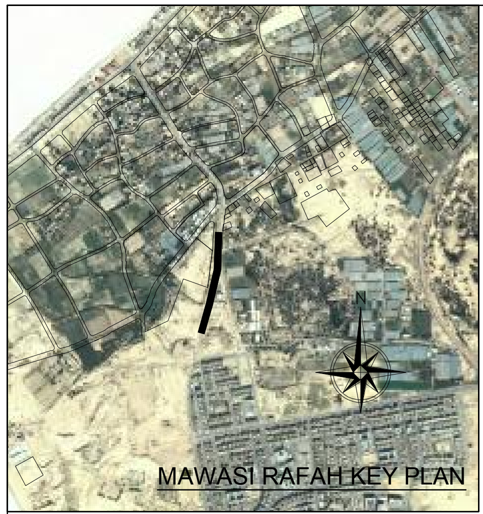
REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP

Project Code.: 11473/OVERSEAS

DRAWING TITLE:
PLAN & PROFILE FOR ROAD R01
FROM St. 50 to St. 100

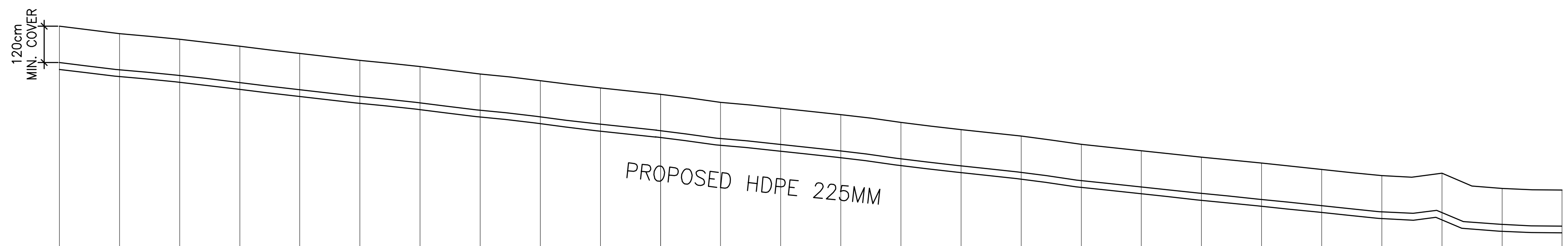
DRAWING NO.: CL-03

DATE:JULY 2020 | SCALE: AS SHOWN



PLAN FOR R01 FROM St. 100 to St. 150

SCALE: 1:1000



EXISTING GROUND LEVEL	21.186	21.062	20.941	20.851	20.752	20.64	20.517	20.399	20.28	20.163	2ST.53	19.95	19.847
CUMULATIVE DISTANCE	1000	1010	1020	1030	1040	1050	1060	1070	1080	1090	1100	1110	1120
STATION No.	ST.100	ST.101	ST.102	ST.103	ST.104	ST.105	ST.106	ST.107	ST.108	ST.109	ST.110	ST.111	ST.112

EXISTING GROUND LEVEL	19.722	19.599	19.498	19.377	19.245	19.129	19.023	18.917	18.795	18.652	18.567	18.459	18.35
CUMULATIVE DISTANCE	1130	1140	1150	1160	1170	1180	1190	1200	1210	1220	1230	1240	1250
STATION No.	ST.113	ST.114	ST.115	ST.116	ST.117	ST.118	ST.119	ST.120	ST.121	ST.122	ST.123	ST.124	ST.125

EXISTING GROUND LEVEL	18.244	18.125	17.986	17.857	17.749	17.642	17.535	17.401	17.259	17.151	17.046	16.936	16.827
CUMULATIVE DISTANCE	1260	1270	1280	1290	1300	1310	1320	1330	1340	1350	1360	1370	1380
STATION No.	ST.126	ST.127	ST.128	ST.129	ST.130	ST.131	ST.132	ST.133	ST.134	ST.135	ST.136	ST.137	ST.138

EXISTING GROUND LEVEL	16.73	16.63	16.524	16.42	16.317	16.215	16.162	16.292	15.864	15.79	15.746	15.738
CUMULATIVE DISTANCE	1390	1400	1410	1420	1430	1440	1450	1460	1470	1480	1490	1500
STATION No.	ST.139	ST.140	ST.141	ST.142	ST.143	ST.144	ST.145	ST.146	ST.147	ST.148	ST.149	ST.150

PROFILE FOR ROAD R01

NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS
GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
ALL FLANGED TEE (T3)
DOUBLE FLANGED TEE (T2)
DOUBLE SOCKET TEE (T1)
ALL SOCKET TEE (T)
FLANGED COUPLING (FC)
FLANGED SOCKET (FS)
STRAIGHT COUPLING (SC)
FLANGE REDUCER (FR)
REDUCER (R)
END CAP (C)
BEND (B)
AIR RELEASE VALVE (ARV)
WASH VALVE (WV)
FIRE HYDRANT (FH)

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FUNDED BY:
ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY:
OVERSEAS
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA
UAWC

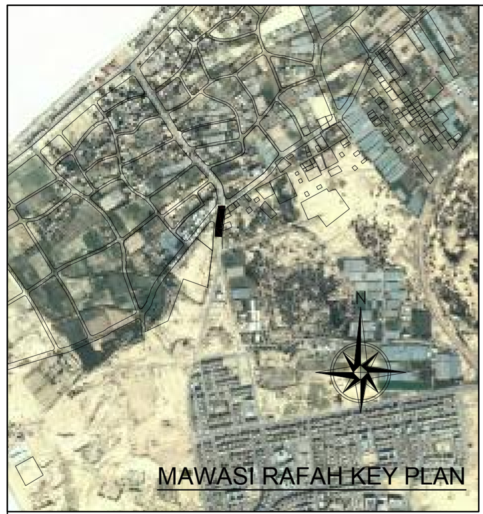
CONSULTANT:
مركز الهندسة والتخطيط
center for engineering and planning

PROJECT TITLE:
REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP
Project Code.: 11473/OVERSEAS

DRAWING TITLE:
PLAN & PROFILE FOR ROAD R01 FROM St. 100 to St. 150

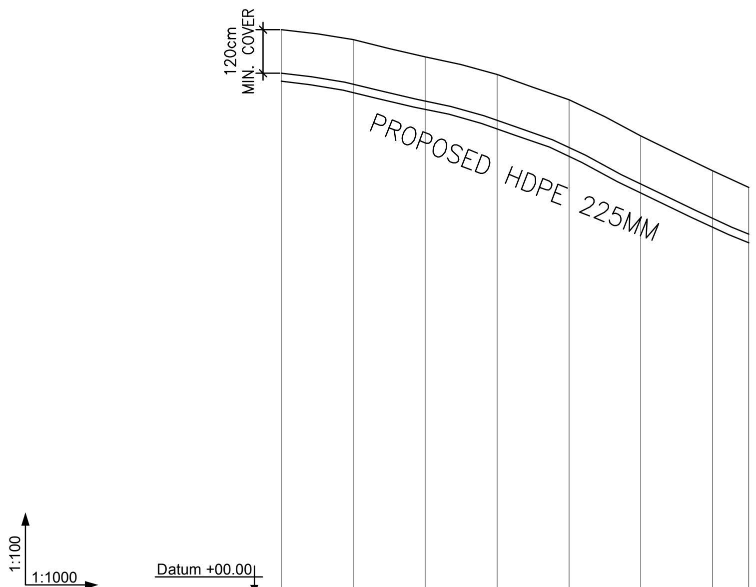
DRAWING NO.: CL-04

DATE:JULY 2020 | SCALE: AS SHOWN



PLAN FOR R01 FROM St. 150 to St. 163

SCALE: 1:1000



EXISTING GROUND LEVEL	15.738	15.617	15.456	15.211	14.977	14.77	14.487	14.137	13.789	13.317	12.779	12.294	11.811	11.352
CUMULATIVE DISTANCE	1500	1510	1520	1530	1540	1550	1560	1570	1580	1590	1600	1610	1620	1630
STATION No.	ST.150	ST.151	ST.152	ST.153	ST.154	ST.155	ST.156	ST.157	ST.158	ST.159	ST.160	ST.161	ST.162	ST.163

PROFILE FOR ROAD R01

NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS
GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
ALL FLANGED TEE (T3)
DOUBLE FLANGED TEE (T2)
DOUBLE SOCKET TEE (T1)
ALL SOCKET TEE (T)
FLANGED COUPLING (FC)
FLANGED SOCKET (FS)
STRAIGHT COUPLING (SC)
FLANGE REDUCER (FR)
REDUCER (R)
END CAP (C)
BEND (B)
AIR RELEASE VALVE (ARV)
WASH VALVE (WV)
FIRE HYDRANT (FH)

FOR TENDER ONLY

FUNDED BY:

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY:

OVERSEAS

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

UAWC

CONSULTANT:

center for engineering and planning

PROJECT TITLE:

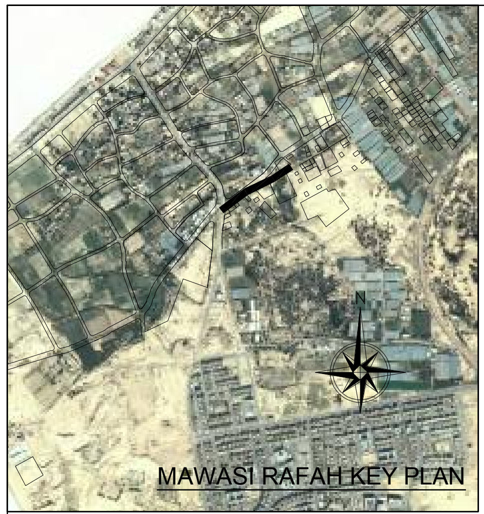
REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP

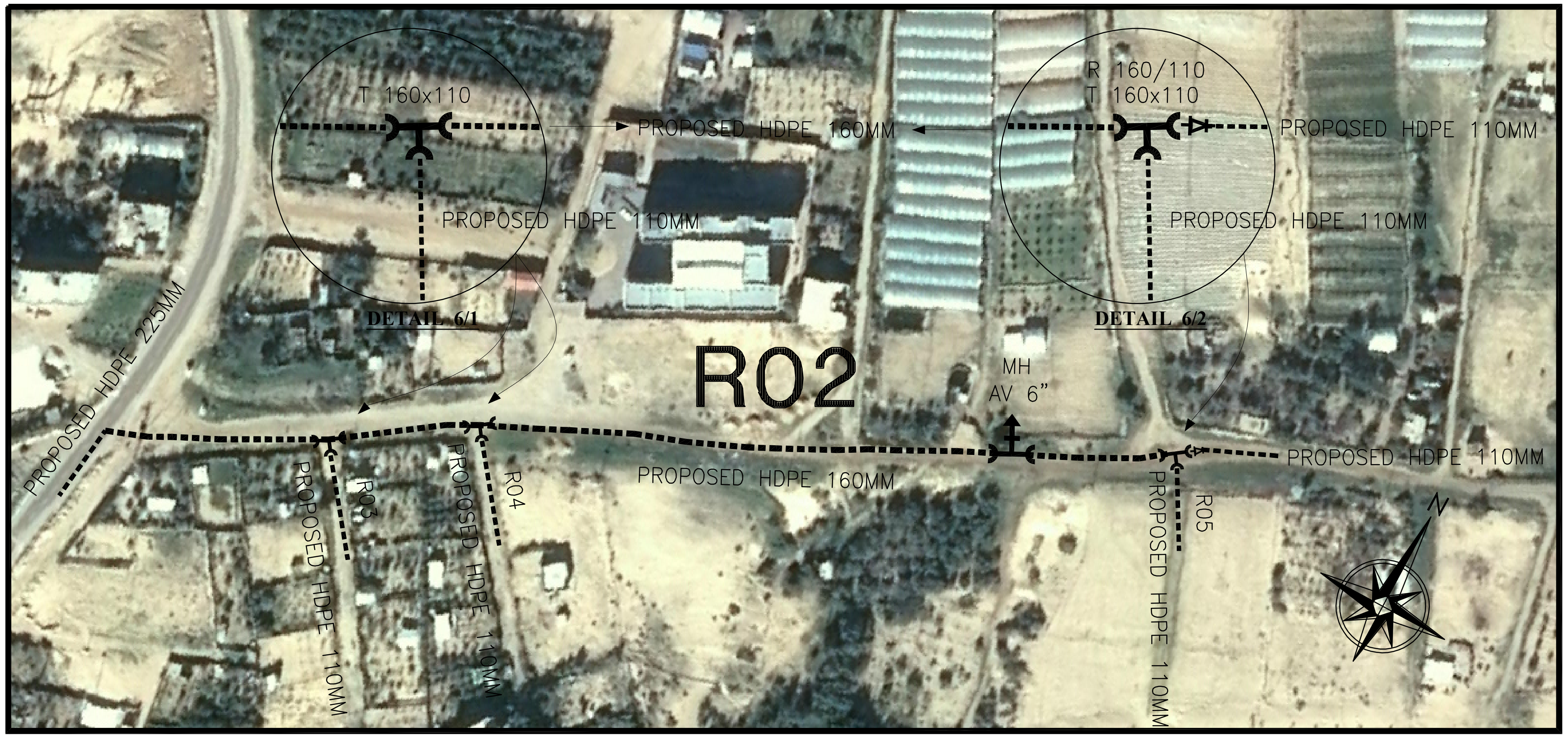
Project Code.: 11473/OVERSEAS

DRAWING TITLE:
PLAN & PROFILE FOR ROAD R01 FROM St. 150 to St. 163

DRAWING NO.: CL-05

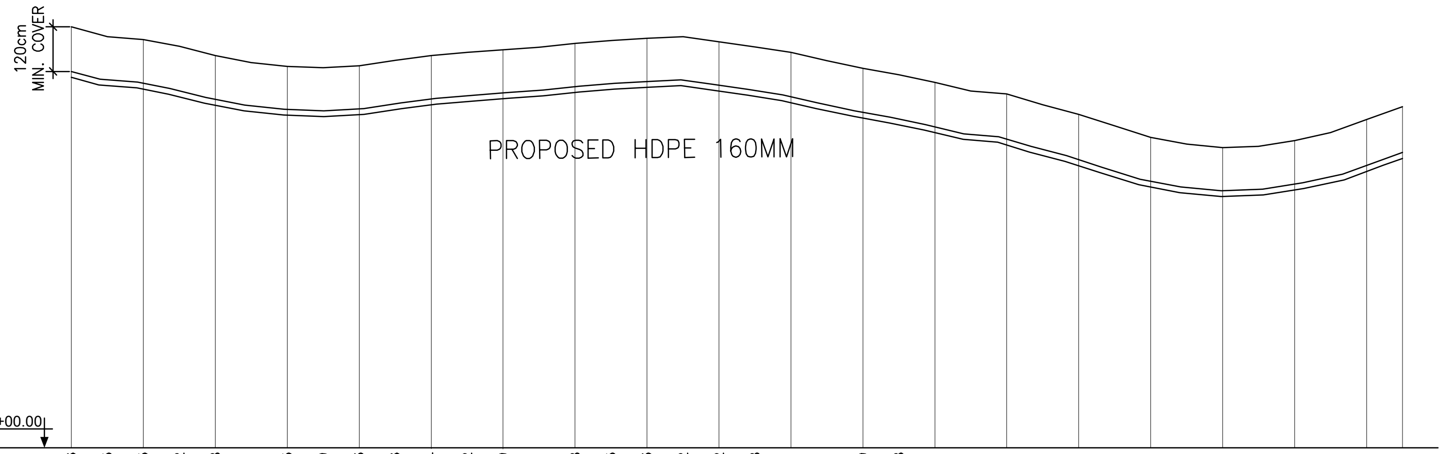
DATE: JULY 2020 | SCALE: AS SHOWN





PLAN FOR R02 FROM St. 0 to St. 37

SCALE: 1:1000



	ST.00	ST.01	ST.02	ST.03	ST.04	ST.05	ST.06	ST.07	ST.08	ST.09	ST.10	ST.11	ST.12	ST.13	ST.14	ST.15	ST.16	ST.17	ST.18
EXISTING GROUND LEVEL	11.716	11.445	11.365	11.172	10.918	10.721	10.615	10.579	10.633	10.786	10.914	11.002	11.079	11.151	11.258	11.335	11.393	11.442	11.302
CUMULATIVE DISTANCE	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
STATION No.	ST.00	ST.01	ST.02	ST.03	ST.04	ST.05	ST.06	ST.07	ST.08	ST.09	ST.10	ST.11	ST.12	ST.13	ST.14	ST.15	ST.16	ST.17	ST.18

	ST.19	ST.20	ST.21	ST.22	ST.23	ST.24	ST.25	ST.26	ST.27	ST.28	ST.29	ST.30	ST.31	ST.32	ST.33	ST.34	ST.35	ST.36	ST.37
EXISTING GROUND LEVEL	11.158	11.001	10.77	10.559	10.378	10.17	9.928	9.846	9.543	9.281	8.955	8.64	8.448	8.357	8.391	8.552	8.768	9.14	9.492
CUMULATIVE DISTANCE	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370
STATION No.	ST.19	ST.20	ST.21	ST.22	ST.23	ST.24	ST.25	ST.26	ST.27	ST.28	ST.29	ST.30	ST.31	ST.32	ST.33	ST.34	ST.35	ST.36	ST.37

PROFILE FOR ROAD R02

NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS

- GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
- ALL FLANGED TEE (T3)
- DOUBLE FLANGED TEE (T2)
- DOUBLE SOCKET TEE (T1)
- ALL SOCKET TEE (T)
- FLANGED COUPLING (FC)
- FLANGED SOCKET (FS)
- STRAIGHT COUPLING (SC)
- FLANGE REDUCER (FR)
- REDUCER (R)
- END CAP (C)
- BEND (B)
- AIR RELEASE VALVE (ARV)
- WASH VALVE (WV)
- FIRE HYDRANT (FH)

FOR TENDER ONLY

FUNDED BY:

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY:

OVERSEAS
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA
UAWC

CONSULTANT:

مركز الهندسة والتخطيط
center for engineering and planning

PROJECT TITLE:

REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP

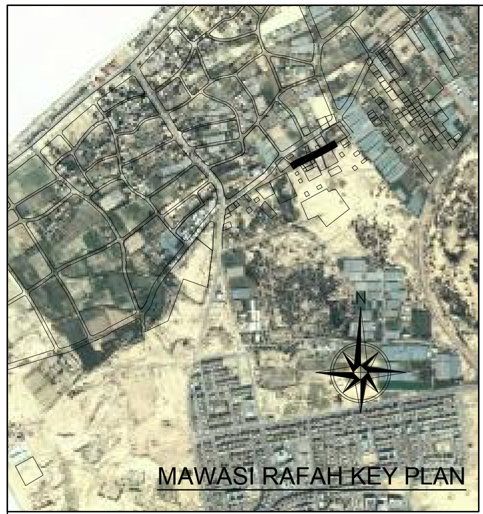
Project Code.: 11473/OVERSEAS

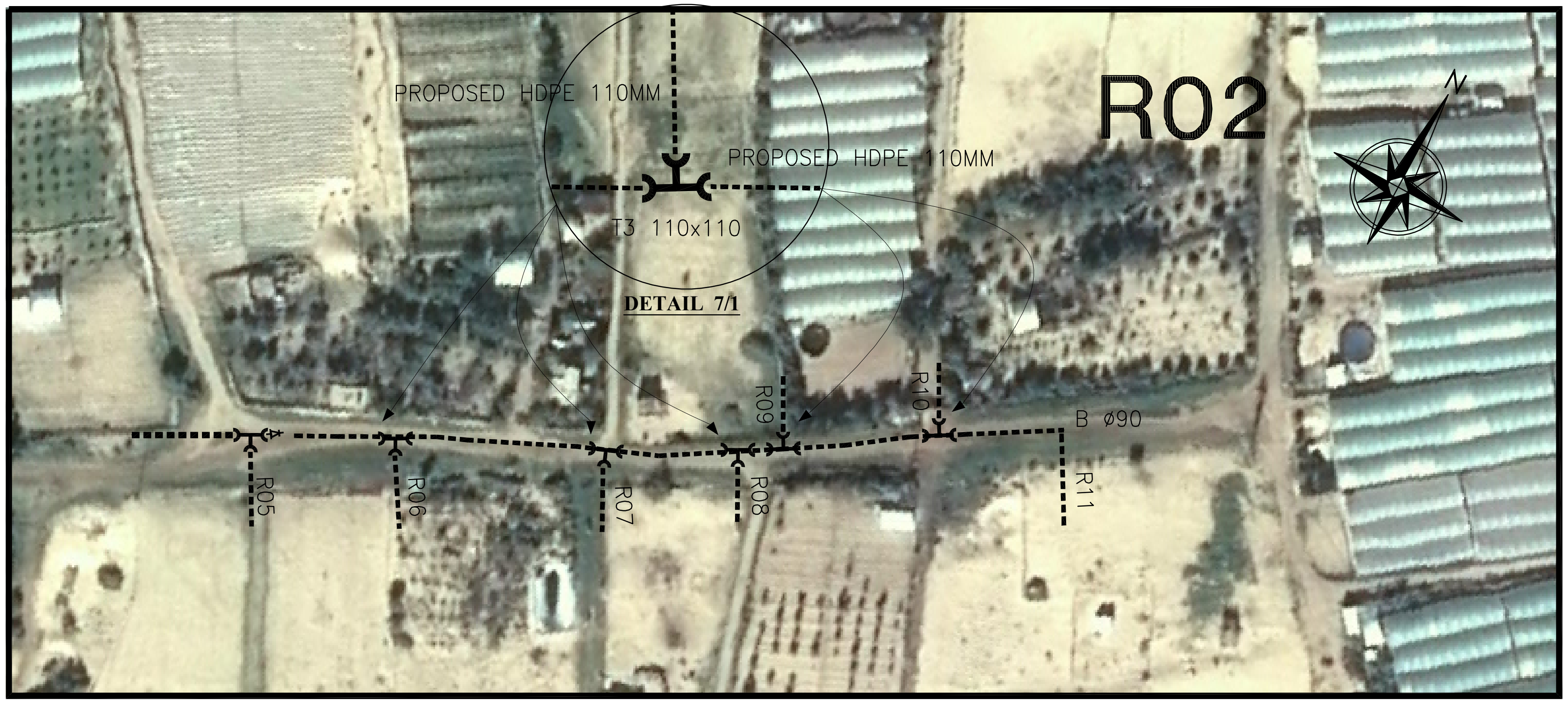
DRAWING TITLE:

PLAN & PROFILE FOR ROAD R02 FROM St. 0 to St. 37

DRAWING NO.: CL-06

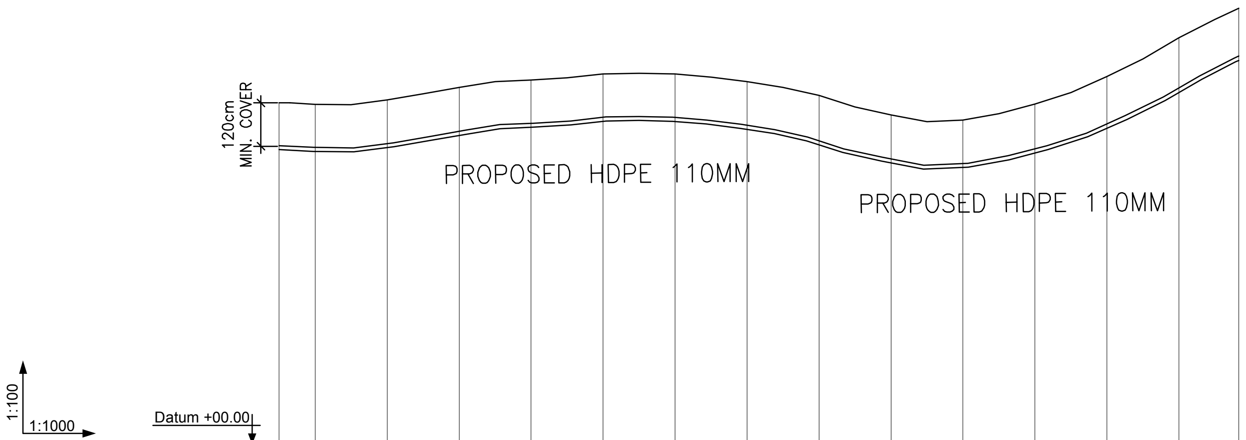
DATE: JULY 2020 | SCALE: AS SHOWN





PLAN FOR R02 FROM St. 37 to St. 64

SCALE: 1:1000



EXISTING GROUND LEVEL	9.492	9.438	9.425	9.557	9.731	9.902	10.066	10.11	10.171	10.282	10.298	10.275	10.192	10.068
CUMULATIVE DISTANCE	370	380	390	400	410	420	430	440	450	460	470	480	490	500
STATION No.	ST.37	ST.38	ST.39	ST.40	ST.41	ST.42	ST.43	ST.44	ST.45	ST.46	ST.47	ST.48	ST.49	ST.50

EXISTING GROUND LEVEL	9.909	9.685	9.361	9.14	8.953	8.994	9.179	9.442	9.761	10.206	10.698	11.281	11.789	12.103
CUMULATIVE DISTANCE	510	520	530	540	550	560	570	580	590	600	610	620	630	636.63
STATION No.	ST.51	ST.52	ST.53	ST.54	ST.55	ST.56	ST.57	ST.58	ST.59	ST.60	ST.61	ST.62	ST.63	ST.64

PROFILE FOR ROAD R02

NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS

- GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
- ALL FLANGED TEE (T3)
- DOUBLE FLANGED TEE (T2)
- DOUBLE SOCKET TEE (T1)
- ALL SOCKET TEE (T)
- FLANGED COUPLING (FC)
- FLANGED SOCKET (FS)
- STRAIGHT COUPLING (SC)
- FLANGE REDUCER (FR)
- REDUCER (R)
- END CAP (C)
- BEND (B)
- AIR RELEASE VALVE (ARV)
- WASH VALVE (WV)
- FIRE HYDRANT (FH)

FOR TENDER ONLY

FUNDED BY: ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY: OVERSEAS; ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA; UAWC

CONSULTANT: مركز الهندسة والتخطيط center for engineering and planning

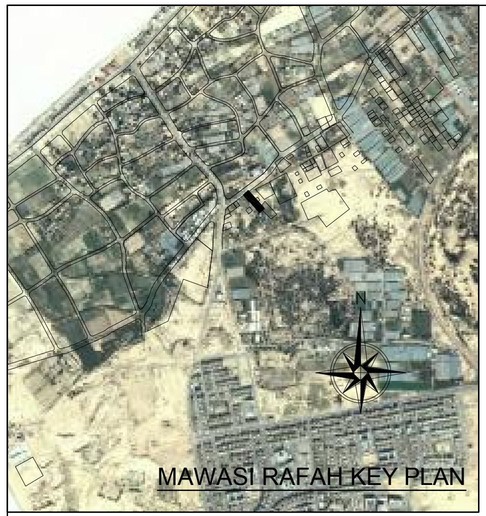
PROJECT TITLE:
REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP

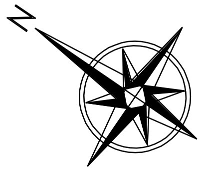
Project Code.: 11473/OVERSEAS

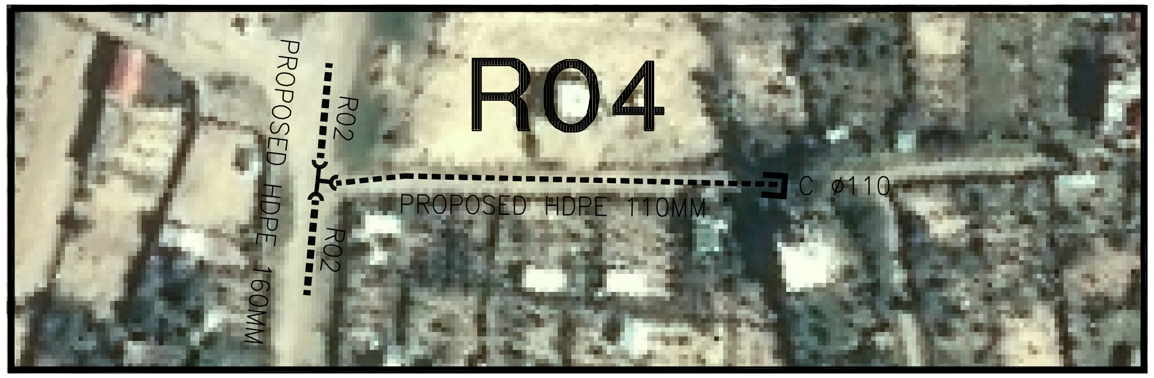
DRAWING TITLE:
PLAN & PROFILE FOR ROAD R02 FROM St. 37 to St. 64

DRAWING NO.: CL-07

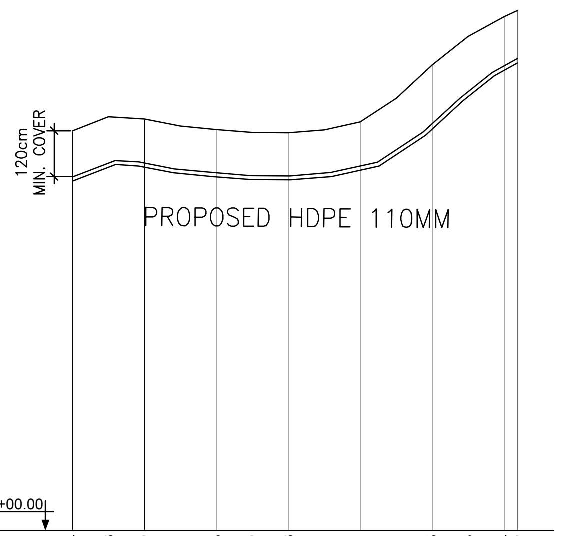
DATE: JULY 2020 | SCALE: AS SHOWN





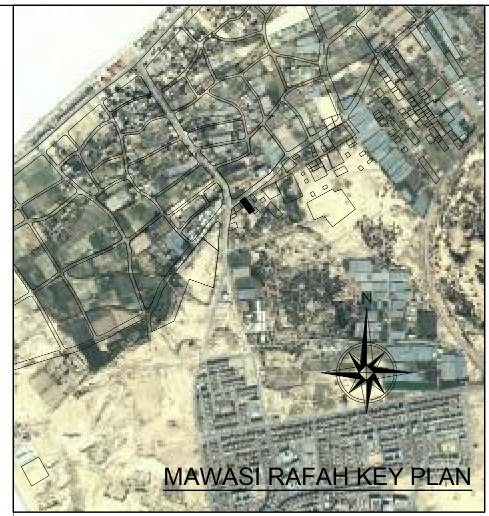


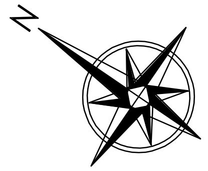
PLAN FOR R04
SCALE: 1:1000

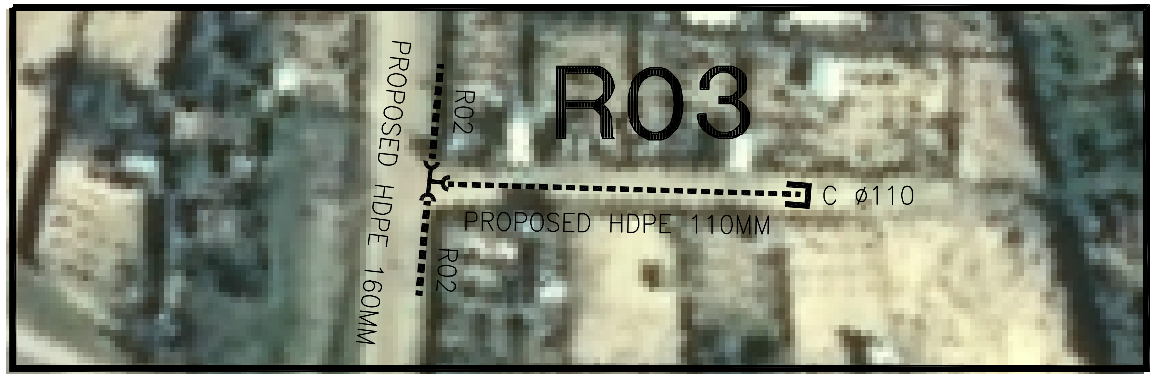


EXISTING GROUND LEVEL	11.114	11.498	11.439	11.241	11.146	11.069	11.058	11.14	11.361	12.021	12.943	13.736	14.284	14.459
CUMULATIVE DISTANCE	0	10	20	30	40	50	60	70	80	90	100	110	120	123.68
STATION No.	ST.00	ST.01	ST.02	ST.03	ST.04	ST.05	ST.06	ST.07	ST.08	ST.09	ST.10	ST.11	ST.12	ST.13

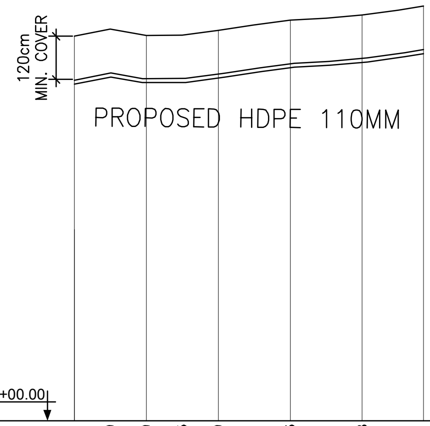
PROFILE FOR ROAD R04







PLAN FOR R03
SCALE: 1:1000



EXISTING GROUND LEVEL	10.69	10.889	10.709	10.715	10.849	11.001	11.133	11.191	11.278	11.53
CUMULATIVE DISTANCE	0	10	20	30	40	50	60	70	80	97
STATION No.	ST.00	ST.01	ST.02	ST.03	ST.04	ST.05	ST.06	ST.07	ST.08	ST.10

PROFILE FOR ROAD R03

NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS
GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
ALL FLANGED TEE (T3)
DOUBLE FLANGED TEE (T2)
DOUBLE SOCKET TEE (T1)
ALL SOCKET TEE (T)
FLANGED COUPLING (FC)
FLANGED SOCKET (FS)
STRAIGHT COUPLING (SC)
FLANGE REDUCER (FR)
REDUCER (R)
END CAP (C)
BEND (B)
AIR RELEASE VALVE (ARV)
WASH VALVE (WV)
FIRE HYDRANT (FH)

FOR TENDER ONLY

FUNDED BY:
ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY:
OVERSEAS
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA
UAWC

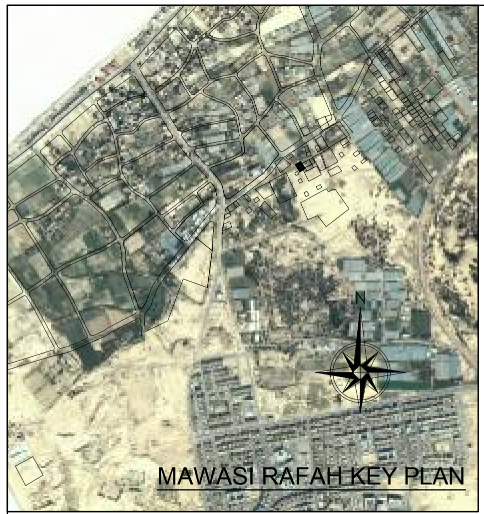
CONSULTANT:
مركز الهندسة والتخطيط
center for engineering and planning

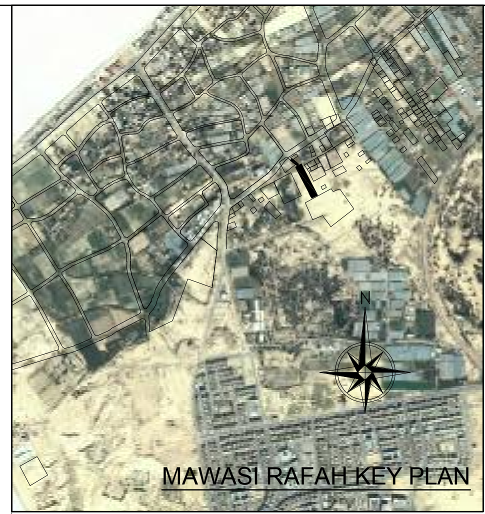
PROJECT TITLE:
REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP
Project Code.: 11473/OVERSEAS

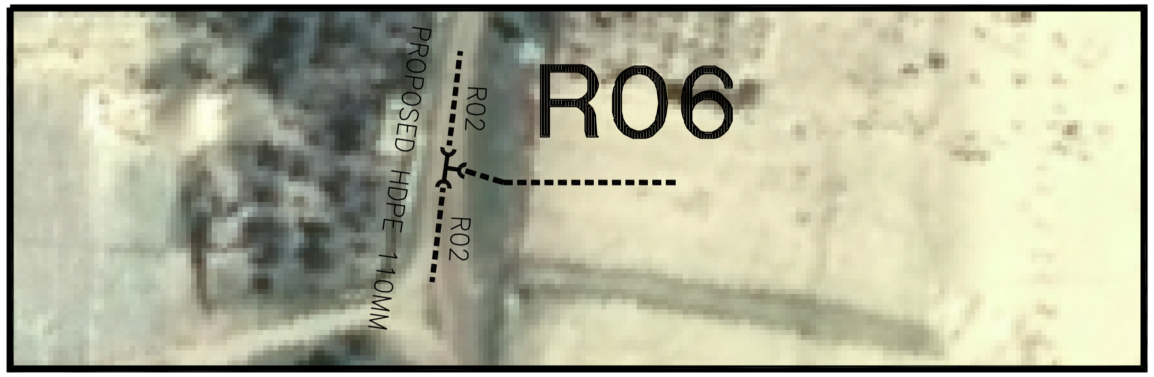
DRAWING TITLE:
PLAN & PROFILE FOR ROAD R03 AND R04

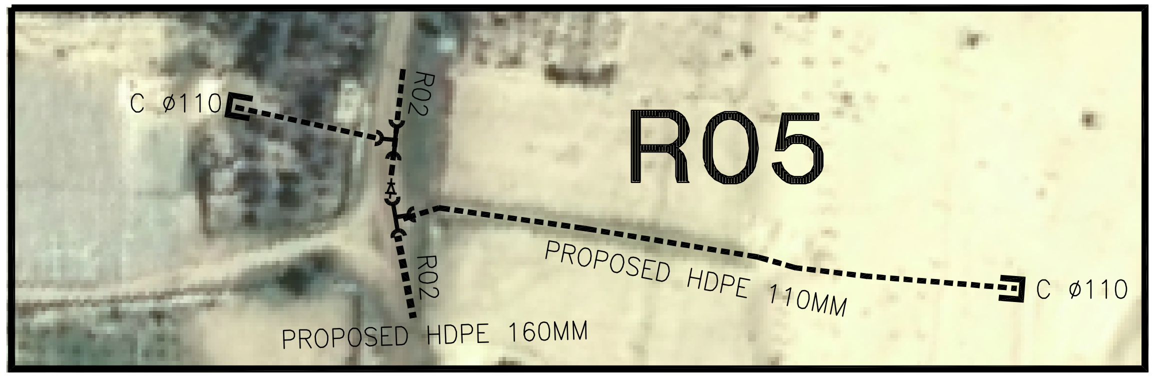
DRAWING NO.: CL-08

DATE: JULY 2020 | SCALE: AS SHOWN







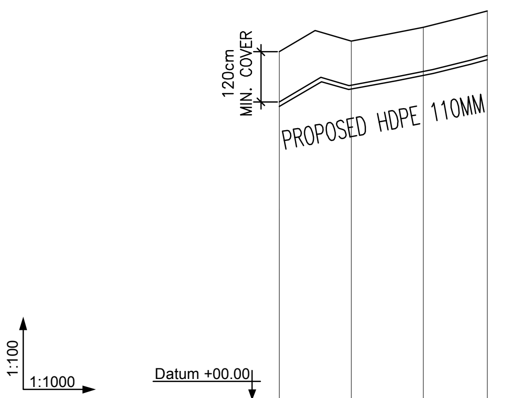


PLAN FOR R06

SCALE: 1:1000

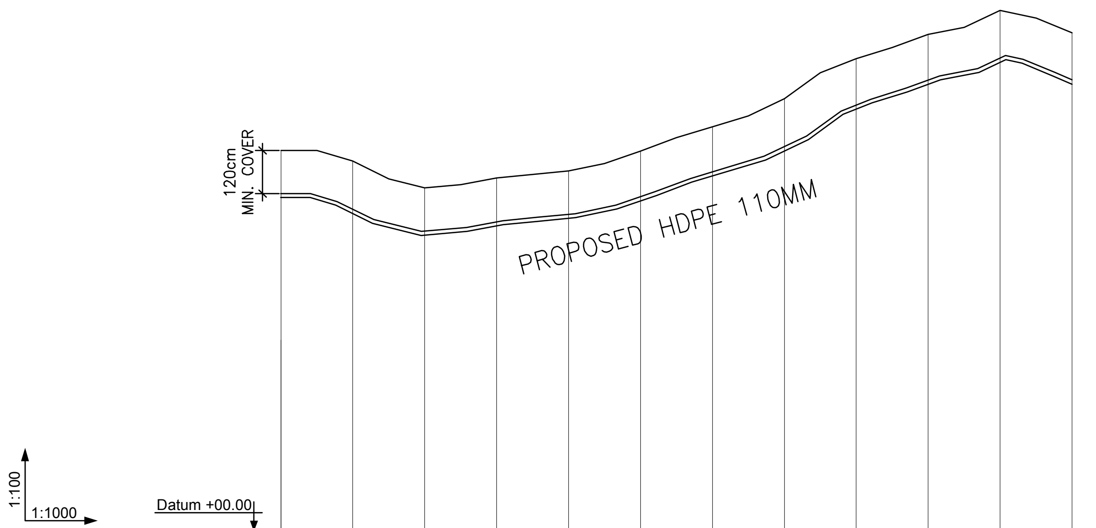
PLAN FOR R05

SCALE: 1:1000



EXISTING GROUND LEVEL	9.676	10.262	9.971	10.156	10.355	10.6	10.811
CUMULATIVE DISTANCE	0	10	20	30	40	50	57.79
STATION No.	ST.00	ST.01	ST.02	ST.03	ST.04	ST.05	ST.06

PROFILE FOR ROAD R06



EXISTING GROUND LEVEL	10.567	10.566	10.27	9.778	9.528	9.618	9.8	9.899	9.998	10.207	10.547	10.925	11.225	11.528	12.006	12.726	13.125	13.436	13.797	13.99	14.468	14.252	13.84
CUMULATIVE DISTANCE	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220
STATION No.	ST.00	ST.01	ST.02	ST.03	ST.04	ST.05	ST.06	ST.07	ST.08	ST.09	ST.10	ST.11	ST.12	ST.13	ST.14	ST.15	ST.16	ST.17	ST.18	ST.19	ST.20	ST.21	ST.22

PROFILE FOR ROAD R05

NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS
GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
ALL FLANGED TEE (T3)
DOUBLE FLANGED TEE (T2)
DOUBLE SOCKET TEE (T1)
ALL SOCKET TEE (T)
FLANGED COUPLING (FC)
FLANGED SOCKET (FS)
STRAIGHT COUPLING (SC)
FLANGE REDUCER (FR)
REDUCER (R)
END CAP (C)
BEND (B)
AIR RELEASE VALVE (ARV)
WASH VALVE (WV)
FIRE HYDRANT (FH)

FOR TENDER ONLY

FUNDED BY:

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY:

OVERSEAS
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA
UAWC

CONSULTANT:

مركز الهندسة والتخطيط
center for engineering and planning

PROJECT TITLE:

REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP

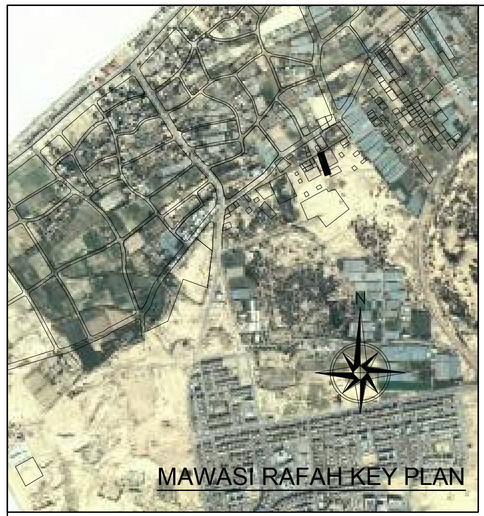
Project Code.: 11473/OVERSEAS

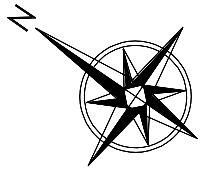
DRAWING TITLE:

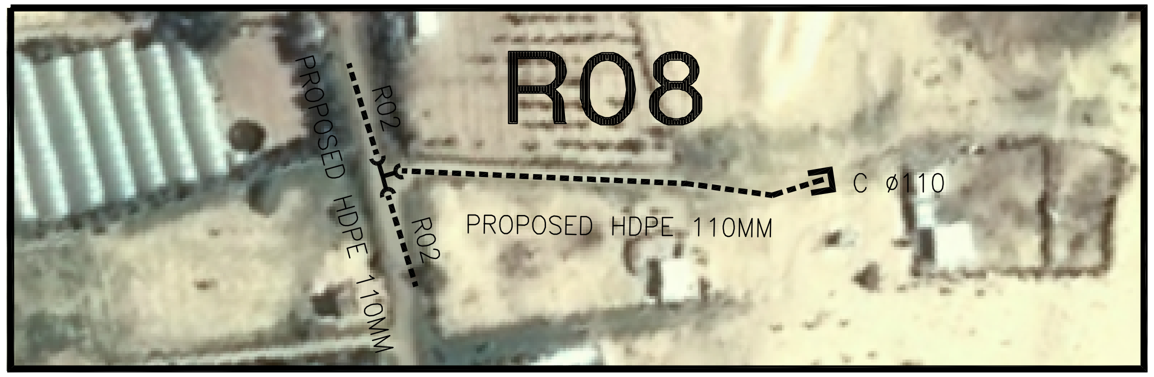
PLAN & PROFILE FOR ROAD R05 AND R06

DRAWING NO.: CL-09

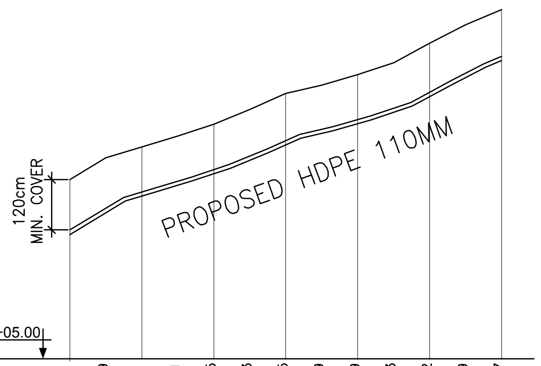
DATE: JULY 2020 | SCALE: AS SHOWN





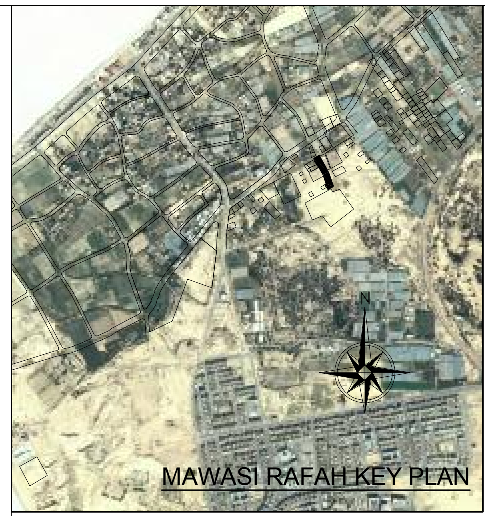


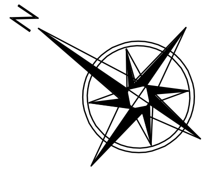
PLAN FOR R08
SCALE: 1:1000

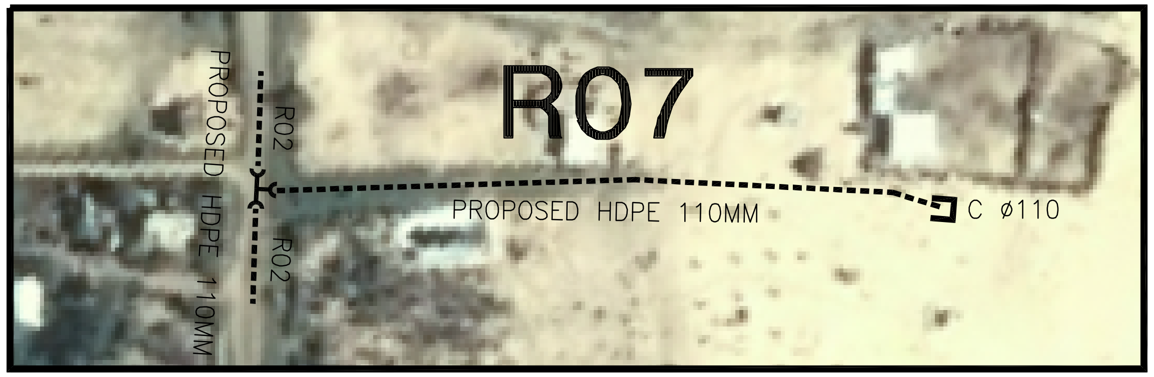


EXISTING GROUND LEVEL	9.986	10.589	10.89	11.191	11.525	11.933	12.375	12.609	12.899	13.233	13.772	14.289	14.707
CUMULATIVE DISTANCE	0	10	20	30	40	50	60	70	80	90	100	110	120
STATION No.	ST.00	ST.01	ST.02	ST.03	ST.04	ST.05	ST.06	ST.07	ST.08	ST.09	ST.10	ST.11	ST.12

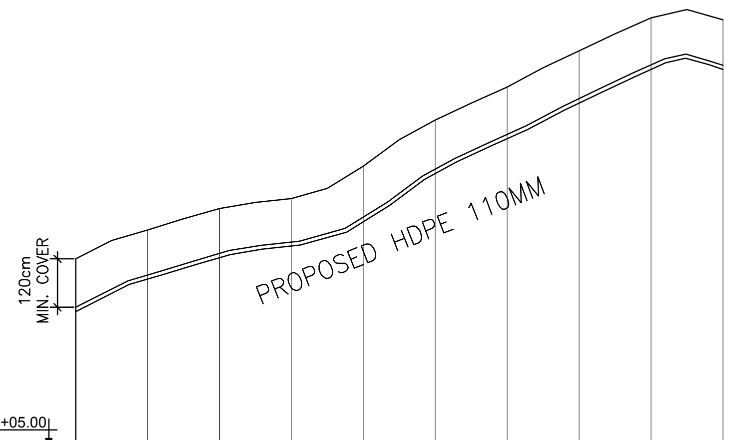
PROFILE FOR ROAD R08







PLAN FOR R07
SCALE: 1:1000



EXISTING GROUND LEVEL	10.274	10.782	11.079	11.383	11.674	11.843	11.948	12.228	12.845	13.588	14.129	14.595	15.043	15.574	16.052	16.522	16.967	17.194	16.914
CUMULATIVE DISTANCE	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
STATION No.	ST.00	ST.01	ST.02	ST.03	ST.04	ST.05	ST.06	ST.07	ST.08	ST.09	ST.10	ST.11	ST.12	ST.13	ST.14	ST.15	ST.16	ST.17	ST.18

PROFILE FOR ROAD R07

NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS

- GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
- ALL FLANGED TEE (T3)
- DOUBLE FLANGED TEE (T2)
- DOUBLE SOCKET TEE (T1)
- ALL SOCKET TEE (T)
- FLANGED COUPLING (FC)
- FLANGED SOCKET (FS)
- STRAIGHT COUPLING (SC)
- FLANGE REDUCER (FR)
- REDUCER (R)
- END CAP (C)
- BEND (B)
- AIR RELEASE VALVE (ARV)
- WASH VALVE (WV)
- FIRE HYDRANT (FH)

FOR TENDER ONLY

FUNDED BY:

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY:

OVERSEAS
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA
UAWC

CONSULTANT:

مركز الهندسة والتخطيط
center for engineering and planning

PROJECT TITLE:

REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP

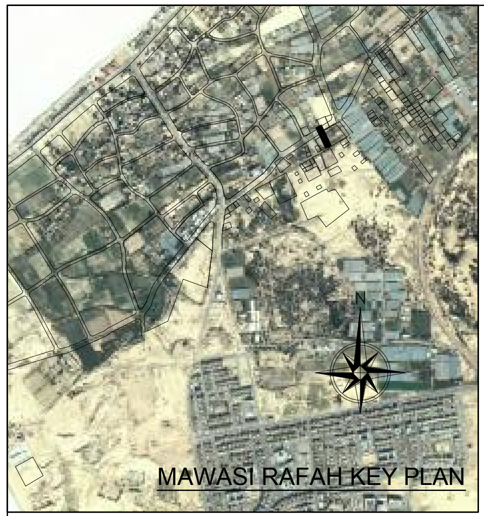
Project Code.: 11473/OVERSEAS

DRAWING TITLE:

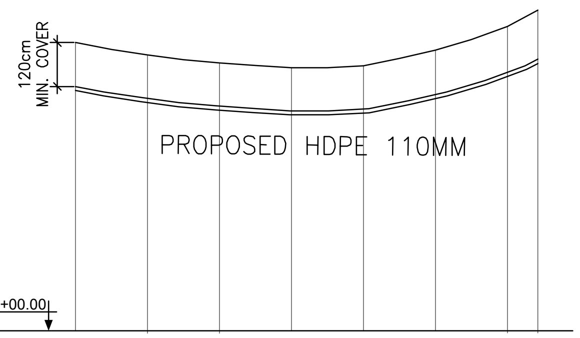
PLAN & PROFILE FOR ROAD R07 AND R08

DRAWING NO.: CL-10

DATE: JULY 2020 | SCALE: AS SHOWN

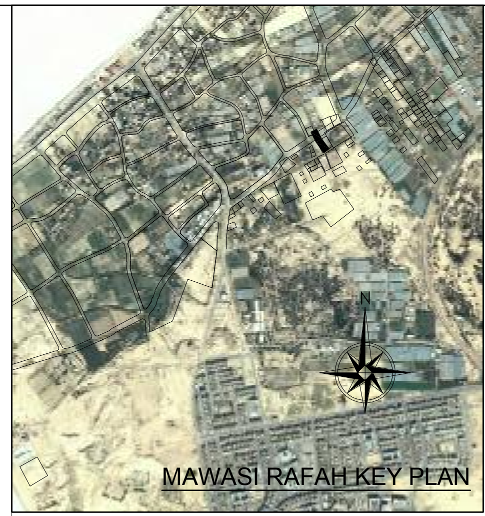


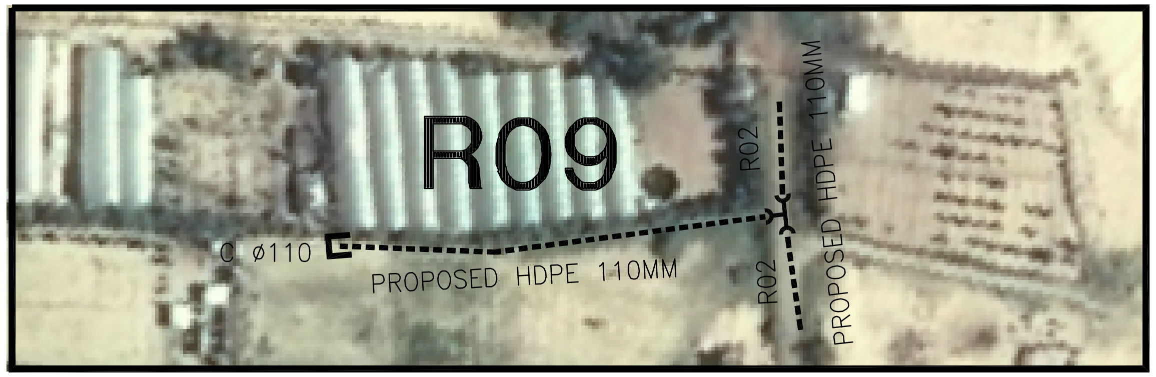
PLAN FOR R10
SCALE: 1:1000



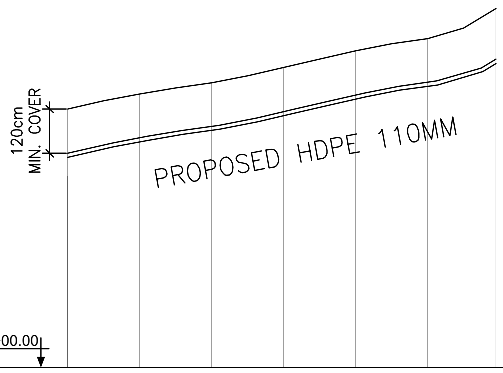
EXISTING GROUND LEVEL	8.013	7.823	7.669	7.532	7.448	7.376	7.312	7.311	7.364	7.567	7.8	8.094	8.464	8.914
CUMULATIVE DISTANCE	0	10	20	30	40	50	60	70	80	90	100	110	120	128049
STATION No.	ST.00	ST.01	ST.02	ST.03	ST.04	ST.05	ST.06	ST.07	ST.08	ST.09	ST.10	ST.11	ST.12	ST.13

PROFILE FOR ROAD R10





PLAN FOR R09
SCALE: 1:1000



EXISTING GROUND LEVEL	7.117	7.348	7.539	7.706	7.85	8.043	8.274	8.505	8.736	8.933	9.072	9.363	9.911
CUMULATIVE DISTANCE	0	10	20	30	40	50	60	70	80	90	100	110	118.98
STATION No.	ST.00	ST.01	ST.02	ST.03	ST.04	ST.05	ST.06	ST.07	ST.08	ST.09	ST.10	ST.11	ST.12

PROFILE FOR ROAD R09

NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS
GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
ALL FLANGED TEE (T3)
DOUBLE FLANGED TEE (T2)
DOUBLE SOCKET TEE (T1)
ALL SOCKET TEE (T)
FLANGED COUPLING (FC)
FLANGED SOCKET (FS)
STRAIGHT COUPLING (SC)
FLANGE REDUCER (FR)
REDUCER (R)
END CAP (C)
BEND (B)
AIR RELEASE VALVE (ARV)
WASH VALVE (WV)
FIRE HYDRANT (FH)

FOR TENDER ONLY

FUNDED BY:
ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY:
OVERSEAS
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA
UAWC

CONSULTANT:
مركز الهندسة والتخطيط
center for engineering and planning

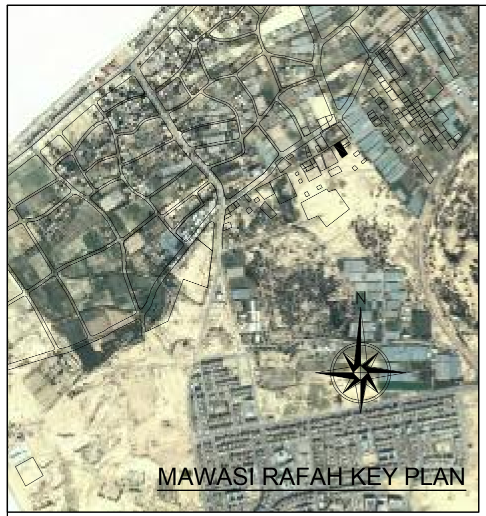
PROJECT TITLE:
REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP

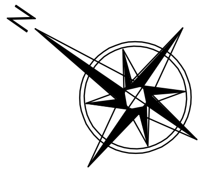
Project Code.: 11473/OVERSEAS

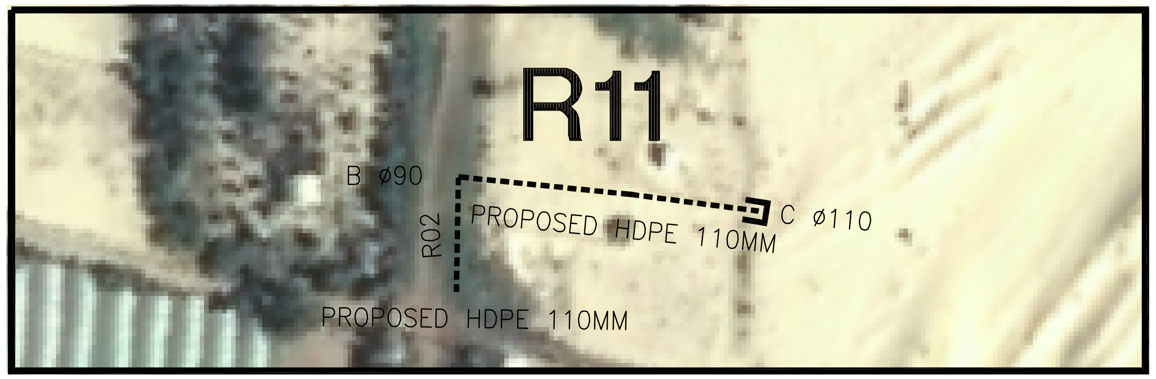
DRAWING TITLE:
PLAN & PROFILE FOR ROAD R09 AND R10

DRAWING NO.: CL-11

DATE:JULY 2020 | SCALE: AS SHOWN

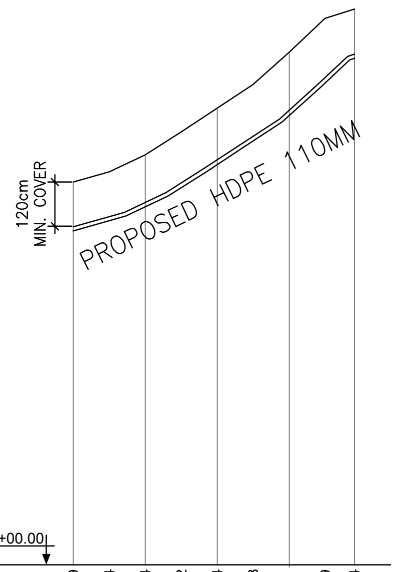






PLAN FOR R11

SCALE: 1:1000



EXISTING GROUND LEVEL	10.649	10.934	11.404	12.042	12.704	13.358	14.26	15.199	15.464
CUMULATIVE DISTANCE	0	10	20	30	40	50	60	70	78.13
STATION No.	ST.00	ST.01	ST.02	ST.03	ST.04	ST.05	ST.06	ST.07	ST.08

PROFILE FOR ROAD R11

NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS
GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
ALL FLANGED TEE (T3)
DOUBLE FLANGED TEE (T2)
DOUBLE SOCKET TEE (T1)
ALL SOCKET TEE (T)
FLANGED COUPLING (FC)
FLANGED SOCKET (FS)
STRAIGHT COUPLING (SC)
FLANGE REDUCER (FR)
REDUCER (R)
END CAP (C)
BEND (B)
AIR RELEASE VALVE (ARV)
WASH VALVE (WV)
FIRE HYDRANT (FH)

FOR TENDER ONLY

FUNDED BY:

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY:

OVERSEAS — ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA — UAWC

CONSULTANT:

مركز الهندسة والتخطيط
center for engineering and planning

PROJECT TITLE:

REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP

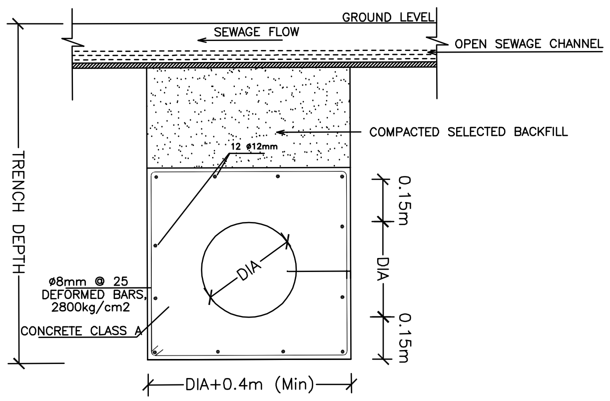
Project Code.: 11473/OVERSEAS

DRAWING TITLE:

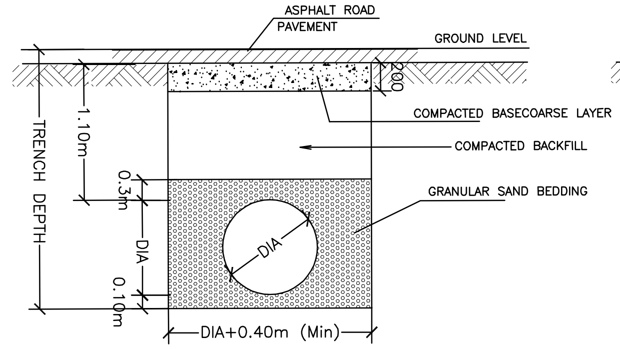
PLAN & PROFILE FOR ROAD R11 AND R12

DRAWING NO.: CL-12

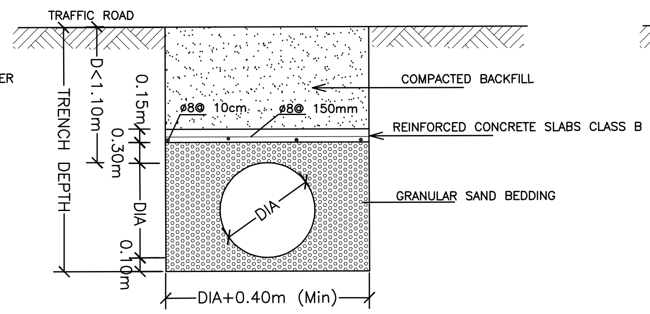
DATE:JULY 2020 | SCALE: AS SHOWN



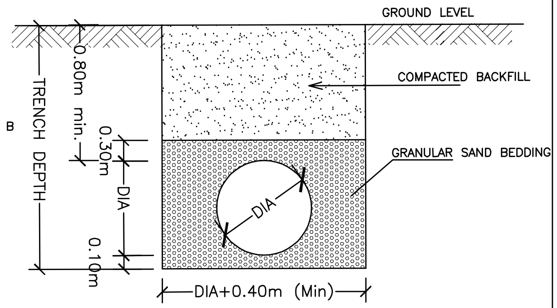
DETAIL OF PIPE LAYING IN CROSSING OPEN CHANNEL
(PIPE ENCASED)



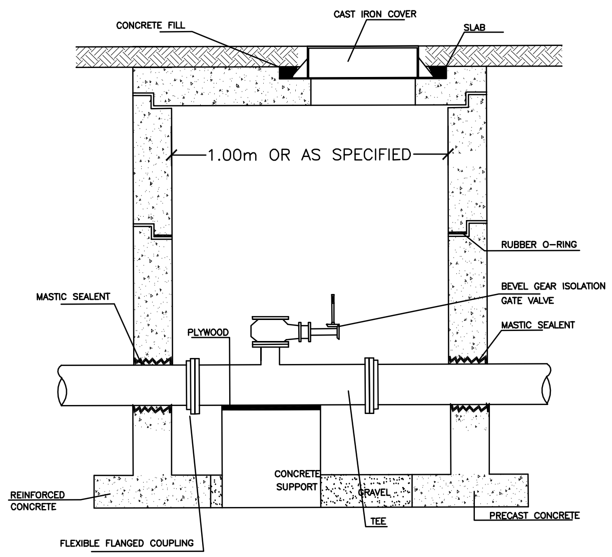
TYPICAL PIPE TRENCH IN TRAFFIC ROADS



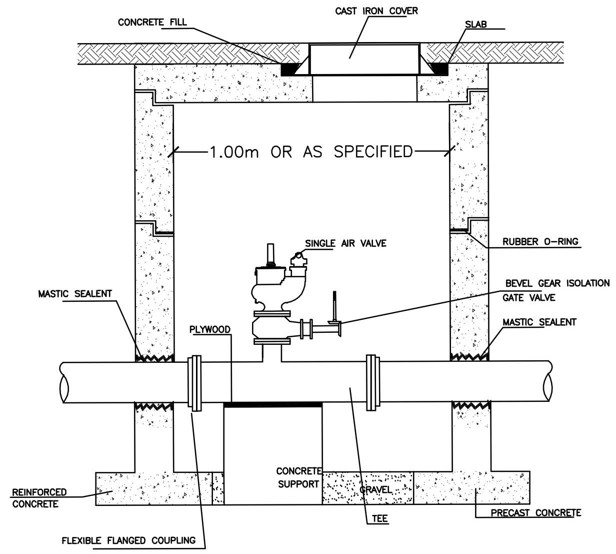
DETAIL FOR PROTECTIVE SLABS ABOVE PIPE
(PIPE ALONG TRAFFIC ROAD)



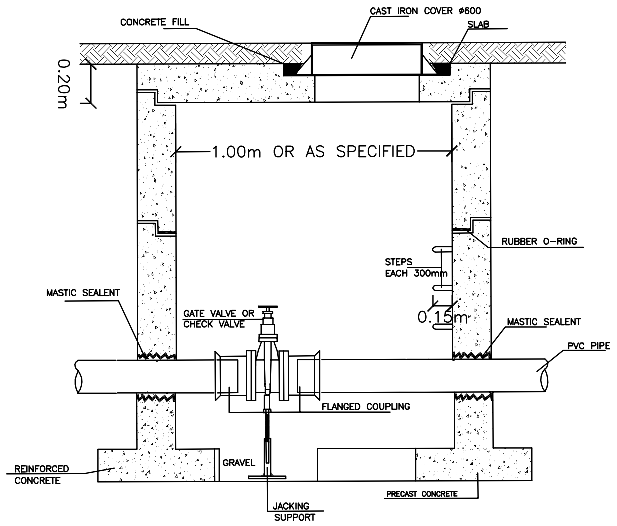
TYPICAL TRENCH CROSS SECTION
(PIPE ALONG ROADS OF NO TRAFFIC)



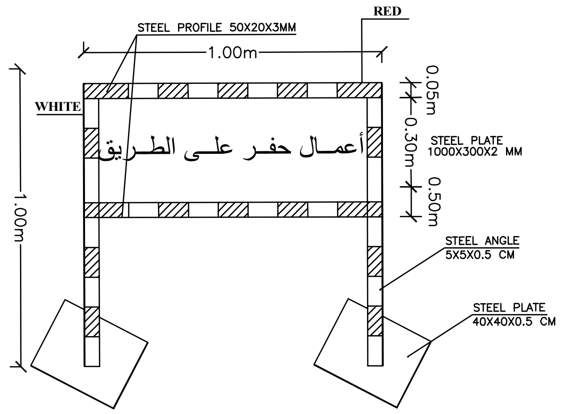
WASH VALVE CHAMBER SECTION



SINGLE AIR VALVE CHAMBER SECTION



PRECAST CONCRETE VALVES CHAMBER ON PVC PIPES



DETAIL FOR SAFETY BARRIERS
ALONG TRENCH, EACH 10 METERES

NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS
GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
ALL FLANGED TEE (T3)
DOUBLE FLANGED TEE (T2)
DOUBLE SOCKET TEE (T1)
ALL SOCKET TEE (T)
FLANGED COUPLING (FC)
FLANGED SOCKET (FS)
STRAIGHT COUPLING (SC)
FLANGE REDUCER (FR)
REDUCER (R)
END CAP (C)
BEND (B)
AIR RELEASE VALVE (ARV)
WASH VALVE (WV)
FIRE HYDRANT (FH)

FOR TENDER ONLY

FUNDED BY:

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

IMPLEMENTED BY:

OVERSEAS — ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA — UAWC

CONSULTANT:

مركز الهندسة والتخطيط
center for engineering and planning

PROJECT TITLE:

REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP

Project Code.: 11473/OVERSEAS

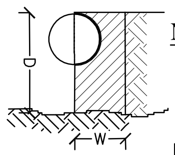
DRAWING TITLE:

GENERAL DETAILS (1/2)

DRAWING NO.: CL-13

DATE:JULY 2020 | SCALE: AS SHOWN

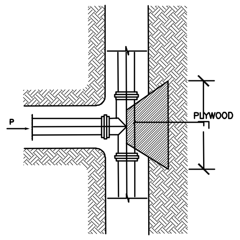
ANCHOR BLOCKS



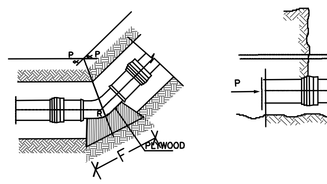
NOTES:

- ** END: CAPS OR BLANK FLANGES
- ** TEE: ALL SOCKETS, DOUBLE SOCKETS AND FLANGED TEES
- ** DIMENSIONS IN CM

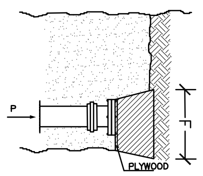
	FITTINGS																											
	250 & 300mm							200 & 225mm							160mm							110mm						
DIMENTION	B11 1/4	B22 1/2	B45	B90	T10"x10" T12"x12"	T12"x10" T12"x8" T10"x8"	END	B11 1/4	B22 1/2	B45	B90	T8"x8"	T8"x6" T8"x4"	END	B11 1/4	B22 1/2	B45	B90	T6"x6"	T6"x4"	END	B11 1/4	B22 1/2	B45	B90	T4"x4"	T4"x2"	END
WIDTH (W)	30	40	40	40	45	50	50	25	35	35	35	40	45	45	20	25	25	35	35	35	35	15	20	20	30	30	25	30
AREA (F=LXD)	1925	2700	4400	1750	7800	7150	4875	1500	2200	3500	6000	6600	6000	4200	1000	1350	2400	4400	4050	3200	2000	600	875	1500	3150	3750	2600	1600
LENGTH (L)	55	60	80	130	120	110	75	50	55	70	120	110	100	70	40	45	60	110	90	80	50	30	35	50	90	75	40	40
DEPTH (D)	35	45	55	55	65	65	65	30	40	50	50	60	60	60	25	30	40	40	45	40	40	20	25	30	35	50	65	40



ANCHOR BLOCK DIMENTIONS FOR TEES



ANCHOR BLOCK DIMENTIONS FOR BEND

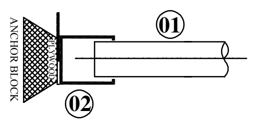


ANCHOR BLOCK DIMENTIONS FOR PIPE END

WATER NETWORK GENERAL DETAILS

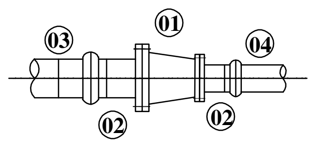
END CAP DETAILS

- 01 PROPOSED HDPE PIPE
- 02 END CAP



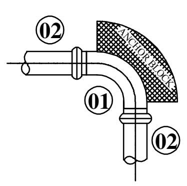
FLANGED REDUCER DETAILS

- 01 FLANGED REDUCER
- 02 FLANGED COUPLING
- 03 PROPOSED INLET PIPE
- 04 PROPOSED OUTLET PIPE



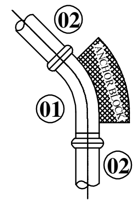
BEND 90° DETAILS

- 01 PROPOSED PIPES
- 02 BEND 90°



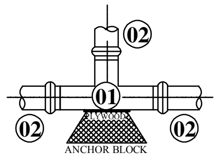
BEND 45° DETAILS

- 01 PROPOSED PIPES
- 02 BEND 45°



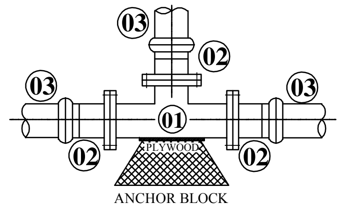
TEE ALL SOCKET (T) DETAILS

- 01 ALL SOCKET TEE
- 02 PROPOSED HDPE PIPES



TEE ALL FLANGE (T3) DETAILS

- 01 ALL FLANGED TEE
- 02 FLANGED COUPLING
- 04 PROPOSED PIPIES
- 04 PROPOSED PIPIES



NOTES :-

- Paper Size: A1

ABBREVIATIONS & SYMBOLS
GATE VALVE, MANHOLE & TWO FLANGED COUPLING (GV, MH & 2FC)
ALL FLANGED TEE (T3)
DOUBLE FLANGED TEE (T2)
DOUBLE SOCKET TEE (T1)
ALL SOCKET TEE (T)
FLANGED COUPLING (FC)
FLANGED SOCKET (FS)
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WASH VALVE (WV)
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FOR TENDER ONLY

FUNDED BY:
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OVERSEAS
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CONSULTANT:
مركز الهندسة والتخطيط
center for engineering and planning

PROJECT TITLE:
REUSE OF TREATED WASTEWATER FOR AGRICULTURE USE IN AL-MAWASI AREA, RAFAH, GAZA STRIP

Project Code.: 11473/OVERSEAS

DRAWING TITLE:
GENERAL DETAILS (2/2)

DRAWING NO.: CL-14

DATE: JULY 2020 | SCALE: AS SHOWN

APPENDIX B2-BILL OF QUANTITIES OF REAL PLANT OF RAFAH, GAZA STRIP

BOQ

Item No.	Description	Unit	Qty.	Unit Rate (US$)	Total Amount (US$)
	Project Name: Reuse of Treated Waste Water in Agricultural Sector within the Al-Masawi District – Rafah, Gaza Strip				
	SECTION NO.01: EXCAVATION and EARTH WORKS				
	• **The Prices for all earthworks works (items) shall include the following:** 1- Submit shop drawings for all works and get the approval of the engineer before commencement of the works. 2- Demolition of any existing structure based on the Engineer instructions. 3- Excavation works in any kind of soil (sand, clay, rocks, kurkar, etc.). 4- Stockpiling selected excavated material near the site based on the Engineer instructions to re-use it later in backfilling works, and the surplus shall be transferred out of the site according to the instructions of the engineer from the project site. 5- All Works must be executed according to drawings, specifications and engineer instructions 6- Cut and restore the existing roads or the surrounding fence of the adjacent sand filter for PEDAR and Oxfam (if needed) according to the engineer instructions.				
1.1	**Clearing and Grubbing** Remove & Clear the site from rubbish, trees, shrubs, debris, concrete, boundary walls and fences …. etc. to be ready to starting the excavation work and cart away the excavated material from the site to any location approved by the engineer.	L.S	1		
1.2	Excavation from ground level up to required designed level for all elements of the project (purification ponds, aeration lagoon, septic tanks ….etc.) and the price shall include compacting the soil surfaces to get at least (98% MDD) under structural elements only and the price include reshaping the side slopes of the aeration lagoon as shown in the drawings.	L.S	1		
1.3	**For structural elements** Backfilling, compact excavated selected clean sand and fill in layers 20 cm thick in all places requiring backfilling to make up levels according to the drawings, (95% MDD) as per specifications, drawings and engineer instructions. This is not including the fills in the purification ponds.	L.S	1		
1.4	**For the purification ponds** **Filter media** Supply and laying of suitable natural gravel (size is not less than 30 mm), the thickness of the layer will be according to the attached drawings, including the burden of protection of draining pipes. All the work will be implemented according to the specifications and the instructions of the supervision engineer.	M3	515		
1.5	**For the purification ponds** **Filter media** laying of suitable layer of excavated selected clean sand, the thickness of the sand layer will be according to the attached drawings, and instructions of the supervision engineer. Minimum permeability = 8 m/d and fill in one layer as per specifications, drawings and engineers instructions. The contractor shall perform testing for permeability coefficient for three samples and get the approval from the engineer before commencement of the works.	M3	865		
1.6	**For the purification ponds** **Filter media** Supply and install a separating filter layer, composed of a double layer of protective net (insect-net or dust-net) to protect the collection pipes. This layer will be placed immediately above the gravel layer and below the clean sand layer.	M2	1080		
1.7	**For the purification ponds** **Vegetation Soil Layer** Supply and laying of suitable layer of loose vegetation soil to cover the filter bed placed above the influent perforated pipes, carried out	M3	270		

	without compaction such as to be finished, completed and leveled, measured as a result, including the burden of the eventual recharge and subsequent watering. The thickness of the vegetation sand layer will be according to the attached drawings. All works will be performed according to the specifications and instructions of the supervision engineer.				
1.8	**For the purification ponds** **Vegetation Soil Layer** Supply Alfalfa seeds with the following specifications: Free of weevils and impurities, germination rate not less than 97%, purity percentage of 95%, the production year is not more than 12 months. The work will be implemented according to the specifications and the instructions of the supervision engineer.	M2	1080		
Excavation and Earthworks Carried to Summary				**$**	

Item No.	Description	Unit	Qty.	Unit Rate (US$)	Total Amount (US$)
SECTION NO. 02: CONCRETE WORK					
	The Prices for all concrete works (items) shall include the following: 1- Submit shop drawings for all concrete works and get the approval of the engineer before commencement of the works. 2- All material must be approved before starting the works. 3- All concrete to be used in the project, must be from ready mix concrete. 4- Approved additives and admixtures 5- Factory of Ready-mix concrete must be approved from pertinent authorities. 6- Supplying, Casting, vibrating and curing all elements of concrete as shown in the documents. 7- All form works, shuttering in any form (wood or steel), shape, decoration, fabrication, arches. Making chamfered and curved edges , making good grooves and sleeves , surface finishing 8- Painting all exposed surfaces of underground reinforced concrete elements with at least one primer coat & two coats of hot bituminous paint (75/25), the strokes of each layer to be opposite to each other 9- The Contractor shall use Galvanized tie Rods "BATANT" 8mm in the wall shuttering. 10- Supplying reinforcement steel of grade 60 (4200kg/cm^2), size and length as detailed in the drawings, storing on the site including cutting, bending and fixing in position and providing all tying wires, spacers , testing and bar bending schedules 11- All materials needed to execute the works completely for example but not limited to : (all concrete types , Vibrators , steel with all diameters & size , stuttering , pipes & fittings for mechanical installation , polythene sheet 200 micron, workmanship , polystyrene 2cm for joints , bitumen , testing material…etc.). 12- Finishing all horizontal surfaces of concrete (slabs, Slab on Grade, Etc.) The concrete surfaces shall be finished mechanically with (helicopter) to give smooth surfaces. 13- All elements of concrete must obtain compressive strength not less than 115% from type of concrete after 28 days (for example B300 must give 345kg/cm^2), and if the concrete not reaches to the required strength, the following steps must be applied: a- check the design, if safe and the compressive concrete value equal or more than the value that denoted in the B.O.Q will be accepted but, b- will make discount at least 20% of the price of the item. 14- All works must be according to drawings, specifications, and the engineer instructions. 15- The contractor shall provide a job mix from an approved laboratory and get the approval from the engineer.				
2.1	Supply and cast plain concrete **B200**, 7cm thick below foundations of Retaining Walls, calm tanks, septic tanks, boundary wall and other elements.	M3	55		
2.2	**For the purification ponds & Aeration lagoon (base only),** supply and cast a reinforced concrete slab on grade of at least 10 cm thickness of **B250** concrete (ϕ8mm/20cm mesh in both directions). The slab will be underlined by polyethylene sheet (Naylon of 0.2 mm thickness). The work includes a semicircular drainage channel and Expansion Joints as shown in the drawings.	M3	127		
2.3	**For aeration lagoon (Side wall), ramp, and slabs between ponds,** supply and cast a reinforced concrete slab on grade of at least 15 cm thickness of **B250** concrete (ϕ10mm/20cm mesh in both directions) The work includes expansion joints as shown in the drawings.	M3	193		
2.4	Supply and cast **B250** reinforced concrete for stairs, boundary walls, main gates columns (30*20cm), the one distribution manholes and foundations of retaining wall, septic tanks & clam tank. The reinforcement is according to drawings.	M3	237		

Item No.	Description	Unit	Qty.	Unit Rate (US$)	Total Amount (US$)
2.5	Supply and cast fair face reinforced concrete **B300** for walls of retaining walls and septic tanks walls. The price shall include isolation works for the inside face for all concrete element with a minimum of one primer coat & two coats of hot bituminous paint (75/25).	M3	207		
2.6	**For the distribution road (Side walls),** supply and cast a reinforced concrete slab on grade of at least 12 cm thickness of **B250** concrete (ϕ10mm/20cm mesh in both directions) The work includes expansion joints as shown in the drawings.	M3	25		
Concrete Works Carried to Summary				**$**	

Item No.	Description	Unit	Qty.	Unit Rate (US$)	Total Amount (US$)
SECTION NO. 03: METAL WORK					
3.1	Supply and install cast iron cover engraved (Wastewater) by English & Arabic letters for manhole openings and calm tank opening (25 tons capacity and 60cm opening), including square frame rings and internal painting. All must be according to Specifications & the Engineer instructions.	NO.	14		
3.2	Supply & install fence made of wire mesh of size 50x50x3mm HOT-DIP Galvanized double twisted, the price includes 2.3m height galvanized steel profile 80x40x2mm each 3m, galvanized straining wires, stiffeners, barbed wires, supports profiles at corners and each four panel, painting for profiles...etc. as per drawing, specifications and the engineer instructions.	LM	352		
3.3	Supply, fix and paint double leaves galvanized steel gate size 400 cm wide x 210 cm high (made of wire mesh of size 50x50x3mm HOT-DIP Galvanized double twisted which includes galvanized steel pipes sections, galvanized straining wires, stiffeners, painting, frame, hinge, hardware locked, ironmongery &…etc. to complete the works. ,..etc. as per drawing, specifications and the engineer instructions.	NO.	2		
3.4	Supply and install handrail around the septic tanks for protection purpose with railing pipe (50mm for top horizontal pipe and vertical pipes and 38mm for middle horizontal pipe) and 3mm thick. The handrail height is 90 cm and the distances between vertical pipes are 90cm. The price includes the steel pipes and fixing plates, painting with one coat primer, under coat and two coats of hummer finish oil paint. Fixing handrails and all necessary works needed shall be according to specifications and approved according to the Engineer instructions.	LM	78		
Metal Works Carried to Summary				**$**	

Item No.	DESCRIPTION	UNIT	QTY	Unit Rate ($US)	AMOUNT ($US)
SECTION NO. 04: MECHANICAL WORK					
4.1	Supply, install, PVC pipes for outlet drain with watertight and flexible joints sealed with approved gasket rubber ring including laying in any soil, connection with manhole and concrete Benching, safety measures and testing. The price includes laying excavated sand from the site around, top and bottom of the pipe. The selected material will be used for backfilling the rest of the trench in layers not exceeding 25cm (for each layer) with compaction not less than 95 %, up to the design levels of the roads, leveling the roads after backfilling, take away the surplus soil as specified and instructed by the engineer.				

Item No.	DESCRIPTION	UNIT	QTY	Unit Rate ($US)	AMOUNT ($US)
	The price shall include different required fitting e.g., **elbows, scam baffles**,… as shown in the drawings and the engineer instructions.				
4.1.1	Supply and install PVC DN400 pipe - SN 8, as shown in the drawings.	L.m	25		
4.1.2	Supply and install PVC DN250 pipe - SN 8, as shown in the drawings.	L.m	25		
4.1.3	Supply and install PVC DN200 pipe - SN 8, as shown in the drawings.	L.m	150		
4.1.4	Supply and install PVC DN160 pipe - SN 8, as shown in the drawings.	L.m	85		
4.1.5	Supply and install PVC DN125 pipe - SN 8, as shown in the drawings.	L.m	15		
4.1.6	Supply and install PVC DN80 pipe - SN 8, as shown in the drawings.	L.m	55		
4.1.7	Transport and install perforated PVC DN80 pipe, as shown in the drawings.	L.m	2000		
4.2	Supply and install 200 mm diameter pressure HDPE pipe for inlet pipe from the 8" part of Y-T connection to the calm tank. The price includes all necessary elbows according to the drawings and specifications and engineer instructions. The work shall include a proper Y-T connection. The work shall be approved from the engineer based on CMWU instructions.	L.m	55		
4.3	Supply and install 125 mm diameter HDPE pipe for inlet pipe. The price includes all necessary elbows according to the drawings and specifications and engineer instructions.	L.m	150		
4.4	Supply, install and cast in place Circular reinforced concrete manholes (B300) and cast iron steps @30cm spacing, built-in collector inlet and outlet pipes. The price includes two external bitumen coating, shuttering, shoring, safety measures, formwork, excavation in any type of soil, backfilling with selected material in layers 20cm thick each and compaction 95% MDD. The price includes also supplying and casting 10cm plain concrete B200 under the bottom of the manhole and plain concrete for benching. All are as per drawings, specifications, and the engineer instructions.				
4.4.1	Diameter of 150 cm and Depth up to 1.50m.	NO.	3	1350	4050
4.4.2	Diameter of 150 cm and Depth of 3.65m.	NO.	2	1500	3000
4.4.3	Diameter of 100 cm and Depth up to 1.50m.	NO.	6	750	6750
4.5	Supply and install 200 mm diameter globe valve (HAKOHAV kind) in the main influent line, soft sealed, and all fittings needed for proper installation and operation as indicated in the drawings, specifications, and according to the manufacturer and supervision engineer's instructions. The work according to the drawings and specifications and engineer instructions.	NO.	1		
4.6	Supply and install 250mm diameter Ball float valve with all other requirements to complete the work according to the drawings and specifications and engineer instructions.	NO.	2		
4.6	Supply and install 200mm diameter Ball float valve for the influent pipe with all other requirements to complete the work according to the drawings and specifications and engineer instructions.	NO.	1		

Item No.	DESCRIPTION	UNIT	QTY	Unit Rate ($US)	AMOUNT ($US)
4.7	**For septic tanks** Supply and Install 200mm circular cast grey iron sluice gate for 200mm pipe SINYAVER or ZET or equivalent, and stainless steel non-rising long stem complete with all requirements for installation and operation according to the drawings and specifications and engineer instructions.	NO.	1		
4.8	Supply and install 8" gate valve manual with gear mechanism and includes one flange couplings and one open flanged as shown on the Drawings and all notes above as described in the Specifications or directed by the Engineer	NO.	2	750	1500
4.9	Supply and install Flow Meter 8"ARAD or Equivalent and includes two flange couplings. As shown on the Drawings and described in the Specifications or directed by the Engineer.	NO.	1	3300	3300
4.10	Install the aeration system as shown in the drawings and as the engineer instructions including (supply and install for main pipe DN100, air left pipes DN65, concrete blocks 40*40*20cm, and pipes supply ¾”) and (transport and install the Blowers). The price shall include the pipe fixation and any needed modification to get the best operation according to the engineer instructions.	L.S	1		
	Mechanical Carried to Summary			**$**	

Item No.	Description	Unit	Qty.	Unit Rate (US$)	Total Amount (US$)
SECTION NO. 05: EXTERNAL WORK					
5.1	Clean, excavate, cut and fill (as needed) by approved material and grade from natural ground level to the bottom of base coarse layer design level of the roads and cart-away disposal of excavated material as per drawings, specifications and engineer’s instructions. (The price includes watering, compaction not less than 98% & CBR not less than 10%).	M2	600		
5.2	Supplying, laying, compacting 8 cm thick colored inter locking tiles; size & shape the price shall include Supplying and laying two layers of basecourse 10 cm each layer as shown in the drawing and according specifications & the engineer’s instructions.	M2	600		
	External Works Carried to Summary			**$**	

APPENDIX C – QUESTIONNAIRE FOR BASELINE SOCIO-ECONOMIC STUDY

Reuse of treated waste water in agricultural sector within the Al-Masawi district– Rafa's Governatorate – Gaza Strip
الاستمارة الموجهة للمزارعين

2019/........ /........	**تاريخ تجهيز الاستمارة Date**

.1 General information بيانات التعريف العامة

	Nameاسم المبحوث/ة	**A01**
☐ Male.1 ذكر ☐ Female.2 أنثى	**Genderالجنس**	**A02**
	Area عنوان المبحوث/ة	**A03**

.2 Household's livelhood Profile البيانات الشخصية للمبحوث/ة

☐ 1.أقل من 15 ☐ 2. (31-45) ☐ 3. (46-60) ☐ 4. (أكبر من60<)		**Age العمر**	**B01**
☐ 1. بدون / أمي ☐ 2. ابتدائي ☐ 3. إعدادي ☐ 4. ثانوي ☐ 5. دبلوم ☐ 6. جامعي ☐ 7. دراسات عليا		**Level of education مستوى التعليم**	**B02**
....		**Other التخصص الدراسي**	**B03**
☐ 1. Governamentalلا يعمل ☐ Private sector2. يعمل بدوام كمل ☐ Agricultural 3.يعمل بدوام جزئي ☐ Private work.4 عمل مؤقت / بطالة		**Source of Income for HHs الحالة العملية**	**B04**
☐ In the same governatorate1. ضمن نفس التجمع السكاني ☐ In other governatorate2.ضمن نفس المحافظة		**Work area of HH مكان العمل**	**B05**
☐ 1. (أقل من 1450<) ☐ 2. (1450 - 2999) ☐ 3. (3000 - 4449) ☐ 4. (4500 - 5999) ☐ 5. (6000-7449) ☐ 6. (7500 فما فوق)		**HHمتوسط دخل الأسرة الشهري monthly Income Average بالشيكل من جميع المصادر (تشمل العائد النقدي)**	**B06**
☐ 1. (أقل من 2<) ☐ 2. (2 - 5) ☐ 3. (6 - 10) ☐ 4. (11 فما فوق)		**عدد أفراد العائلة المعتمدين على دخل المبحوث Family size**	**B07**
☐ Food المجموع	☐ Non food ذكر ☐ أنثى	☐ متزوج ☐ Seasonal expenses أعزب	**عدد أفراد الأسرة (شامل رب Spending average on الأسرة) different Items حسب الجنس والحالة الاجتماعية**	**B8**
☐ 10-0	☐ 15-10	☐ 24-15	☐ 40-25	**عدد أفراد الأسرة حسب العمر Frequency (%) of the Respondents who have Financial Obligationsوالجنس**	**B9**
☐ 65-40	☐ 75-65	☐ 85-75	☐ 100-85		
☐ Food رياض الأطفال ☐ Agricultural Inputs المرحلة الابتدائية ☐ Medicines المرحلة الإعدادية Consumation material for house المرحلة الثانوية ☐ Other الجامعة		**عدد أفراد الأسرة في Borrowing Causes ofالمراحل the Respondents التعليمية المختلفة**	**B10**

.3 Agricultural Activitiesمصادر دخل الأسرة ومتوسط الإنفاق

Dimension of the area تفاصيل الإنفاق على السلع المختلفة شيكل / شهر			**C01**
(%) Percentالقيمة	**Dunumالمصروفات**		
☐☐☐☐	**المواد الغذائية**		
☐☐☐☐	**المواد غير الغذائية**		
☐☐☐☐	**النفقات الموسمية**		
☐ **1.** Agricultural activities زيادة ☐ No Agricultural Activities.**2** **نقصان** ☐ **3.** Other **لا تتغير**	**كيف تقارن معدل دخل الأسرة من الزراعة خلال Type of Activitiesالفترة الحالية مقارنة بالأشهر الثلاث الماضية؟**		**C02**
☐ **1.**Plant Production نعم ☐ **2**Mixed.**لا** النسبة	**هل يكفي دخل الأسرة لتغطية الاحتياجات المذكورة؟ بأي نسبة؟**		**C03**
☐ **1.%**نعم ☐ **2.%لا**	**Type of Agricultural Activities and Percentage**		**C04**
☐ Trees.1شراء طعام ☐ 2vegetables. تسديد ديون سابقة Non cultivated .3 landsشراء مدخلات زراعية	**ما هو سبب الاقتراض؟**	**Average areaالقروض الحالية of crops type**	**C05**

APPENDIX C – QUESTIONNAIRE FOR BASELINE SOCIO-ECONOMIC STUDY

C06	القيمة دخل الأسرة Percentage of each crop and its لتغطية الاحتياجات average area المذكورة؟	المصروفاتDunum	☐ Citrus.1 عدم توفر المستلزمات الزراعية ☐ Olive.2 انتظار ☐ Olive and vegetables .3عدم توفر مصدر للمياه ☐ Oter .4 أخرى، حدد/ي ......
		القيمةPercent (%)	☐ 1 ☐ .2 ☐ .3 ☐ 4

.4 البيانات الزراعيةAgricultural activities

D01	نوع الحيازة الزراعية	☐ 1. نباتية ☐ 2. حيوانية ☐ 3.مختلطة
D02	عدد سنوات الخبرة في المجال How many years of experience do you have in agricultural? الزراعي	☐ 0لا يوجد خبرة ☐ (5-1) ☐ (10-5) ☐ (أكثر من 10)
D03	هل تقوم بزراعة الأرض في Marketing channels ofالوقت الحالي agricultural crops	☐ ....
D04	كيف تقوم عادة ببيع الإنتاج How the income from Agriculture Differ from the last 6 Months	☐ بشكل مباشر للتاجر ☐ بشكل مباشر للمستهلك ☐ الدلال (الحسبة) ☐ شركات توزيع ومصانع ووحدات انتاج ☐ طرق أخرى أذكرها : ....
D05	ما هي مصادر المياه المستخدمة في Factors affected the darming الري على مدار الموسم الزراعيactivities	☐ lack of rain أمطار ☐ Flooding بئر زراعي خاص ☐ High temperature لا يوجد مصدر مياه ☐ Diseases شبكات ري عامة ☐ Electricity problems شراء ☐ soil problems مصدر آخر، اذكر انتاج ☐ Water salinity طرق أخرى أذكرها ☐ : Other ....—————
D06	حالة مصدر المياه (يجيب المبحوث Causes for not planting the عن السؤال في حالة كان المصدر بئرlands أو شبكة ري)	☐ ☐ ....
D7	نظام الري المستخدم في Agricultural water sourcesالزراعة	☐ Rain only.1 تنقيط ☐ Private well .2 سطحي ☐ Public irrigation network.3 Publicرشاشات ☐ Buy water.4 أخرى انتاج ☐ No source .5 طرق أخرى أذكرها
D8	The status of current water المياه اللازمة للريsources إجمالي التكلفة	——— Good كوب ——— Medium اشات ———Bad _ شيكل
D9	Irrigation مكافحة أمراض التربة system	☐ ....

.5 التحديات وكفاءة الأداءTreated wastewater

	برجاء تحديد مستوى Topic	Noازة	Yesسطة
.1	مكافحة ملوحةTreated wastewater knowledge المياه		
.2	التعامل مع نقصWastewater treatment methods موارد المياه		
.3	Control and precaution for use wastewater in التعامل مع انخفاض سعر البيع في السوقagriculture		
.4	Palestinian Guideline for treated استخدام طرق إنتاج جديدة مبتكرة في الزراعةwastewater		
.5	Agriculturak crops that are allowed to be التأثير في سلسلة القيمةirrigated with treated WW (قرارات البيع والشراء)		

.6 برأك ما هي المعيقات التى تواجه إعادة استخدام المياهObstacles to use treated wastewater

	المعيقات التى تواجه إعادة استخدام المياه العادمة Source of المعالجة للأغراض الزراعيةUse of treated wastewater	موافق Stronglyagree	موافق بشدةAgree	محايدneutral	معارضnon agree	معارض Strongly بشدةdisagree
	العادات والتقاليد فيCustoms and traditions المجتمع					
	التخوف النفسيPsychological fear					

APPENDIX C – QUESTIONNAIRE FOR BASELINE SOCIO-ECONOMIC STUDY

					عدم وجودLack of acceptance in community تقبل لذلك في الثقافة المجتمعية	
					ضعف الوعيweak environmental awareness البيئي	
					Lack ofعدم معرفة مدى امكانية استخدام المياه العادمة knowledge about reuse of WW in المعالجة في الزراعة agriculture	
					Health concernsالتخوف الصحي	
					Farmers ar areعدم قناعة المزارعين بأهمية الري not convinced in the importance of this resource	
					Lack of wwعدم وجود محطات معالجة مياه العادمة treatment plants	
					Lack عدم وجود كمية كافة من المياه العادمة المعالجة المنتجة منof clarity laws and legislations المحطة للإعتماد عليها	
					Lack ofعدم وضوح القوانين والتشريعات confidence in the precautions and controls	
					Nonعدم الثقة في جودة ونوعية المياه العادمة المعالجة acceptance in the society of products المنتجة irrigates with treated WW	

7. Promoting the use of treated WWبرأك ما هي أهم سبل تعزيز المياه العادمة وطرق معالجتها واستخدامها للاغراض الزراعية؟

معارض Strongly بشدةdisagree	معارضnon agree	neutralمحايد	موافق Agreeبشدة	Stronglyموافق agree	Sourceالمزارعين	
					إنشاء محطات معالجة قادر على تزويد المزارعين Establish treatment plants capable of بالمياه العادمة المعالجة بشكلsupplying farmers مستمر	
					Increaseزيادة وعي المزارعين بأهمية استخدام المياه العادمة المعالجة كمصدر ري farmers awarness رخيص	
					تفعيل دور الجمعيات التعاونية الزراعية Activating the role of agriculturalوالهيئات المحلية cooperatives and local bodies	
					Theوجود برامج توعية للمزارعين عبر الوسائل experience of awareness programs for المرئية والمسموعة farmers	
					Interest in agriculturalإهتمام بالارشاد الزراعي extension	
					Definition ofالتعريف بالمردود الإقتصادي للمزاره the economic return of farms	
					Policyوجود سياسة تدعم إعادة استخدام المياه العادمة المعالجة to support the reuse of WW	
					Incentives for farmersوجود محفزات للمزارعين	
					استخدام تكنولوجيا حديثة لانشاء محطات Modern technologies to establish wwمعالجة مياة عادمة treatment plants	

APPENDIX C - QUESTIONNAIRE TRAINING SESSION

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

OVERSEAS

UAWC

إتحاد لجان العمل الزراعي

الكلية الجامعية للعلوم التطبيقية

University College of Applied Sciences

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA DIPARTIMENTO DI INGEGNERIA CIVILE, CHIMICA, AMBIENTALE E DEI MATERIALI

مشروع اعادة استخدام المياه العادمة المعالجة فى الري بمنطقة مواصى رفح

(اختبار قبلي وبعدي)

Name of Farmer .... / اسم المزارع

ماذا تعرف عن المياه العادمة المعالجة المستخدمة في الري /

1.What do you know about treated wastewater in irrigation?

....

....

....

ما هي نسبة تأييدك للري باستخدام المياه العادمة المعالجة

2.What is your support rate for irrigation with treated wastewater?

% 100 – 75 % 75 – 50 % 50 – 25 % 25 – 0

من وجهة نظرك ايهما أفضل الري باستخدام مياه البلدية أو المياه العادمة المعالجة

3.In your opinion, which is better for irrigation using municipal water or treated wastewater?

مياه البلدية المياه العادمة المعالجة

من وجهة نظرك ما هي نسبة نجاح الري باستخدام المياه العادمة المعالجة

.4 In your opinion, what is the success rate of irrigation using treated wastewater?

% 100 – 75 % 75 – 50 % 50 – 25 % 25 – 0

هل تلقيت تدريب بخصوص استخدام المياه العامة المعالجة بالري من قبل

5 .Have you had previous training in using treated waste water for irrigation?

نعم **لا**

ما مدى قبولك للري باستخدام المياه العادمة المعالجة

6.What are your acceptable to irrigate with treated wastewater?

% 100 – 75 % 75 – 50 % 50 – 25 % 25 – 0

هل قمت باستخدام المياه العادمة المعالجة من قبل

7.Have you ever used treated wastewater before?

نعم لا

هل أنت على استعداد للري باستخدام المياه العادمة المعالجة في أرضك

8.Are you ready to irrigate with treated wastewater on your land (if you have)?

نعم لا غير مقرر حتى الان