April 28, 2005

Mr. Adrian Hewitt
Principal Environment Officer
Environment & Regeneration Department
London Borough of Merton
Merton Civic Centre
London Road
Morden, Surrey SM4 5DX
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Dear Mr. Hewitt:

Enclosed is our report entitled Distribution Route Assessment for a Combined Heat and Power System. It was written at the Merton Civic Centre during the period March 14 through April 28, 2005. Preliminary work was completed in Worcester, Massachusetts, prior to our arrival in London. Copies of this report are simultaneously being submitted to Professors FitzPatrick and Salazar for evaluation. Upon faculty review, the original copy of this report will be catalogued in the Gordon Library at Worcester Polytechnic Institute. We appreciate the time that you and your staff have devoted to us.

Sincerely,

Andrew Papia
Brian Day
Denise Donoghue
Ryan Casey

MSF- 0505
GFS- 0513

Distribution Route Assessment for a Combined Heat and Power System

A Report Submitted to:

Professor Malcolm FitzPatrick and Professor Guillermo Salazar

London, Project Center

By

Ryan Casey ____________________________

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In Cooperation With

Adrian Hewitt, Principal Environment Officer

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April 28, 2005

This project report is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinions of Merton Council or Worcester Polytechnic Institute.

This report is the product of an educational program, and is intended to serve as partial documentation for the evaluation of academic achievement. The reader should not construe the report as a working document.

Abstract

The London Borough of Merton (LBM) has determined that a pyrolysis combined heat and power (CHP) plant has the potential to supply local sites with inexpensive heating and electricity while eliminating waste and reducing overall CO_2 emissions. The objective of this project was to investigate the most effective route for heat and power distribution from the Willow Lane Industrial Estate to the Canons Leisure Centre based on economic, technical, environmental, and social considerations. This route assessment will guide the LBM in their implementation of a CHP distribution network.

Authorship Page

This report is a collaborated effort of all research team members. Every section was written and edited by more than one person; however each person developed an area which they focused on. Environmental issues were researched by Denise. CHP and construction specifications were determined by Andrew. Brian concentrated on constraint mapping and route determination. All maps were compiled and/or created by Ryan.

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Thanks also to Merton's Environment & Regeneration Department for accommodating us during this research project.

Executive Summary

The modern industrialized world's increasing dependence on fossil fuels as a main source of energy has had the unanticipated effect of global warming, which is primarily caused by escalating levels of CO_2 emissions. An international summit on climate change created the Kyoto Protocol, which calls for a reduction in CO_2 emissions beyond the year 2000. The European Union, of which the UK is a member, signed the Protocol on April 29, 1998. Additionally the UK set its own more aggressive domestic CO_2 reduction targets. As a result, the UK is actively pursuing ways to reduce its carbon emissions.

One of the most promising methods for reducing carbon emissions is combined heat and power (CHP) technology. This technology captures the waste heat given off during electrical power generation and utilizes it to heat buildings. The Killoughery Group, a waste disposal company, has expressed interest in constructing a pyrolysis waste disposal plant in Merton. The London Borough of Merton (LBM) has determined that the methane produced by this pyrolysis waste incineration process can be used as fuel for a combined heat and power plant. This plant will be capable of supplying local sites with affordable heat and electricity while simultaneously reducing overall CO_2 emissions.

Located one kilometer north of the initial CHP site, the Canons Leisure Centre currently uses inefficient, out of date heating and cooling systems. The Centre's high heating, cooling and electricity demands make it an ideal first candidate to draw heat and electricity from the CHP plant.

This project investigated the optimal route(s) for distributing heat and power from the CHP site to the Leisure Centre. The route assessment was based on the technical aspects of the network's installation and operation, surface and subsurface features, environmental considerations and policy constraints. This project should help the Borough of Merton design and implement an efficient, cost effective, and environmentally friendly source of heat and power.

In order to perform a thorough analysis of potential routes for this CHP network, information had to be gathered from a wide array of sources. Initially, archival research along with professional contacts helped to define the technical aspects of the network and the necessary construction methods. A key element to this project was locating information about potential

route obstacles. Much of this information was found in Merton's GIS database in the form of map layers. Additionally, some obstacles, such as subsurface infrastructure were found using other sources of information including traditional maps and other forms of mapping software.

By examining the information gathered through archival research and conversation with professional contacts, potential routes were defined. On-site observation was then used to gather more information about these routes that was not obvious by looking on a map. Analysis of this information identified a primary route area from the CHP site to the Canon's Leisure Centre. Following the determination of this route, a risk analysis was performed on the route to determine the potential risks, or unknown elements, which would come into play during implementation.

To determine the technical requirements of the distribution system, a desktop load assessment was necessary. This load assessment estimated an upper bound of 3.9 MW total heat load and 3.2 MW total electrical load. A best practice guide indicated a temperature rating of up to 120°C and pressure up to 16 bar was preferred for this type of system. The heat pipes required for this system are dual 125 mm pre-insulated steel pipes within a 400 mm diameter high density polyethylene outer casing. The electrical transmission lines should be 35 mm^2 three-core aluminum XLPE cable operating at 11 kV and 96 A at 65°C.

Through research in the areas of construction requirements for this system, it was found that the heat pipes would need to be buried with a minimum 400 mm of cover, with 100 mm of stone-free sand surrounding the pipe. In between the heat pipe and transmission lines, there should be a clearance of at least 300 mm. Transmission lines require a minimum depth of 450 mm under footways and 600 mm under roads, resulting in a total minimum required trench depth of 900 mm and width of 900 mm for the heat pipes and electricity cables.

Once the technical requirements of the CHP distribution network and its construction were identified, a method known as constraint mapping was used to recognize potential routes. This process begins with a digital map of the areas of interest, and potential barriers are layered on the map in order of their level of constraint. For this assessment, initial layers were buildings and property ownership, including railways and roads, followed by existing subsurface infrastructure and biodiversity areas. Further considerations were flood zones and contaminated land, geology, archaeology, road traffic, and surface features (walls and street furniture). Points of opportunity for route crossings are identified after the addition of each layer. At the conclusion of the constraint mapping exercise, a more defined area for running this network was identified for further investigation. Using the information obtained from on-site observation, a route recommendation was formed (Figure 1).

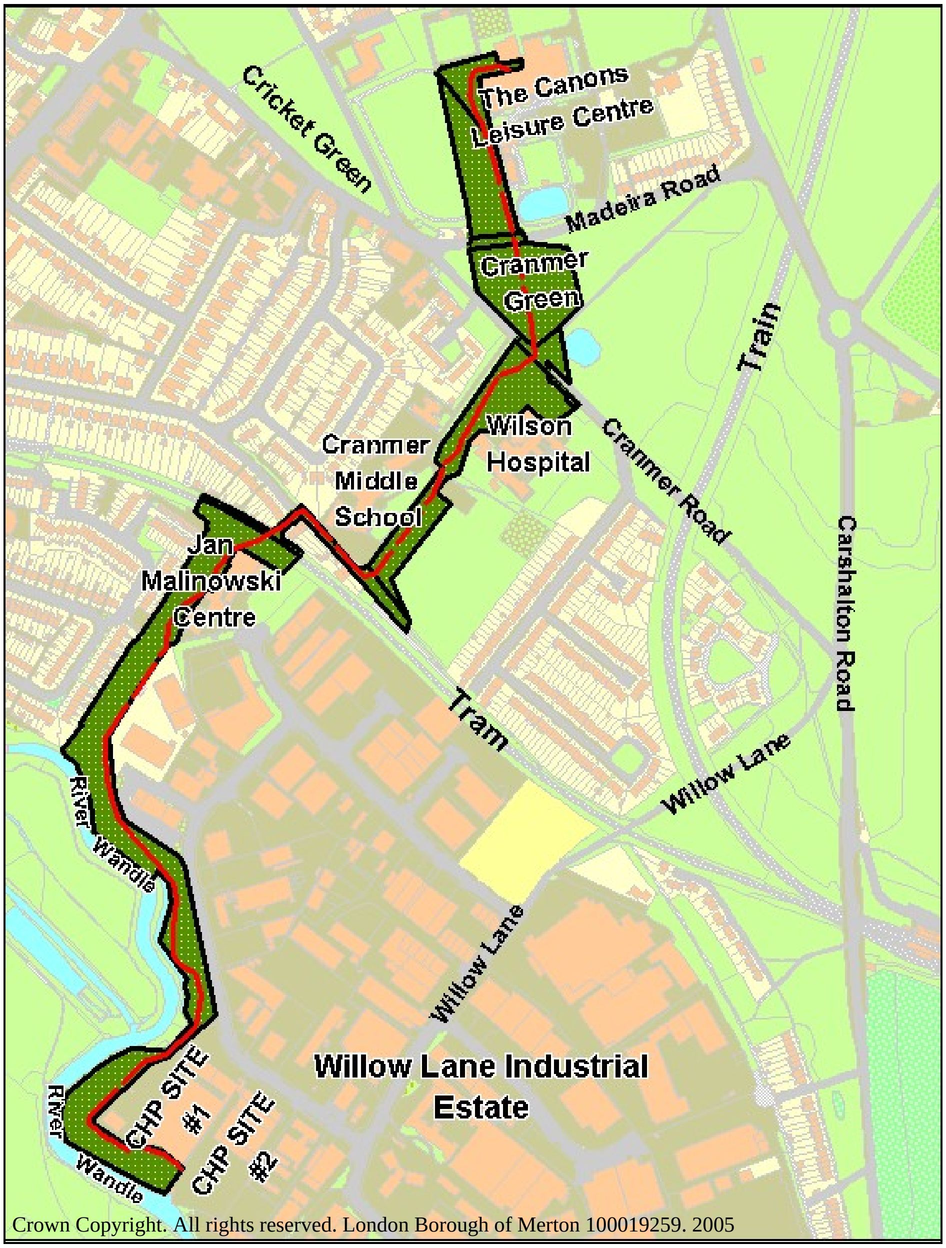

Figure 1: Proposed Route Shown in Red

The route will begin from the rear of CHP Site #2. Utilizing the area along the River Wandle, a lack of existing underground utilities will simplify excavation. The route will run north between the industrial park and the river, underneath the Wandle Riverside Walk. This area is clear of vegetation, and is a stable surface suitable for infrastructure installation. The route will run north into the Jan Malinowski Centre's parking lot along the west side of the building and out of the rear of the property. At this point, the route will have to cross the tramline and will enter under the end road branching off of the street named The Close. The lines will continue east down the tramway path behind the Rose Cottages and will turn north into the playing field at Cranmer Middle School. From here, it will run along the line of trees on the edge of the field and will continue into the back of the Wilson Cottage Hospital. The route will run through their parking lot and will exit underneath the wooden gate. After crossing Cranmer Road it will run through Cranmer Green towards the Leisure Centre. Then, the route will go under Madeira Road and continue down the footpath on the west side of the Canon's Leisure Centre where it meets its destination.

Through this intensive data gathering and analysis process, a number of variables were identified that must be further investigated. The relative uncertainty of these unknowns was quantified in a risk assessment. The following radar graph (Figure 2) shows the relative risks broken down by category for easy identification. The graph shows that the greatest risks were transport, sub-surface, and environmental. Recommendations were made on how to minimize each of these risks for the proposed route. For example, an Environmental Impact Assessment should be performed for the proposed route, a detailed subsurface infrastructure survey should be conducted, and a plan for crossing the railroad without disrupting tram service should be prepared.

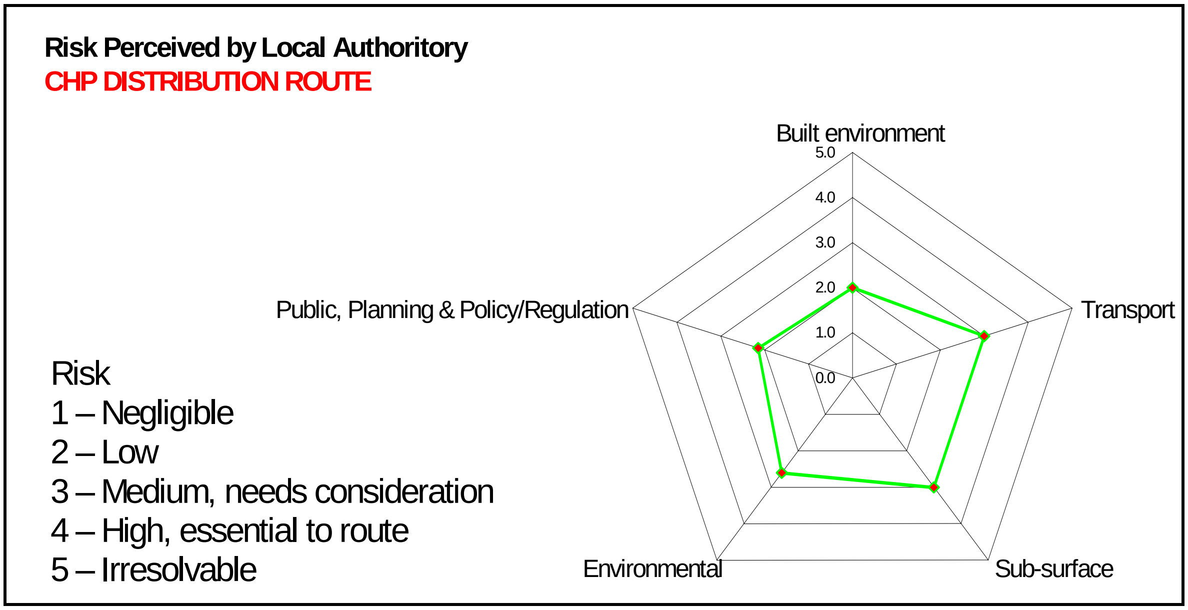

Figure 2: Graph of Perceived Risk

Additional work remains beyond the scope of this project to move towards the implementation of a CHP system. End-user loads will have to be assessed, the CHP plant designed, and the distribution system engineered. A construction plan for installing the infrastructure along the route must also be worked out in detail. Following these recommendations will help the Borough of Merton implement the first phase of a district heat and power system.

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1. Introduction

Industrialization in the modern era has rapidly increased the global demand for energy. Today's industrial society depends heavily on the use of fossil fuels, including its use for heating and the generation of electricity. Unfortunately, high levels of carbon dioxide are a byproduct of fossil fuel combustion. The accelerating rate of CO_2 emissions has created global warming and climate change (The Department of Trade and Industry [DTI], 2003). In an effort to reduce CO_2 emissions, members of the European Union (EU) signed the Kyoto protocol in 2002, which called for the allocated reductions of emissions worldwide (European Union [EU], 2002). As a European Union member, the United Kingdom issued a White Paper, which outlined plans for reducing carbon emissions by switching to alternative energy sources.

As a leader in this effort, the London Borough of Merton (LBM) is investigating alternative power generation methods such as solar power, wind power, geothermal heat pumps, fuel cells, energy from waste, and combined heat and power (CHP). In the winter of 2003, a team of WPI students studied geothermal heat pump feasibility for LBM. This team determined that the system was technologically incompatible with existing structures (Aery, Draper, Giang, & Smith, 2003). Since then, a CHP driven district heat and power (DHP) scheme has emerged as "the most cost effective way of achieving major CO_2 emissions reductions" (Rawes, Hewitt, & Makin, 2005, p.13). CHP technology has the ability to convert up to 90% of the energy stored in fuel into usable heat and power (Evans, 1996). This is achieved by utilizing thermal waste produced during power generation to supply heat to local buildings. The scheme could also be supplemented by solar, wind, or geothermal technology. Another WPI research team working with the Borough of Merton in 2004, collected data to help the Borough conduct a CHP feasibility study (Contrino, Ford, Trexler, & Wing, 2004). The Borough of Merton has also worked with outside consultants and reviewed successful district heat and power (DHP) schemes. As a result of this research, the LBM would like to implement a DHP network within the next three years to power new developments and renovated buildings in southeast Merton.

Merton has proposed locating a CHP plant on the Willow Lane Industrial Estate. This plant will eventually supply heat and power to a network of industrial, commercial, leisure, and residential sites in the surrounding area. The first site identified for the DHP network was the Canon Leisure Centre. In order to proceed with the design and implementation of the new system, immediate answers were needed by Merton to determine the most effective method and route for delivering heat and power from the CHP plant to the Leisure Centre. The cost of materials for the distribution network and construction costs for particular routes were necessary in order to make a route assessment. The environmental impact of the distribution system, specifically its effect on urban open spaces such as green corridors needed to be addressed. Social considerations with regards to construction of the distribution network and its effect on noise and traffic also needed to be made. For Merton to be successful in implementing this energy scheme, it was essential that these assessments be made.

In order to make a route assessment, it was necessary to collect information about many different aspects of the distribution system. Initially, the technical specifications of the distribution heat pipes and transmission lines were determined. Then the construction codes and methods were researched in order to determine the technical requirements for infrastructure installation. Potential obstacles were identified and prioritized such as railroads, buildings, right-of-ways, conservation land, and existing subsurface infrastructure. All of this information was combined and analyzed to provide a specific route recommendation and a risk assessment to the Merton Council.

This project will help the Borough of Merton design and implement an efficient, cost effective, and environmentally friendly source of heat and power. Although small in scale, this initial system will be the first phase of Merton's DHP scheme. This will serve as a pilot for future systems in Merton, ideally resulting in the integration of these systems into one network at a later date. Once implemented, this concept can function as a model for other communities seeking to reduce carbon emissions.

This report was prepared by members of the Worcester Polytechnic Institute London Project Center. The relationship of the Center to the London Borough of Merton and the relevance of the topic to the Borough of Merton are presented in Appendix A.

2. Background

2.1 Introduction

The modern industrialized world's increased dependence on fossil fuels as a main source of energy has had an unanticipated effect on the environment. Carbon dioxide emissions create global warming through the greenhouse effect, which results in climate change and its effects such as flooding and drought (DTI, 2003). Concern over these environmental extremes has prompted the international community to initiate reductions in the overall level of carbon emissions. This can be accomplished by using alternative energy sources and more efficient methods of energy production (EU, 2002). The London Borough of Merton is one of the leading communities in the UK in this effort to develop alternate energy. This chapter addresses the environmental concerns of carbon emissions, the government response in the EU and the UK, and looks at the London Borough of Merton's specific reasons for pursuing CHP generation. It also explains combined heat and power (CHP) technology and it can be used to reduce carbon emissions. This chapter concludes with the Borough of Merton's opportunity to implement a CHP system on Willow Lane to power the Canon Leisure Centre.

2.2 Environmental Concerns

2.2.1 Air Pollution

A growing concern for the smog and air pollution levels in London has developed over the past 50-100 years (London Air Quality Network [LAQN], 2005). Traditionally, smog was created by burning coal throughout the city for heating and industry. Even though coal is no longer used as frequently today, the pollution levels have still increased. The majority of this pollution results from the combustion of fossil fuels such as the gasoline, natural gas, and oil used to power cars, heat houses, and create electricity. The increasing concentrations of pollutants have a negative effect on citizens, especially the elderly and those with asthma (LAQN, 2005). Although it is not believed to cause asthma, poor conditions can greatly affect the breathing ability of those with asthma, requiring them to spend less time outside and use their medication more frequently (LAQN, 2005).

Carbon dioxide is a recognized form of air pollution, with its elevating concentrations allowing a higher percentage of infrared (IR) rays to be trapped in the atmosphere and reflected to the earth in a phenomenon known as the greenhouse effect. This effect is slowly increasing the temperature of the planet as more rays cannot escape and their heat is retained in the atmosphere, causing the polar ice caps to melt, oceans to rise, and weather patterns to change. "The 1990s were the warmest decade since records began," (DTI, 2003, Summary p.2) and continued global warming could have an immense impact on the planet. Sea level rose 10-20 cm during this past century, and as polar ice continues to melt, the additional water supply will increase levels as much as an 88cm during the next hundred years (Hileman, 2004). Greenland along with the West Atlantic Ice Sheet may melt entirely unless the concentrations of green house gases, such as carbon dioxide, can be reduced. In the opinion of the United Kingdom's chief science advisor, David King, "…Climate change is the most severe problem that we are facing today--more serious even than the threat of terrorism" (Hileman, 2004). To prevent the drastic climate changes, new technology and emission reducing regulations must be created and enforced.

2.2.2 Diminishing Fossil Fuel Sources

Today's dependence on fossil fuels is also challenged by their limited quantities. Diminishing fossil fuel supplies as well as increasing fuel prices presents the need for alternate sources and more efficient uses of energy for the future (Hewitt, 2004 & DTI, 2003). Presently, this research includes not only methods using no fossil fuels such as solar panels, but also method which can produce more from the fossil fuel consumed. The North Sea oil and gas, which currently supply the region, will soon be exhausted and other local assets such as coal are expected to run out in approximately ten years (DTI, 2003). In the meantime, prices continue to rise and many households spent more than 10% of their income to heat their homes in 1996 (DTI, 2003). Reducing this *fuel poverty* has become a goal of the UK, and more efficient, environmentally friendly systems are being investigated in order to reduce the amount of fossil fuels needed to create the demanded energy. These systems burn less fossil fuel, therefore releasing fewer carbon emissions and costing less money to operate002E

2.3 Government Response

2.3.1 Kyoto Protocol

Beginning in 1992, the international community recognized the dangers of climate change and began working together to improve environmental conditions by reducing emissions. The Kyoto Protocol was introduced in 1997 as an agreement to reduce emissions between 2008 and 2012. The measure was approved by the European Union in 2002 with members agreeing to collectively reduce greenhouse gas (GHG) emissions by 8% below the 1990 levels before 2012. Each of the 15 original members has agreed, under the EU burden-sharing agreement, to an individual target in order to achieve the overall reduction. As of 2002, eleven of the fifteen original members expect to meet their goals between currently existing programs and projects they intend to implement. The United Kingdom was well on track, and has expectations to exceed their goal by 2010. (European Environment Agency [EEA], 2004)

To achieve these targets, the protocol recommends a variety of new strategies and targets for improvements. Renewable energy such as wind, water, or solar can be used to produce electricity, thereby reducing the fossil fuels burned. Implementation of a combined heat and power (CHP) system is also suggested in the UK White Paper to reduce emissions and increase efficiency (EEA, 2004 & DTI, 2003). Energy efficiency can be improved by updating insulation, and installing new windows to increase the energy performance of buildings (Defra, 2005). The United Kingdom (UK) has already reduced emissions by using natural gas to generate electricity instead of the traditional oil or coal (EEA, 2004). For transportation improvements, bio-fuels can be considered as well as subjecting new cars to higher emissions standards (EEA, 2004 & EU, 2001). Modes of transportation will be the largest obstacle for member countries to overcome due to the growing number of vehicles and the time needed to phase in new, more environmentally conscious alternatives (EEA, 2004).

2.3.2 UK Response

The UK issued a White Paper which outlines plans for further emission reduction and improvements (DTI, 2003). The goal is a 60% reduction of greenhouse gas emissions by 2050. An additional target is the generation of 10% of required energy from renewable systems, which will help adapt the country to the declining energy supply from fossil fuels by 2010 (DTI, 2003).

The center of this White Paper focuses on switching to renewable energy sources such as wind farms, which the UK has a large natural opportunity for offshore. One consideration for the design of these farms is to insure they will not interfere with the Ministry of Defense's training and radar in the area.

Combined heat and power plants are another a promising technology being promoted in the UK, which have the ability to generate heat and electrical power from a single, central unit, realizing higher energy efficiency than conventional plants. The UK is also researching biomass and fuel cells for future implementation; however, nuclear technology has been ruled out for economic and waste management reasons. One strategy for reducing emissions is implementing higher efficiency standards on new construction, and higher standards for general goods and appliances, such as refrigerators, to conserve energy.

The United Kingdom created incentives in an attempt to guide the market towards renewable sources, improving the environment and decreasing overall costs of energy. In order to entice a movement towards more environmentally conscious sources of energy, any required fuels for a system with reduced emissions, such as CHP, are exempt from the Climate Change Levy, which taxes fossil fuels. The UK emissions trading scheme is providing additional incentive. Similar to existing programs for agricultural and fishery policies, companies are allotted a certain number of emission credits, which they can release into the atmosphere. If a company releases less carbon emissions than it is allowed, it can sell the excess credits to another company who may be above their limit. These sales provide an additional source of revenue without increasing damage to the environment (European Union [EU], 2000). Government backed organizations and committees are assisting the cities and boroughs in the process by providing as much funding as possible. Research and studies are currently taking place throughout the UK investigating various methods and systems to achieve reduced emissions and improved efficiency. The London Borough of Merton (LBM) is on the forefront of this research.

2.4 The Borough of Merton

The Borough of Merton is an urban suburb situated in the southwest corner of London. The Borough covers 14.7 square miles and is approximately eight miles from central London. Merton's present day boundaries were formed in 1965 when the Boroughs of Mitcham, Morden, Merton and Wimbledon were combined under one governing authority called the Merton

Council. According to Merton census data, 190,000 residents live in the Borough (National Statistics, 2005). Merton also has a number of urban open spaces and common areas. One urban open space is Cranmer Green, which covers 3 hectares and is located .5 km southwest of Mitcham Town Centre (Nicholson & Scott, 2001). The Green also abuts Mitcham Common, a 168-hectare open space. Both Cranmer Green and Mitcham Common are areas rich in biodiversity including wetlands, secondary woodlands, ponds and grasslands (Local Agenda 21, 2001).

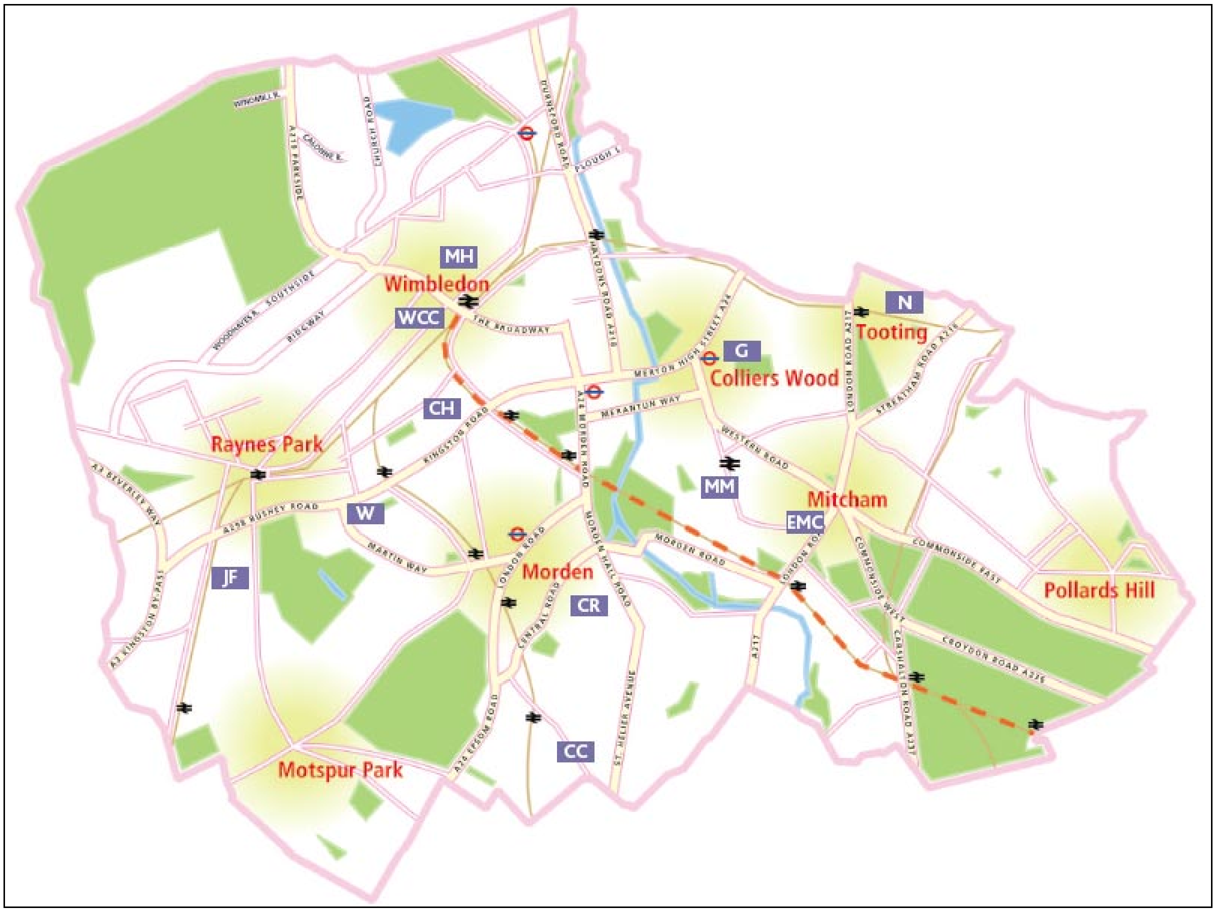

Figure 2.1: Map of the London Borough of Merton
Source: http://dev.limehouse.co.uk/merton/images/map_large.jpg

2.4.1 Local Response to Climate Change in Greater London

In compliance with the U.K. White Papers, the London Borough of Merton has made it a priority to develop local strategies for reducing carbon emissions to combat climate change. According to the Merton Council, “As a local authority, it would be irresponsible for Merton to ignore this growing threat to the future well-being of its own residents – as well as the wider global community" (Hewitt, 2004). One of the Merton Council's top local priorities is to reduce carbon emissions through more efficient energy usage practices and generation methods.

Three categories can be used to classify sources of carbon emissions from the burning of fossil fuels: industry, transportation, and buildings. It is difficult for local governments to play a significant role in reducing carbon emissions from transportation or industry. However, local government's such as the Merton Council can effectively use their authority to regulate carbon emissions from all buildings within their jurisdiction. For example, the Borough of Woking has introduced a number of measures to protect the environment and reduce pollution. The Woking Council has adopted a variety of energy and water saving techniques for Council-owned buildings and public places. One example is a combined heat, power and cooling system in the Woking Town Centre. This system distributes electricity, heat and chilled water to local customers around the town center, including two hotels, a nightclub, a leisure complex, an event center, and the Woking Civic Offices. Implementation of this combined heat and power system has reduced energy consumption in the town center by 30% since the plant was completed in 2001 (Thamesway Energy Ltd., 2001 & Luckey, 2001). Subsequently, this has reduced Woking's carbon emissions.

2.4.2 Merton's Response

The Merton Council has also proposed measures for reducing carbon emissions from buildings using a Borough wide planning policy. Merton's Unitary Development Plan encourages this recommending a number of energy saving measures including the development of renewable and local energy facilities. The Merton Council also requires that 10% of energy used by new non-residential developments larger than 1,000 sqm. come from renewable generation methods (Borough of Merton, 2003a). In addition, through membership in programs such as the London Local 21 Agenda, Merton has positioned itself as a leading force in regional efforts promoting energy conservation and environmental protection. These efforts have also included providing educational resources to Borough residents explaining how changing energy usage habits can reduce carbon emissions and help combat climate change.

Additional initiatives reflecting Merton's progressive energy, environmental, and social proposals include the Air Quality Action Plan, the Community Plan, the Housing Strategy for 2004-2007, the Recycling Plan, and the Open Spaces Strategy (Borough of Merton, 2005b). The

Borough is also a partner in the European Union Local Energy Technology Implementation project or EU LETIT. The primary objective of LETIT is to develop a methodology for local authorities to identify the sustainable energy potential of local assets under their control. The LETIT's secondary objective is to serve as a central location for exchanging information related to new energy technologies (LETIT, 2005). Additionally, the Merton Council plans to initiate infrastructure projects similar to those undertaken in the Borough of Woking. Merton's progressive energy policies have given the Borough the reputation as a leading force behind sustainable, renewable, and environmentally friendly energy in the United Kingdom. Reducing carbon emissions in the Borough of Merton, however, is only one incentive the Merton Council has for investigating more efficient and sustainable methods of energy generation.

2.4.3 Economics

The Merton Council also has an economic reason for investigating more efficient, sustainable methods of energy generation. Average temperatures in Merton during the winter months vary between 0˚C and 10˚C. Average temperatures in Merton during the summer months vary between 9˚C and 22˚C (Weather Channel, 2005). This type of temperature swing requires long periods of energy usage for both heating in the winter months and cooling in the summer months.

Energy demands by Borough residents and businesses are continually increasing. At the same time, global fossil fuel prices have risen as well. Oil prices in the U.K. have increased at an even faster rate. In fact, from May 2004 to November 2004, Merton has seen a 49% increase in gas prices and a 39% increase in wholesale electricity prices. During this same time period, business users in LBM have seen a rise in the retail price of gas from 0.9 pence per kilowatt-hour (kWh) to 1.8 pence per kWh. This is a 100% price increase. The impact rising energy costs have had on the Borough of Merton is seen in the following chart (Table 2.1) of Merton Civic Centre energy costs from the years 2002-2003 and 2003-2004, put together from LBM Estates Department data.

Table 2.1: Energy usage by Merton Civic Centre

Year	Electric	Gas heating	TOTAL	£ Increase	% increase
2003	£131,750	£20,000	£151,750		
2004	£162,000	£34,500	£196,500	£44,750	29.5%

Source: Adrian Hewitt, 2005

The cost to the Merton Council for energy usage in the Civic Centre has increased by almost 30% from 2003 to 2004. In addition, the amount spent on electricity by the Merton Council has increased 7.5% in this same period (Hewitt, 2004). A more efficient method of energy generation could decrease this spending and benefit the borough.

2.4.4 Hazard Management & Insurance Risk

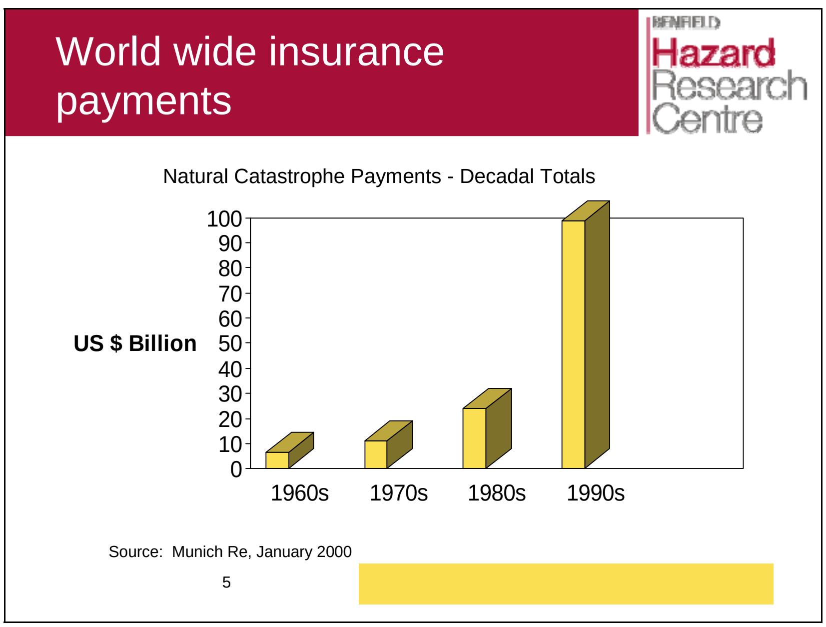

Figure 2.2: Natural Catastrophe Payments in US $
Source: Crichton, 2004

The London Borough of Merton also has reason for pursuing more efficient and sustainable methods of energy generation based on the increasing insurance risk posed by the harmful effects of climate change. As shown in Figure 2.2, in the period from 1980 to 2000 and accounting for inflation, insurance claims worldwide for natural catastrophes have nearly doubled (Crichton, 2004). Weather patterns in the United Kingdom are also changing. According to the Met Office, an environmental and meteorological service for the UK, the amount of precipitation falling in winter is increasing. At the same time, the amount of precipitation seen in the UK during the summer months is decreasing (Crichton, 2004). Moreover, in the last twenty years, according to the Met Office, the number of storms crossing the UK has doubled. Figure 2.3 shows the rapid rise in average temperature of the Northern Hemisphere over the last one hundred years. Throughout Europe and especially in the UK, these economic and climatic trends are being linked to the negative effects of climate change. Over time, reducing greenhouse gas emission will slow climate change and reduce the trend of rising insurance costs. Therefore, Merton has an insurance and hazard management incentive for reducing greenhouse gas emissions.

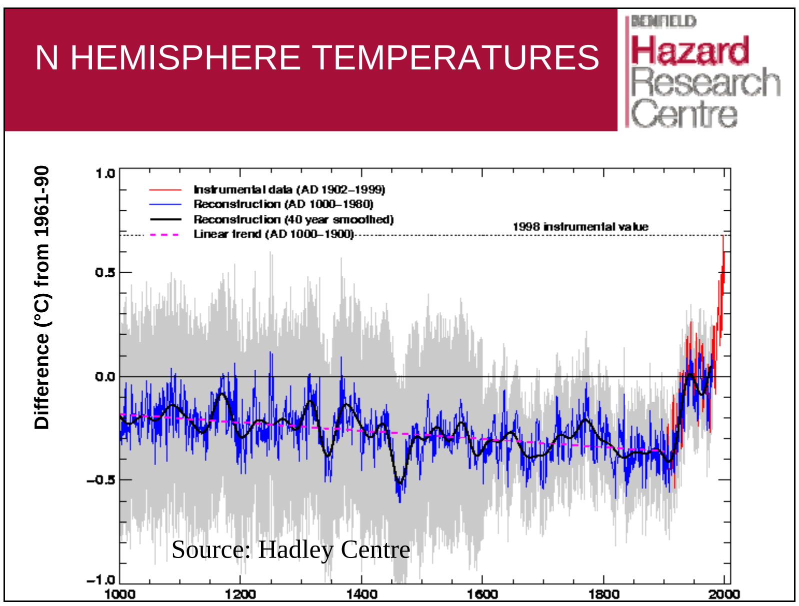

Figure 2.3: Northern Hemisphere Temperatures from the year 1000 to the year 2000
Source: Crichton, 2004

2.5 Combined Heat and Power

In compliance with recently adopted EU and UK emissions regulations, along with Merton's current policies, the Merton Council is planning the implementation of a more effective energy generation to reduce carbon emissions.

CHP technology has emerged as potentially the most effective option for reducing CO_2 emissions for the Borough of Merton. LBM officials are planning the implementation of a CHP driven district heat and power (DHP) scheme, and require data collection and analysis to help them make informed decisions about the distribution network of the system. Before assessments can be made about a CHP distribution system, it is necessary to discuss CHP technology and how it has evolved.

CHP is a technique of energy generation that is continually being improved and innovated. Conventional power generation strives to maximize the amount of useful electrical power produced per unit of fuel and releases the residual heat as a waste product. CHP systems generate electricity in a similar manner, but utilize this waste heat to create steam or hot water for heating and in some applications cooling. By doing this, CHP can maximize the amount of useful energy produced from the fuel. A typical coal-fired power plant can achieve only 36% electrical efficiency; however CHP plants are capable of reaching 90% total energy efficiency (Evans, 1996).

The cogeneration of heat and power is not a new technology like geothermal heat pumps or photovoltaic solar cells. It was in fact more common in the early 20th century than it is today (Evans, 1996). As power plants grew in scale, they increased in efficiency. The power grid was developed to transmit the power to the consumer. The availability of inexpensive power from the power grid and heating from natural gas pipelines reduced the attractiveness of constructing cogeneration plants for new developments. This has changed in recent years as privatization of the electricity production and heating industries has increased competition in the power and heating markets. The heightened awareness of environmental concerns surrounding carbon emissions from the combustion of fossil fuels has further added to the attractiveness of alternative power generation systems. The demonstrated high fuel efficiency of modern gas-powered technologies such as combined cycle gas turbines (CCGT) used in CHP schemes has increased the power generation industries' willingness to use gas-based power generation (Evans, 1996). For these reasons, Europe especially has heavily expanded the use of cogeneration over the last two decades.

Recent developments in CHP technology have shown the suitability of CHP schemes to also provide cooling through the absorption process. Advanced CHP systems now provide tri-generation of heat, electricity, and cooling.

2.5.1 Small-scale CHP

There are three broad sectors to the CHP market: small-scale CHP, district heat and power (DHP), and industrial CHP. Small-scale CHP is for applications where the power demand is less than 1MW. CHP units in this sector are primarily natural gas driven reciprocating engines (Evans, 1996). However, several companies have recently starting producing gas turbines in the 30 to 500kWe range designed especially for CHP (Dettmer, 2000). These are often referred to as *micro-CHP*.

Another possibility to drive a small-scale CHP currently under development is the fuel cell. There are four competing fuel cell technologies, all of which use a chemical reaction to produce electric current and heat. They have achieved electrical efficiency up to 45% with only negligible amounts of pollution (Kaarsberg, 1998). One barrier to the use of fuel cells in small-scale CHP is the relatively low temperature of their exhaust heat. This makes them less suitable for applications such as absorption chilling and industrial processes that require higher water temperature to operate effectively (Kaarsberg, 1998).

Typical applications for this market sector are hotels, offices, and large scale residential buildings (Evans, 1996). CHP has been broadly expanding in this sector but it still largely untapped. As of 1998, of the UK's 69,849 non-domestic electricity customers, 92% had power demands of less than 1MW but only 1.8% used small scale CHP for their power (Dettmer, 2000). Small-scale CHP was previously held back by the relatively high cost of purchasing small-scale CHP units but now is becoming more attractive as technology improves and higher production numbers reduces costs.

2.5.2 District Heat and Power

The second major market sector for CHP is district heat and power (DHP). In this application, a central power station provides electricity and heating to a discrete number of buildings in the local community. The prime power generators for the majority of these applications are large gas turbines. These systems have been relatively successful in Germany, Denmark, and other regions of Europe but competition from established gas grids has prevented large market penetration. In the mid-1990s, less than 10% of electricity production in the European Union was from cogeneration with significant variation among the Member States

(Grohnheit, 2003). The cost of developing the necessary transmission and distribution systems for DHP is a major barrier to its widespread adoption.

2.5.3 Industrial CHP

The final market sector is industrial CHP. Industrial complexes are often very suitable for CHP because they typically have large heat and power demands. Industrial companies also generally have more capital to invest in heat and power generation plants in order to reduce their overall power and heating costs. CHP can often be adapted to the specific heat and steam requirements of industrial processes such as paper, chemical, petro-chemical, and pharmaceutical production (Evans, 1996). A customized CHP plant designed for a certain industrial complex can significantly reduce power and heating costs when compared to buying directly from electricity and gas grids. For these reasons, significant investment has been made in industrial CHP over the last several decades (Evans, 1996).

2.5.4 District Cooling with Absorption Chillers

Recent developments in CHP technology have shown the suitability of CHP schemes to also provide cooling through the absorption process. Advanced CHP systems can provide tri-generation of heat, electricity, and cooling. Cooling can be achieved by the use of absorption (ABS) chillers; either at the individual sites or by generating and pumping chilled water at the plant. Centralizing the ABS chiller at the plant can reduce the space requirements for equipment at individual sites and make use of very large and efficient chillers. However, additional pipes would be required to circulate the chilled water throughout the distribution network. Distributing the absorption chillers among the various sites ensure that the local chiller is sized to meet the site's cooling needs. A diagram of an absorption chiller used in a community heating network is shown in Figure 2.4.

The ABS chiller is made up of five main components: the generator, condenser, evaporator, absorber, and exchanger. The generator works by using the hot water provided by the CHP to boil a refrigerant solution, typically water or ammonia, with an absorbent, lithium bromide or water respectively. As the solution boils, the refrigerant vaporizes and the absorbent concentrates. The refrigerant vapor is then drawn into the condenser, which condenses the refrigerant with cooling water. The liquid refrigerant then flows into the evaporator. The lower pressure of the evaporator causes flashing which cools the remaining liquid refrigerant down to the saturation temperature. This is approximately 4°C for lithium bromide and water chillers. Chilled water is circulated through the refrigerant, cooling the water and vaporizing the refrigerant. This vapor is then drawn into the absorber, which liquefies the refrigerant and is circulated back to the generator (Energy Efficiency Best Practice programme [GPG234], 2002).

The final component of the system is the heat exchanger, which transfers heat from the warm concentrated solution to the absorber. The dilute solution is then transferred back to the generator. This reduces the amount of heating required by the generator and the amount of heat rejected by the absorber. An auxiliary cooling fan or tower cools the cooling water required by the condenser and absorber (GPG234, 2002).

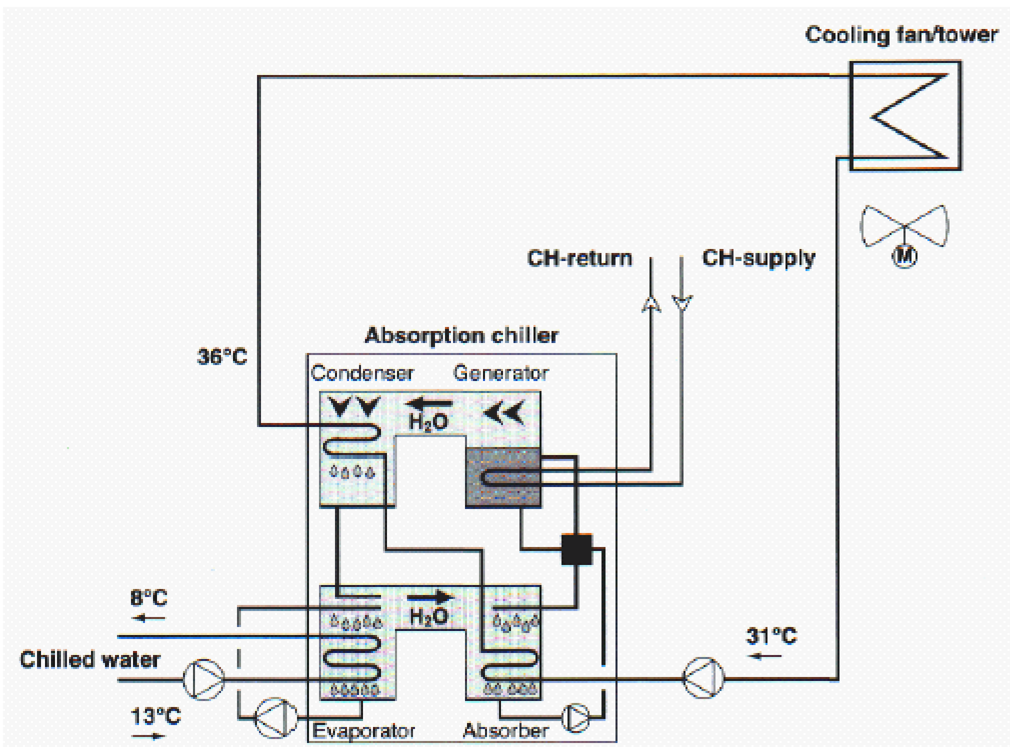

Figure 2.4: Typical absorption chiller used in community heating network
Source: GPG234, 2002

An important design consideration is that the larger the hot water temperature from the CHP, the less expensive the required ABS chiller is. Modern ABS chillers are designed to operate from 90- 120°C (GPG234, 2002).

2.5.5 Power Generators

Central to the design of any CHP system is the power generator. The most prevalent power generators used in CHP systems are reciprocating diesel engines and gas turbines (Dettmer, 2000). These engines require fossil fuels such as natural gas or diesel oil and have some level of CO_2 emissions. Though far more efficient than separate heat and power systems, greenhouse gas emissions still pose a threat to the environment. Recent developments in alternative fuel sources have been made to further reduce the greenhouse gas emissions of CHP systems.

2.5.6 Bio-fuel

One alternative to fossil fuel is bio-fuel. Although bio-fuel, derived from wood-chippings or agricultural crops, still emits CO_2 during combustion, it is considered to be renewable energy because the bio-mass is continually being grown in a *closed carbon* cycle (Hewitt, 2004). Though there is some merit to using bio-fuel, it still poses a risk to the environment and has much of the same issues as fossil fuel.

2.5.7 Anaerobic Digestion

Another alternative is anaerobic digestion. Compostable material, such as paper and kitchen waste, is digested by bacteria producing methane (Compact Power, 2005). The methane is then used to fuel the power generator for the CHP system. This has the added benefit of consuming waste that would otherwise be deposited in landfills. Waste incineration is also a possible driver for CHP but has many constraints that make it difficult to implement in the Borough of Merton (Hewitt, 2004).

2.5.8 Pyrolysis CHP

Another interesting option is pyrolysis CHP. Pyrolysis is a process in which domestic and commercial waste is baked in a sealed oxygen free chamber (Compact Power, 2005). No carbon emissions are produced because the process involves no oxygen and therefore no combustion. The process produces methane, similar to anaerobic digestion, which is used to fuel the CHP system. Pyrolysis leaves behind non-leachable residue of carbon char, inert materials, and heavy metals, and results in an 85 to 95% reduction by weight in waste for disposal

(Compact Power, 2005). Emissions for pyrolysis CHP are well below control standards and compare favorably with modern incineration plants (Compact Power, 2005). Pyrolysis CHP combines effective waste management with efficient heat and power generation for optimally low carbon emissions.

2.5.9 Heat and Power Generation from Pyrolysis

While methane derived from pyrolysis provides an inexpensive source of fuel for CHP, innovative plant design is required to make the most effective use of it. Heat can easily be generated from methane by simple combustion. However, electricity can be sold to consumers for far more per kWh and is more desirable in CHP schemes where the natural waste heat created in electricity generation can be captured and used. Perhaps the simplest electricity generation method using methane is a steam reciprocating engine or steam turbine. Methane is burned to boil water and create steam. The steam is used to turn a turbine and create electricity. Compact Power uses this cheap and simple method in their pyrolysis CHP plants (Compact Power, 2005). The problem with this method is that it ends up producing far more heat than in does electricity. Compact Power's design parameters for their CHP plants show that they produce over 5 times more thermal output than electrical output (Compact Power, 2005). This is not ideal because electricity is worth more, relatively easy to transmit to consumers, and has higher demand. Enormous heating loads would be required to consume the entire thermal output of Compact Power's largest plant. The problem becomes too much heat and not enough ways to use it without using cooling towers, thermal storage, or dumping hot water to eliminate excess heat.

Another possibility would be to purify the methane to make it suitable for use in gas turbines, gas reciprocating engines, or combined cycle gas turbines (CCGT). These generators are able to deliver electricity much more efficiently while still supplying plenty of heat for CHP (GPG234, 2002). The largest barrier here is challenges with purifying the methane for these generators.

A final possibility still being explored is using fuel cells. Hydrogen can be extracted from the methane using chemical processes and used in fuel cells to create electricity very efficiently. Direct methanol fuel cells have the added advantage of using methane directly, however, they are currently under development. Another developing technology, direct carbon fuel cells, are also promising because they can use any number of different hydrocarbons, including methane, directly to produce electricity. The high temperature of these fuel cells makes them especially suitable for CHP. The byproducts of direct carbon fuel cells are hydrogen and carbon dioxide. The hydrogen produced could potentially be captured and used in typical hydrogen fuel cells. This technology is still in very early development so the likelihood of implementing direct carbon fuel cells in Merton in the next few years is very low.

2.6 DHP Scheme in Merton

Initial plans for implementing a district heat and power system in the London Borough of Merton are taking shape. The first section of this DHP scheme will be built in the southeast corner of Merton. The Killoughery Group, which operates a waste transfer plant on the Willow Lane Industrial Estate, plans to install a pyrolysis waste disposal plant on its property. London area hospitals currently pay the Killoughery Group to truck this waste to the Avonmouth pyrolysis plant in Bristol for disposal. The high temperatures used in the pyrolysis process ensure the destruction of any biohazards in the medical waste. When the LBM learned that Killoughery planned to install a pyrolysis plant, Merton proposed using the methane produced by this pyrolysis plant as the fuel source for a combined heat and power plant located on the same site. The Killoughery Group agreed to install and pay for a combined heat and power (CHP) plant on their industrial site if permission to build and operate this waste disposal plant was granted by the Borough of Merton. Ideally, Merton Council would sell the heat and electricity produced by the CHP plant to local customers at a lower cost than their current electricity, heating, and cooling costs.

The customer most eager to use the electricity and heat from the proposed CHP plant on Willow Lane is the Canons Leisure Centre located on Madeira Road. The Canons Leisure Centre is enthusiastic about such a system because its outdated heating and cooling systems, which are more than twenty years old, are becoming increasingly expensive and inefficient to operate. The facilities at the Leisure Centre include a 25 m swimming pool, a sports hall, squash courts, a dance studio, a sauna suite, and a fitness centre. Other sites which have potential for utilizing the heat and power from this CHP system include the High Path Housing Estate, the Mitcham Urban Village, and the Merton Civic Centre, as well as sites in the southeast corner of Merton (Hewitt, 2004, p.5). However, the Leisure Centre's high energy usage for climate control and lighting, as well as its close proximity to the Willow Lane Industrial Estate (approximately 1 km, 0.6 mi), make it a good first candidate for drawing heat and electricity from the CHP plant. For these reasons, the Borough of Merton would like to begin developing its district heat and power scheme by first linking the Canons Leisure Centre to a CHP plant at the Killoughery waste transfer site.

At this point in the development process, the design of the CHP plant has not been started. The company Compact Power is being considered to install the pyrolysis CHP plant because of their experience with the Avonmouth pyrolysis plant. However, it is unclear if their CHP system which uses steam turbines is the best way of utilizing the methane produced by the proposed pyrolysis plant to generate heat and electricity. Detailed load assessments will be required before the design stage can begin. The hope is to develop a borough-wide DHP network from these starting locations, adding additional CHP plants and infrastructure as more sites are connected to the network.

The objective of this project was to determine the optimal route(s) for a heat and electricity distribution system and make a preliminary feasibility assessment of the route(s) for the London Borough of Merton (LBM) as they move toward implementing the first phase of a proposed borough-wide district heat and power system.

Using information provided by Compact Power, the Borough of Merton knew how much heat and electricity different types of pyrolysis CHP plants would be able to produce. The LBM also determined that the Canons Leisure Centre, owned by LBM, would be the first customer to draw heat and power from this CHP plant. The Leisure Centre provided Merton with data for natural gas and electricity usage for their current heating and cooling system. It was evident from initial estimates that a pyrolysis CHP plant installed by Compact Power would be more than capable of continuously supplying all of the Leisure Centre's peak and average heat and electricity demands. However, the particular route, cost of implementation, and technical requirements of the heat and electricity distribution network between the CHP plant and the Leisure Centre were still unknown.

2.7 Conclusion

Today, governing authorities throughout Europe have made it a top priority to reduce greenhouse gas emissions. The United Kingdom has emerged as a leader in driving this agenda. Specifically, the London Borough of Merton has taken unprecedented steps to combat climate change by ensuring that carbon emissions from buildings within the Borough are well below targets called for by the Kyoto Protocol and U.K. White Papers. Implementing a CHP driven DHP scheme in Merton will help the Merton Council meet its goals outlined in the Unitary Development Policy and reduce the Borough's greenhouse gas emissions.

3. Methodology

3.1 Introduction

This methodology will discuss the rationale behind the procedure chosen for performing a route assessment of the heat and electricity distribution network. Through brainstorming, the information necessary for the route assessment was determined and organized in a table by topic. The topics matrix compiled can be found in Appendix F. The table also listed where this information was found and what sources were used. The information was classified into three main categories. These categories were CHP distribution system specifications, construction factors, and route determination factors.

In order to perform a route assessment, it was first necessary to understand the technical specifications of the CHP distribution system. These specifications dictated the minimum technical requirements for the route such as the route length and the area occupied by the infrastructure. Construction factors including methods, codes, guidelines, and costs, determined the requirements for installing the infrastructure. Next, route determination factors including potential obstacles such as railroads, buildings, existing subsurface infrastructure, and conservation lands indicated the physical constraints for the distribution route. Combined, these factors established the feasibility and risk associated with particular route selections.

For each of these categories, the following sections discuss in more detail where and how this data was obtained and how this data was used to analyze possible distribution routes. The conclusions and recommendations produced by this analysis should help the Borough of Merton begin to answer the unknowns associated with the first phase of Merton's DHP distribution network.

3.2 CHP Distribution System Specifications

Essential to the route assessment were the technical specifications for the distribution system. The specifications that had to be determined or estimated were the size of the pipe, the material of the pipe, the number of pipes required for the system, the forward and return water temperatures, and the pressure of the system. In order to make these determinations, it was also important to approximate the expected load of the Leisure Centre as well as any additional loads that could be added to the system and the amount of electricity and heat deliverable from the CHP plant. These requirements helped to determine the construction technique, the area of excavation, the installation requirements, the performance of the system with distance, and the cost of the distribution system. This influenced the route selection by determining the required clearance from obstacles for construction, the total route distance that would be feasible, and the cost tradeoffs between different routes.

The heat and electricity loads of the Leisure Centre were determined from historical records of fossil fuel and electricity consumption at the Canons. The information was based on the existing outdated energy systems at the Leisure Centre so estimates were required to determine what the loads would be with updated systems utilizing the DHP system. It was also necessary to estimate any additional loads that could eventually be added to the system. The capability of the CHP plant in terms of heat and power production was determined from information provided by Compact Power.

The information required for the system specifications was challenging to come by mostly due to its technical nature. Contractors and corporations tightly guarded much of the information regarding the technical specifics of heat transmission systems. It became clear that a qualified consultant would have to make some of these assessments at a later date. For this project's purposes, it was sufficient to make approximations that could give an estimate of the requirements for the route itself. Adrian Hewitt, Merton's Principle Environment Officer, was able to use some of his contacts in CHP organizations and companies and his connections with other government officials that had experience with DHP schemes to fish out some of these technical specifications.

Mike King, a contact with the CHP Association (CHPA), was able to provide a bibliography of useful documents that could be found on the web and provided Internet links to organizations that had experience with district heating distribution systems and CHP. Particularly helpful was the Danish Board of District Heating (DBDH), a private organization of leading consultants, companies, and manufacturers in the Danish district heating sector. Denmark has had extensive experience with district heating since the 1970's and today almost 60% of the Danish population is connected to a district heating system (DBDH, 2005). Their website provided a number of technical articles related to district heating distribution systems.

Another source of information was a DBDH member company, ALSTOM Power FlowSystems. ALSTOM is a manufacturer of pre-insulated transmission and distribution pipes widely used in Denmark. Their website provided technical details of various pre-insulated piping systems and installation instructions for each system.

Alan Jones, Member of the British Empire (MBE), a contact from the London Regional Government and former Energy Services Manager for the Borough of Woking, provided the names of two other manufacturers of pre-insulated pipes. Logstor Ror is another Danish manufacturer that offers distribution materials specifically for district heating. Their website <http://www.logstor.com> contained information on the technical specifications of their pre-insulated pipes and installation instructions and requirements. Perma-Pipe, a North American manufacturer, also supplies pre-insulated pipe systems. Their website <http://www.permapipe.com> included technical specifications of products designed for district heating and cooling applications and even provided a "quick quote" tool to quickly estimate the cost of a particular system based on its requirements.

Alan Jones was also able to provide basic advice as to what pipe material to use, what size pipe would be required, and what depth it should be buried at based on his experience with the Borough of Woking's implementation of a DHP system.

One of the documents listed in Mike King's bibliography was the *Guide to Community Heating and CHP: Commercial, Public, and Domestic applications* (GPG234). This was a government document produced in consultation with members of the CHPA. It contained guidance for conducting feasibility studies, planning and financing a CHP scheme, designing the distribution system and power generation system for the CHP scheme, and operating and maintaining the CHP system. The bibliography contained many other references to community heating guides but none contained as much technical detail as GPG234.

The ABB Group provided technical specifications for high voltage underground cables that were used to determine the requirements for the subsurface transmission lines. James Nelson, Senior Electrical Engineer from American Power Conversion (APC), also gave technical advice on the basic design of an electrical transmission system.

3.3 Construction

Another important aspect when making the route assessment was to identify the construction methods and codes necessary to build the distribution system. Information was gathered concerning the two primary methods of pipelaying: trenching and trenchless technologies. This information was found by archival searches on the Internet and through correspondence with Jason Russell, a Highways Senior Engineer from the Street Management Department. He was able to access documents from an information database for local authorities pertaining to construction codes, guidelines, and methods. This information was used to determine the feasibility of potential routes and the associated risk of particular obstacles along the routes.

The construction method was important to make cost estimates for the construction of pipelines along particular routes and to determine the amount of social and environmental disruption the construction would create. The construction method also identified the technical constraints for potential routes such as the amount of space required for construction machinery.

Construction codes and guidelines added further constraints to the route selection by specifying factors like the required depth of the pipes and transmission lines and the clearance required from other utilities. They also helped to make cost estimates and perform risk analysis by identifying potential construction hazards and specifying the requirements for reinstating roads and walkways disrupted by trenching.

3.4 Distribution Route Considerations

Another essential component of the route assessment was to analyze how both surface and subsurface features between the CHP plant on the Willow Lane Industrial Estate and the Canons Leisure Centre could constrain the path of the heat and electricity distribution system. These surface and subsurface features were categorized as building locations, property ownership, existing subsurface utility infrastructure, environmental constraints, geology and archeology, motor vehicle traffic, noise, the location of miscellaneous surface structures and features, and legal liability issues. A breakdown of these considerations is shown in the following table.

Table 3.1: Breakdown of Distribution Route Considerations

Breakdown of Distribution Route Considerations	
Consideration	Details
Buildings	
Land Ownership	• Merton Council Owned & Controlled Property • Private Property and/or Leasehold Property • Railroads (tramline) • Public Right of Ways (ie. bridal ways, roads)
Existing Subsurface Infrastructure	• Electricity / Natural Gas / Water / Sewer / Telecommunications (telephone, broadband)
Environmental Considerations	• Conservation Areas • Biodiversity (protected trees, plants, wildlife) • Flood Zones (risk of flooding) • Contaminated Land
Geology and Archeology	• Soil conditions & Underground Unknowns (ie. buried foundation, concrete slab hidden under asphalt)
Motor Vehicle Traffic	• Detour Routes (if road closures needed) • Access to Businesses & Residential Complexes (due to construction)
Noise	• Noise disturbance due to construction
Surface Infrastructure/Features	• Trees • Walls • Fences • Street Furniture
Legal Liability Issues	• Liability risks due to route selection

The following sections explain where and how the data for the considerations listed in Table 3.1 was obtained. The following sections also discuss how the data was incorporated into a constraint mapping analysis to determine the optimal distribution network route(s).

The constraint mapping analysis process used for this specific route assessment can be described as a layering of multiple types of route constraints specific to this type of distribution network. The order in which the categories of Table 3.1 were prioritized and layered onto the constraint map is the same order as they appear in the table. The first features placed on the constraint map were the CHP site and Canons Leisure Centre buildings and property boundaries. Next, building locations were added to the constraint map. As successive categories of information in Table 3.1 were overlaid on the constraint map, more potential route areas were eliminated. Once the constraint mapping process was completed, the optimal route(s) for the CHP distribution system was shown. These details follow.

3.4.1 Buildings

For this project, it was determined that for routing a heat and electricity distribution system between the Willow Lane Estate and the Canons Leisure Centre, the location of buildings should be considered as the first constraint. Tunneling under buildings to lay pipes and cables in Merton would be impractical. This is because the expense of tunneling under buildings could not be justified when there was a vast amount of land surrounding these buildings through which subsurface infrastructure could be run. It was also impractical based on maintenance and replacement considerations. If a pipe underneath a building requires replacement, construction costs required to access and replace the pipe would exceed the costs of a pipe or cable buried under open surface or a roadway.

Based on these conclusions, the location of buildings was factored into the constraint mapping analysis by considering buildings as a barrier to the proposed distribution route. The maps in Merton’s MapInfo database were used to find the location of all buildings in the area between the Industrial Estate and the Leisure Centre. On the constraint map, all buildings were marked as an area through which the distribution route could not be run.

3.4.2 Land Ownership

Determining land ownership between the Willow Lane Estate and the Canons Leisure Centre was another key consideration. For this specific route assessment, land ownership was split into four categories. These categories were private owned or leasehold property, railroad owned property, Merton Council owned and/or controlled property, and public right of ways.

Private property was the first land ownership constraint. In order to run infrastructure through privately held property in Merton, an agreement must be made between Merton Council and the private property landowner, which usually involves monetary compensation. Complications arise if an agreement cannot be reached. Two options exist if this occurs. Either Merton Council walks away from pursuing the agreement, or they can take the land by compulsory purchase. Merton Council wishes to avoid engaging in compulsory purchase at all costs because based on past experience, this type of action almost always results in citizen protest and years of legal battle (Hewitt & Stegner, 2005).

The data for determining private property ownership was obtained from Tony Skilbeck, Merton's Property Liaison Manager. Also, a book of property maps in the Estates Department on the 12th floor of the Merton Civic Centre showed Merton Council owned properties. Property lines, addresses and building occupants were found in Merton's MapInfo database.

The second land ownership constraint for this route assessment was tramline property. In an ideal situation, it would be best to avoid the tramline just as it would be best to avoid private property. This is because the tramline service cannot be disrupted or detoured. As a result, from a construction standpoint, laying pipe and cable under an operational tramline would bring with it many additional construction and maintenance complications. The locations of the tramlines in the area of interest were found using the maps in Merton's MapInfo database.

The final two categories of land ownership were Merton Council owned properties and public right of ways. Choosing to run infrastructure through property owned by Merton Council has multiple advantages. One advantage is that permission to use this property can be handled internally on the departmental level. Additionally, running the distribution route through a Merton owned property will give it the potential to draw heat and electricity from the CHP network.

Public right of ways are areas of land through which the Council has the right to lay infrastructure. In Merton, these right of ways are classified as roads and bridal ways. Roads are public right of ways that have street names. Road locations were found in Merton's MapInfo database. Bridal ways are public rights of way that do not have a road name associated with them. Instead, in Merton a bridal way is assigned a number. Bridal ways come in many different forms. They can be anything from a path across a common to a path between two houses. The location of all bridal ways in the area of interest for this route assessment was found in Merton's MapInfo database. Utility companies and local authorities have the right to lay infrastructure under roads and bridal ways.

The large amount of Merton Council controlled property and public right of ways that exist between the Willow Lane Industrial Estate and the Canons Leisure Centre made it clear that running subsurface infrastructure through private property for the proposed distribution route could be avoided.

Property information was incorporated into the constraint mapping analysis by marking all privately owned and controlled property as an area through which heat pipes and electrical cables for the CHP distribution network could not be run. Also, Merton Council owned properties and public right of ways were marked on the map as areas of opportunity for running the distribution network.

3.4.3 Existing Subsurface Infrastructure

Existing subsurface infrastructure was a primary consideration for this route assessment because the hot water pipes and electric cables for the CHP distribution route will be buried underground. The Merton Council requires that this type of infrastructure be buried for both aesthetic and safety reasons. New underground pipe or cable must be laid around existing underground utilities. Also, digging near existing underground utilities, especially high voltage electricity cables and natural gas mains, is a construction hazard. For example, incorrectly supporting an intermediate or high pressure gas main when excavating nearby could cause the pipe to sag and crack. This would most likely require evacuating residences and businesses in the vicinity. Therefore, before a distribution route(s) could be chosen, existing line locations were needed. In addition, information such as minimum pipe depth and required minimum distances from neighboring utilities needed to be found. A breakdown of where this information was found follows.

3.4.3a Electricity

The electric company EDF Energy-London, owns and maintains the electricity distribution networks in the Borough of Merton. A request for the location of underground electrical lines in Merton was sent to Mark Ellis at the Plan Provision Team for EDF Energy-London. This knowledge would allow more accurate construction and fewer disturbances to neighboring lines as well as being mutually beneficial for both EDF and Merton if this data was available to Merton Council.

3.4.3b Telecommunications

British Telecom (BT) operates all telephone lines in Merton. The Street Management Department in the Borough of Merton has the ability to request the location of BT cables. This system provides the location of BT cables in a small area, such as the cable locations outside of a specific building address. A request for cable locations in a larger area must be made in writing to BT. Telewest operates all broadband cables in Merton. As with BT, Telewest must be contacted in writing to obtain cable location maps. Maps from BT and Telewest could not be obtained in this project's timeframe.

3.4.3c Water Pipes

The Asset Location Team at Thames Water Company was contacted to find the location of underground water pipes in the Borough of Merton. Cooperation with these requests was expected because the proposed DHP network will not compete with the services provided by Thames Water. Water pipe maps were obtained from Thames Water Company.

3.4.3d Sewer

Maps of sewer lines in the Borough of Merton were stored in the GIS Mapping Department at the Merton Civic Centre. Merton's GIS consultant, Gary Shaw, provided a Thames Water Company Sewer CD-ROM. This CD-ROM contained maps of the sewer pipe network in Merton. Jason Russell, Senior Highway Engineer for Merton, had the dongle to access the sewer information on this CD-ROM.

3.4.3e Natural Gas

Transco PLC is in charge of operating and maintaining all subsurface natural gas lines in the Borough of Merton. Jason Russell, the Senior Highway Engineer at the Merton Civic Centre, provided a Transco gas line map on CD-ROM.

Again, finding the location of these underground utilities was necessary for choosing the distribution route path as well as necessary to satisfy construction safety and installation clearance requirements. In the ideal case, it would be best to run the new infrastructure on a route that avoids existing subsurface utilities. In addition, subsurface utility access points found through on-site observation were also placed on this constraint which further helped in determining the exact location of those utilities whose maps were not that accurate. All of this existing utility data was put on the constraint map and defined as areas through which crossing should try and be avoided. If sections of existing infrastructure could not be avoided, the risk of running near this infrastructure was assessed.

3.4.4 Environmental Considerations

Before selecting a distribution route, the impact on the environment it will pass through had to be considered. The integrity of the environment and local habitats needed to be maintained in order to protect local wildlife and biodiversity. Land in the Borough of Merton has been classified according to the land's character and purpose in order to preserve the land and how it is used. Each classification of land has corresponding guidelines for what can and cannot be done on that site.

3.4.4a Land Classification

Before construction, the classification of the land under consideration needed to be identified to determine if a potential route would be permitted. Conservation areas have special guidelines governing the development and construction allowed on the land. All potential routes were evaluated to insure they did not conflict with these guidelines. Adrian Hewitt, Principal Environmental Officer, provided the Unitary Development Plan (UDP) document, which described the guidelines applying to each classification of land. A corresponding UDP map, provided by Phil Ryder, Principle Design Planner, displayed the classifications that apply to every area in Merton. A location can qualify as more than one category of land, and the UDP map allowed all classifications of each potential site to be identified. The corresponding guidelines for each classification were researched in the UDP and any route that did not satisfy all guidelines was eliminated.

3.4.4b Contaminated Land

One classification which was not located within the UDP was contaminated land. Given the strong industrial history of the region, especially the Willow Lane Industrial site, there was a high potential for the land being contaminated. Special considerations were required when considering contaminated soil and sites in order to isolate the contamination and prevent spreading. The procedure for construction and development on contaminated sites was described by Louise Halloran , Senior Environmental Health Officer from the Merton Civic Centre. A layer of GIS data displaying contaminated land in Merton was located on the Merton network. After research, the route was evaluated to avoid these regions of land where possible.

3.4.4c Flooding

Especially near the river, flooding within the selected region was a concern. Locating a CHP plant within a flood zone could decrease the efficiency of the heat pipes if they became flooded due to the change in its thermal environment. Gary Shaw, GIS consultant, supplied the location of GIS MapInfo map displaying the flood zones along the potential route. This map displayed flood zones classified as a threat once every 100 years, once every 1,000 years, or having a general risk of flooding. Once the zones were determined, the potential route(s) was adjusted as much as possible to avoid these regions.

3.4.4d Impact on Biodiversity

In addition to regulations describing construction, the impact on the environment must be assessed for both during construction and after installation. Construction could disturb the wildlife and destroy vegetation depending on how equipment, excavation, and personnel are managed. Considerations included the required distances from trees and the River Wandle that must be maintained during construction. Trenching near trees could damage the root system of the tree and potentially kill it. To avoid this, the required distance to avoid this was researched as well as regulations for protected trees including if some may be removed to allow construction. The replacement of disturbed grass and vegetation had to be considered as well because the land should be returned close as possible to its initial condition before construction. Documents describing the specifications and guidelines for an Environmental Impact Assessment (EIA), and the effects of pipeline installation were collected by means of archival research. Jason Russell, Street Management Department, provided access to many of these documents. Once these guidelines were located, the route was assessed to ensure any large obstacles could be avoided because these rules must be complied with.

Any long-term impact of having heating pipes under the land, such as thermal pollution of heat from the lines radiating into the subsoil, must be considered. Thermal pollution had the potential to impact the grass and biodiversity living on the surface, specifically the root systems and animal tunnels underground. To assess this, David Somervell, Energy Manager from Edinburgh University, was contacted.

3.4.5 Geology and Archaeology

The condition of the subsurface is an additional consideration for the potential route. The soil conditions and geology could greatly influence the time and cost required by the project. Trenching could prove difficult if the subsurface is layers of hard rock, which must be cut through, or much simpler if it is soft soil, which could be achieved with a backhoe/digger. Geological information obtained through archival research was a government document on Cranmer Green written by the London Conservation Services as well as GIS maps for the United Kingdom produced by the British Geological Survey. A description of the conditions in Merton was gathered from a contaminated land report, assisted by Louise Halloran, Senior Environmental Health Officer.

Archaeological considerations also have the potential to influence trenching. Past structures and impact of the use of the sites selected may still be present on the site even if they cannot be seen. The remains of old buildings may be buried under grass or hard surfaces that were laid on top. These structures, such as an old concrete foundation, would be invisible above ground but would be an obstacle to trenching when uncovered. A map displaying land classified as regions with a high archaeological presence was located at the Merton Civic Centre by Lone Le Vay, Conservation Officer in the Environment and Regeneration Department.

3.4.6 Motor Vehicle Traffic

Construction in general is disruptive to society, especially in a densely populated area such as Merton. The impact of infrastructure installation in Merton, particularly the impact on traffic patterns, must be considered. There are three main areas between the Willow Lane Industrial Estate and the Canons Leisure Centre where traffic disruption due to infrastructure installation must be considered.

The Willow Lane Industrial Estate is an area of high traffic density and contains approximately 60 industrial site businesses. The second important area to assess the impact of traffic is in the driveways and parking lots of the Wilson Hospital and the Cranmer Middle School. The third section in the area of interest was Cranmer Road and Madeira Road, two roads carrying high volumes of traffic.

Declan Stegner, GIS Manager for Merton, provided traffic volume data for the years 2003 and 2004 (Appendix G). The traffic volume data was used to analyze what impact closing part or all of a road would have. The analysis also included finding what entrance routes to residential, commercial and Council owned properties, such as the Cranmer Middle School, would be affected by construction. In order to try and minimize blocking entrances to properties, these areas were considered places to avoid. In addition, it was necessary to determine how long traffic might be affected due to a road crossing for installing infrastructure. The time would vary with choice of construction method. This analysis concluded with determination of detour routes.

3.4.7 Noise

Another factor of social disruption is noise. Construction generates the majority of this concern from the excavation and equipment required. The disruption to the community's lives must be considered when evaluating the distribution route. High noise levels can have an impact on nearby businesses, sleeping schedules of both adults and children along with distractions to daily lives. Current regulations on working hours for construction and acceptable levels of noise were researched to help assess what could be done to limit the impact of construction noise.

3.4.8 Surface Structures and Features

One of the last categories of information examined dealing with distribution route considerations was surface structures and features. Features in this category included walls and fences, mailboxes, benches, rubbish bins, lamp posts and signage. It was necessary to know the location of these features to avoid as many as possible and to save on construction and reinstatement costs. The location of all street furniture is located in Merton's MapInfo database. In addition, many walls can be seen from the aerial photography maps in the database. Still, on-site observation was required to confirm the location of all these features. Once these features were located, the potential route(s) was adjusted to avoid them.

3.4.9 Legal Liability Issues

The *General Practice Guide for Community Heating and CHP* (GPG234) gave information on the insurance necessary to construct and operate a CHP distribution system. This information was used to assess the effect of legal and liability issues on the route selection.

3.5 On-site Observation

The potential route areas were further narrowed by incorporating data found through on-site observation. For some types of information, specifically certain utility line locations and surface materials, MapInfo data was not available. An on-site investigation enabled these gaps to be filled in and confirmed the data pulled from the database.

Information was collected by visual inspection. The modified route was recorded on a map of the local area during observation. An initial inspection to better understand the site was performed on March 14, 2005, and a detailed investigation was carried out on April 1, 2005. The investigation began at the proposed site in the Willow Lane Industrial Site and traveled up along the river following the potential route of the pipeline to the Jan Malinowski Centre and railroad tracks. On the other side of the tracks, the inspection continued on the grounds of the Cranmer Middle School, specifically examining the driveway and playing field, then along the property line near the parking lot of the Wilson Hospital. Across the street, Cranmer Green was inspected; however, the conservation land portion of the green located to the east of King George VI Avenue will not be disturbed. The Canons Leisure Centre, the final destination of the route, was across Madeira Road from the green and a few potential paths were walked checking for obstacles and available space. A large amount of valuable data was collected through this method, which assisted in selecting a recommended potential distribution route.

3.5.1 Trees and Existing Vegetation

Information on many of the trees, which inhabit the area, was available in Merton's MapInfo database; however, this file could not account for all the trees. Walking potential routes allowed large trees as well as areas of vegetation to be identified. The route was then adjusted to avoid these dense areas and large trees.

3.5.2 Wetlands

The existence of wetlands along the potential route, especially the region near the Wandle River, was another concern. Wetlands were not a desired location for a pipe system due to the complications caused by unstable ground. The high water content could also have an effect on the temperature of the heat pipes, drawing heat away from the pipe. How far the wetlands extended was unknown, and the area's biodiversity needed to be identified in order to assess possible impact.

3.5.3 Access Points

Accessibility was another point clarified on-site. In order to lay the pipe system the construction equipment and crew will require access to the route; therefore, the route could not be exceedingly narrow or closed in. Gates along the river and near the railroad were especially important because they could provide access to the route for construction vehicles.

3.5.4 Utilities

Along the roadways and through parking lots, access covers such as manholes marked the utilities running underground. By following these covers, the location of existing lines was extrapolated and compared with utility maps. Walking the route was the only method of determining other utilities buried within the region not marked on utility asset location maps. Modified routes through specific regions of parking lots, driveways, etc., could then be drawn to best avoid the current infrastructure.

3.5.5 Surface Data

Data not available through MapInfo such as surface material and surface structures were collected during this investigation. Construction through soft land and paths is easier and preferred over cutting through concrete. Concrete is both more time consuming and expensive to cut through than other surfaces and was avoided as much as possible when modifying the route. Identifying the surfaces of the roads, river paths, parking lots, and all sites under consideration helped improve the route.

Other existing structures were identified including stonewalls, fences, sheds, and gardens which did not appear in Merton's MapInfo data. These structures would need to be avoided, burrowed under, or taken down and rebuilt to accommodate construction.

On-site observations were an important component of data collection and allowed a combined assessment of current obstacles. Exploring the route in person allowed realistic routes to be identified more effectively by taking more elements into account. Practical considerations for the construction were more easily identified as well when the route was physically viewed.

3.6 Route Assessment Summary

To effectively perform a route assessment, all the variables mentioned in this chapter needed to be considered in a logical way. The CHP distribution system requirements were the first consideration because they defined what needed to be installed along the route. The construction requirements were the next factor because they define the amount of space required as well as the difficulty level of crossing different types of obstacles. Then, the barriers that constrained the route selection were identified. These included buildings, land ownership, existing subsurface infrastructure, environmental features, traffic, noise, surface features, and legal-liability factors.

The analysis of the distribution route considerations was done by using constraint mapping. The factors for the route selection were organized by their priority for this particular assessment. The information that was suitable for being inputted into MapInfo was placed into layers in the GIS. The other relevant data that could not be quantified this way were assessed separately. The constraint mapping analysis was done by placing the highest priority constraint layers on the map first and the possible route areas that would avoid them were determined. As the lower priority constraints were placed on the map, the possible routes were modified but with the understanding that all obstacles could not be completely avoided. This process resulted in a few potential routes. On-site observation was used to verify the information about the routes and uncovered important surface features that were used to modify those routes. Through this process, one optimal route became clear based on the information that was available.

A risk assessment was performed to identify the areas of high risk along the route. The costs and risks of implementing this route were unclear at certain key points. The level of risk was determined for these key points based on the level of certainty of the information available for these areas.

3.7 Information Sharing with WPI GIS Research Team

For this project, it was necessary to collaborate with another WPI research team doing research on Geographical Information Systems (GIS) and City Knowledge. Their role was to determine how projects such as this one collect and organize data related to the city. They explored ways of storing this data in a GIS to make data collection easier in the future. One storage possibility would be to utilize a distributed City Based Knowledge GIS. This project provided the GIS team with the specific types of city information that were needed to perform a CHP distribution route assessment. The extent of collaboration with the GIS team was limited to the following interactions. First, the GIS team provided the location of Map Info database files on the Borough of Merton computer network. In return, the GIS team was supplied with the topics matrix compiled to organize the required information for a route assessment. This matrix described the location, source and accessibility of the information required for this specific route assessment (Appendix F).

4. Results

4.1 Introduction

As the research for this project commenced, it was clear that a great deal of information would be necessary in order to perform a distribution route analysis. Some of this information was readily available in the LBM's existing GIS database or in other formats within the Merton Civic Centre. Other information had to be sought out from utility companies, professional references, and case studies. As the data was being collected, new questions arose that broadened the considerations included in the route assessment. The information that has proven to be vital to our project's success consisted of technical specifications of the CHP system, GIS data (maps), distribution route considerations, the aspects of construction, and environmental classifications.

4.2 CHP Distribution Network Specification

4.2.1 Load Assessment

It was important early on to get an understanding of the specifications for the distribution network in order to determine what route should be followed and how it should be constructed. First, it was necessary to understand the power generation capabilities of the CHP unit and the the heat and electrical loads it will be driving. One of Compact Power's pyrolysis CHP plants has been proposed for the Willow Lane site. Compact Power's smallest unit, the MT2 plant, is capable of consuming 8,000 tons of waste per annum. This unit is designed to generate about 330 kW of electricity and 1.8 MW of heat (Compact Power, 2005). The Canons Leisure Centre energy usage for the year 2004 was 1,948,252 kWh of natural gas and 768,283 kWh of electricity. Based on these values, the average load was determined to be about 222 kW of heat and 87 kW of electricity. The Leisure Centre can further reduce the amount of energy it uses by replacing its outdated and inefficient heating system. This data shows that Compact Power's smallest plant is more than capable of meeting the average heat and electrical loads of the Leisure Centre, even with the outdated infrastructure.

Compact Power's next largest unit, the MT8, is designed to process 32,000 tons per annum of waste with a gross thermal output of 12 MW and an electrical output of 2.7 MW

(Compact Power, 2005). This plant is being considered in order to process more waste and supply heat and power to many other sites across the Borough. Because of their modular design, two of these units could potentially be built on the two Willow Lane sites owned by the Killoughery Group. This would effectively double the waste capacity to 64,000 tons per annum. The thermal output of two MT8 units is designed to be 30 MW with an electrical output of 5.6 MW (Compact Power, 2005).

The gross thermal output of the two MT8 units is so large that there is some question whether enough thermal loads could be identified in a practical distribution area. For our route assessment, the worst case or strictest set of requirements was considered in order to design for the upper load requirement of perspective sites. To help establish the upper boundary of the thermal load expected for the two potential CHP sites, the proposed Mitcham Town Centre development, the largest expected load demand on the CHP network, was assessed for its maximum potential heat load. With the land area information from the Urban Design Brief and energy benchmarks for certain building types from the London Renewables Toolkit, a rough estimate for the thermal load of the new Mitcham Town Centre was determined (Secretary of State for Trade and Industry, 2004).

Appendix H shows the matrix that was used to determine the maximum potential heat load of both the Mitcham Town Centre and the Leisure Centre. The closest available energy benchmark information was used for the proposed building types. The matrix shows an estimated thermal load of 1.84 MW and an electrical load of 1.586 MW. These numbers, however, only represent an average load over a year's time. Daily as well as seasonal changes will significantly vary the peak load for these buildings. This is addressed in the *Guide to Community Heating and CHP* (GPG234). Figure 4.1 shows a heat demand profile plotted as a heat demand/hours duration curve. The plot shows that the peak demand occurs for only relatively few hours of the year. For this reason, common practice for CHP is to design to meet 50% of the peak load. For the heat demand profile shown, the base load covers 85% of the total annual heat demand. The peak load is met by utilizing low capital cost peak boilers (GPG234, 2002). For this analysis, the base load could be approximated as the average load.

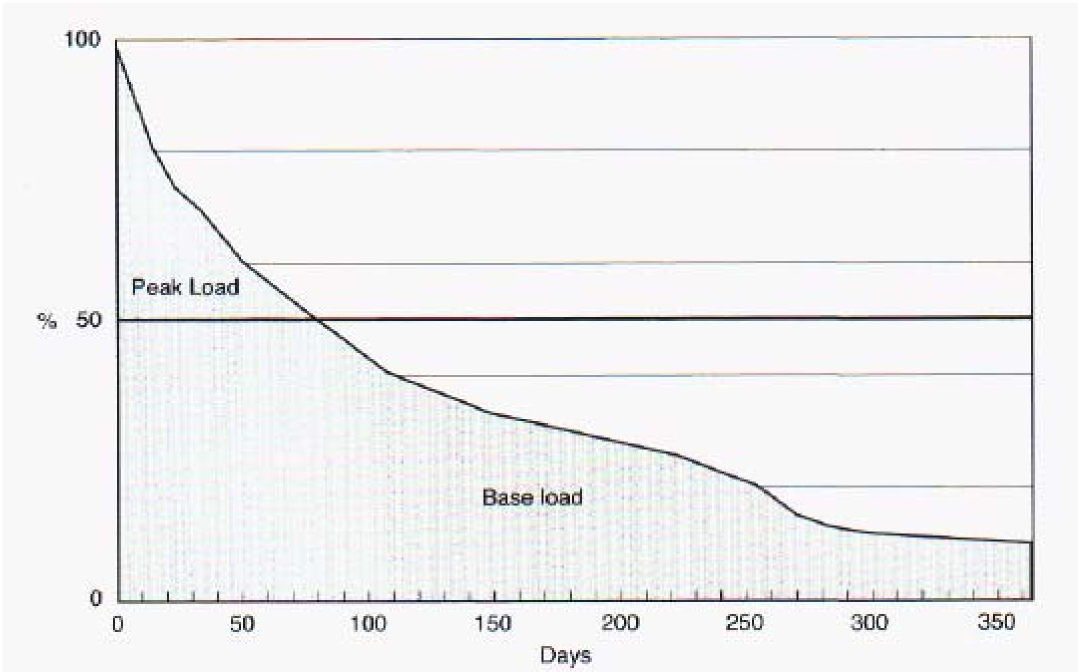

Figure 4.1: Duration curve of the annual heat consumption based on hourly heat demand
Source: GPG234, 2002

Many factors have the potential to influence this required load. Utilizing domestic hot water (DWH) applications and district cooling by absorption chillers could potentially increase the average thermal load. The addition of new sites in the area beyond just the Town Centre and Leisure Centre could be identified as ideal candidates for DHP, also increasing the system demand. This rough survey of the loads required by these sites had a fairly high degree of uncertainty due to the estimations within the benchmark values and assumptions made regarding proposed sites. For these reasons, the average loads were doubled as a worst-case condition. This gave an upper limit of 3.68 MW for the entire new Town Centre plus the Leisure Centre's heating. This number was used to determine the distribution system specifications.

4.2.2 System Water Temperature and Heat Mains Material

The *Guide to Community Heating and CHP* (GPG234) gave basic technical guidance to begin to define the specifications that this distribution system would require. One of the most important specifications for the design of a community heating (CH) system is the system water temperature. Typically, in small-scale CH systems a system temperature of less than 90°C is chosen in order to reduce losses through the heat mains and improve the efficiency of electricity generation. However, if operating at this lower temperature reduces the temperature differential between the forward supply and the return of CH system, a larger volume of water is required for heat delivery, increasing the size and cost of the mains and the pumping costs. In order to optimize for these constraints, two types of systems are typically used depending on the application (GPG234, 2002).

The first type of system, ‘medium temperature’, operates at up to 120°C and 16 bar. This system is suitable for larger CH systems where static pressure is high. These temperature and pressure limits require a pre-insulated piping system, which meets the European Standards EN 253, EN 448, EN 488 and EN 489. This system uses a steel carrier pipe with polyurethane insulation and a high-density polyethylene (HDPE) casing. The system is usually capable of operating at 16 bar and 140°C continuously with a peak temperature limit of 150°C. To reduce both capital and running costs, a return temperature of at most 50°C is typically specified for these systems. The supply temperature can be varied in these systems as low as 70°C based on ambient temperature changes (GPG234, 2002).

The second type of system, ‘low temperature and low pressure’, typically operates at up to 90°C and 6 bar. This is recommended for small-scale CH systems, as it is the lowest cost option and is amenable to all-plastic piping. The pre-insulated plastic piping is more flexible, which reduces the need for as many joints, and is not susceptible to corrosion. The system is available in coils of 50 m length and is rated for 20-year life. Unfortunately, the 90°C and 6 bar limitations make the system unsuitable for future expansion (GPG234, 2002).

The medium temperature system, while typically more expensive, must be considered for this CHP distribution system because of the potential for future expansion. Additionally, the plan to use absorption (ABS) chillers to provide cooling at the sites also suggests a higher temperature system will be necessary. ABS chillers used in CHP systems are designed for use with hot water as low as 90°C but the lower temperature ABS chillers are more expensive and less efficient than those in the 120°C system temperature range (GPG234, 2002).

Given the requirement for a medium temperature system, manufacturer information for pre-insulated HDPE piping systems was used to determine additional CHP system specifications. ALSTOM Power FlowSystems is a leading manufacturer of district heating pre-insulated pipes. They offer a steel carrier pipe system with polyurethane foam insulation and HDPE casing, available in 6, 12, or 16 m lengths. This system is rated for continuous operation at 140°C for 30 years with short peaks of up to 150°C (ALSTOM Power FlowSystems [ALSTOM], 2005).

4.2.3 Electrical Transmission System

Now that the heat delivery system has been identified, the electrical transmission system must be determined. The most common distribution voltage for urban areas in the UK is 11 kV (phase to phase) (good source please). Power generators of all types typically generate three phase power. Three phase simply means that it generates three AC waves phase shifted by 120°. Certain industrial and commercial appliances use three phase power to run highly efficient motors. The assumption is then that three phase power will need to be supplied to certain buildings that might require it while other will only need single phase. Electrical substations will step down the voltage on the receiving end and will be responsible for supplying the single or three phase power to the buildings it serves.

To transmit the three phase electricity, three wires will be required, one for each of the phases. The electrical load assessment, doubled for purposes of this assessment, was 3.2 MW. Dividing this load by the three phases gives the necessary power transmitted on a single phase wire: 1.1 MW. Since ideally the power is the voltage multiplied by the current, the current the wire must carry can be determined by dividing the load, 1.1 MW, by the transmission voltage, 11,000 V. This gives an estimated current of 100 A.

The standard for high voltage underground cables less than 220 kV is the XLPE cable system. These cables are manufactured to international standards and available from a wide variety of manufacturers. The ABB Group is a United Kingdom company and supplier of a wide range of high voltage components. In the analysis, their manufacturer specifications for their XLPE cable system will be used to identify the size wire required for this application.

4.3 Construction

4.3.1 Construction Methods

The method of construction for the distribution route is an important consideration because it determines not only what requirements the system calls for, but also the disruption each method may cause to locations along the route. Different strategies can be employed to lay pipelines with varying degrees of disruption and flexibility for avoiding obstacles.

4.3.1a Trenching

Trenching is the most common method of installing pipelines in an open space. The chosen route is first surveyed and the construction right-of-way is marked by a series of stakes. A clearing and grading crew removes obstacles such as trees and boulders from the pre-approved route. In certain agricultural areas, the topsoil is removed and stored until construction is complete (Interstate Natural Gas Association of America [INGAA], 2005).

Once the construction area is prepared, the trenching crew uses a wheel trencher or a backhoe to dig the pipe trench. The pipe sections can either be installed in the trench or pieced together along the trench above ground and then lowered in. Figure 4.2 shows the pipes resting on cushions of sand or sleepers which are then removed before the trench is backfilled. Welding and installing the muffs (straight joint connections) in the trench requires at least another 250 to 300 mm of trench width at the joints (ALSTOM, 2005). Figure 4.3 shows the pipe sections being fitted above the trench. The welding crew joins the pieces together using a side boom machine that aligns the pipes and makes the first pass of the weld (INGAA, 2005). The muffs are then installed, pressure tested, and insulated. Once the pipeline is pieced together, a series of small cranes called side booms can be used to lower the welded pipeline into the trench (Figure 4.4).

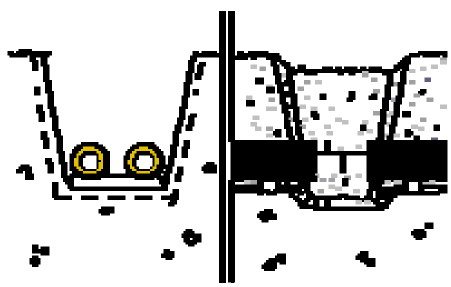

Figure 4.2: Installing in the trench
Source: ALSTOM, 2005

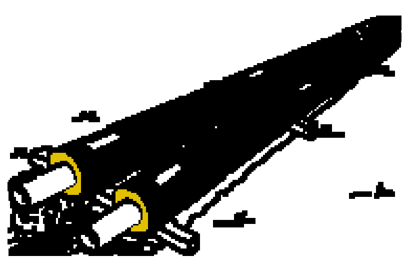

Figure 4.3: Connection above trench
Source: ALSTOM, 2005

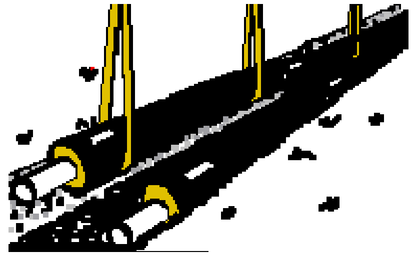

Figure 4.4: Lowering into trench
Source: ALSTOM, 2005

The pipes are typically heat pre-stressed to a temperature determined by the operating and installation temperatures. The pipes can be heated by hot water or electrically by applying a voltage and using the resistance of the pipes to heat them to the required temperature. The heating causes the pipes to expand so they can be backfilled and the sand layer secures the pipes in place. This creates an even stress level along the pipe. Figure 4.5 shows pipes being heat pre-stressed electrically. The downside to heat pre-stressing is that the pipes cannot be backfilled until the pre-stressing is complete.

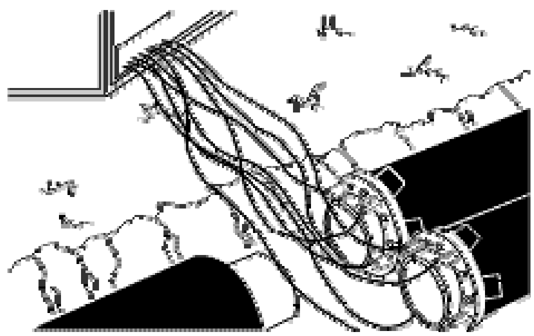

Figure 4.5: Heat Pre-stressing Pipes
Source: ALSTOM, 2005

The bottom of the trench is backfilled with 100 mm minimum of stone-free sand. The sleepers are removed and the rest of the area around the pipe is backfilled with stone-free sand using a backhoe or padding machine. When the pipe has been covered with at least 100 mm of sand, the warning tape is placed over the pipeline and the rest of the trench filled with the topsoil.

The final step is to restore the construction area to its previous state. This can involve fertilizing the soil, planting grass, and removing subsoil and large rocks dug up from the ground (INGAA, 2005).

When trenching across or along roadways, the *open-cut* method is often used. Traffic is diverted while the contractor digs the trench through the road and lays the pipeline. Subsequently, the contractor repairs the road and replaces the pavement (INGAA, 2005). Besides causing traffic issues, the open-cut method has been shown to degrade the integrity of the pavement around the area of construction. This can lead to additional costly road repairs in the future.

Estimates for the cost of trenching vary from £500 to £700 per meter. Trenching through open space is less costly, around £500/m, while open-cutting through roadways costs £700/m or more. Crossing subsurface infrastructure increases costs even further by 20% or greater.

4.3.1b Trenchless Options

Because of the costly nature of the open-cut method, *trenchless* or *dig-less* methods have been developed for inserting pipes under and along roadways. Trenchless methods work by digging a pit on either end of the pipeline section. A tunneling machine such as a directional drill, percussive mole, pneumatic hammer, auger bore, or microtunneling machine creates a tunnel between the pits in which a pipe can be inserted (United Kingdom Society for Trenchless Technology [UKSTT], 2005). Trenchless methods vary in the machinery required, pipe size and material requirements, geology that can be tunneled, and tunnel distance.

Trenchless methods are not only ideal for preventing disruption of roadways. They can also reduce surface disruption, making them ideal for environmentally sensitive areas. Trenchless methods allow pipes to be laid at far greater depth than trenching, allowing other existing subsurface infrastructure to be more easily avoided (Grimes & Martin, 1998). Trenchless methods also have the potential to significantly reduce the duration of construction, traffic disruption, and noise all while persevering the surface appearance of the area (Grimes & Martin, 1998).

Trenchless methods can even be less expensive than open-cut trenching when considering the required depth of the pipeline, the amount of subsurface infrastructure that must be avoided, and the cost of road repair associated with open-cut trenching. There are also the environmental and social savings of trenchless options mentioned previously. All these factors must be considered when choosing an appropriate method of construction.

One technical disadvantage of trenchless options is the inability to make or remake side connections without some excavation (Grimes & Martin, 1998). This is an important consideration for a DHP because it is designed to be expandable, allowing new sites to come onto the distribution network.

4.3.2 Codes and Guidelines

Underground excavation is subject to many different codes, guidelines, and regulations. Since this project includes both subsurface electrical and hot water lines, multiple directives apply. These include the Water Act of 1948, the Water Act of 1989, the Water Industry Act of 1991, the Electricity Act of 1989, and the Electricity Regulations of 2000 and 2001. Because of the detailed nature of these laws, legal assistance will be required to assess the full ramifications on Merton's proposed DHP scheme. A number of official codes and guidelines will prove more helpful in assessing the specific construction requirements for laying the district heat and power distribution network. The codes and guidelines relevant to this project were obtained and the applicable information is described in the following sections.

4.3.2a Avoiding Danger from Underground Services

One important guideline is *Avoiding Danger from Underground Services*, published by the Health and Safety Executive in 2000. This document explains the dangers of subsurface infrastructure such as gas pipes, electrical cables, telecommunication cables, water pipes and sewers, and other pipelines on excavation projects. It offers guidelines from the planning stage to the actual construction that help to ensure safety from these dangers.

During the planning stage, the guidelines stipulate that maps of the existing subsurface infrastructure must be obtained and the respective owners be notified of the excavation. Certain utility companies may send their own representatives to ensure that the excavation does not damage their lines. Where possible, utilities that may be affected by the excavation should be turned off. Maps alone are not sufficient to identify the location of subsurface infrastructure. Maps are often inaccurate and must be assumed to be so. Exact depths are usually not known. For this reason, locating devices should be used to identify the exact location of infrastructure near the excavation site.

Hum detectors can be used to locate electrical cables by detecting the magnetic field radiated by the current. They will not detect cables that are not conducting current, highly shielded cables, or direct current cables. Radio frequency detectors can locate long, metallic pipes and cables by picking up low radio frequency that the metal re-emits. Interference by other metallic objects can distort the exact location of the pipes and cables. Metal detectors can be used to detect subsurface, flat, metal objects but often miss round pipes and cables. Ground surface radar can be used to find ground surface anomalies, which may be pipes or cables. An experienced technician is required to operate this device and therefore this work may need to be contracted to a qualified company. Any identified services must be marked by waterproof crayon, chalk, or paint on paved surfaces or by wooden stakes in unsurfaced areas.

When digging near identified services, power tools and mechanical excavators must not be used. Trial holes should be dug to confirm the presence of identified pipes or cables. Hand tools such as spades and shovels should be used to uncover the utilities in the excavation route. Each uncovered utility should be determined and marked. Minimum spacing between adjacent services should be either 250 mm or one and a half times the diameter of the pipe being laid, whichever is greater. For electricity cables, clearances for maintenance work should be at least 300 mm. Exact clearances can be found in NJUG publication Number 9. If these minimums cannot be attained, as much separation as practically possible should be given. The details should be provided to the utility company affected for their records.

4.3.2b Construction (Design and Management) Regulations

In conjunction with these guidelines, the Construction (Design and Management) Regulations of 1994 (CDM) must be considered. This code issued by the Health and Safety Commission clarifies the duties and responsibilities of all parties during construction to ensure health and safety. An appropriate health and safety plan must be created for all parties involved with the construction before the project can be approved.

4.3.2c Specification for the Reinstatement of Openings in Highways

As a part of the New Road and Streets Act of 1991, the Department for Transport issued the *Specification for the Reinstatement of Openings in Highways*. These codes apply to excavation in which roads must be cut open and repaired. They cover the specific details of excavation such as breaking the road surface, treatment of excavated material, side support, drainage, trenchless pipe laying, backfill requirements, and road reinstatement methods.

4.3.2d NJUG Publication Number 9

The NJUG Publication number 9, *Guidelines on the Positioning and Colour Coding of Utilities' Apparatus*, defines the clearances required for different utility infrastructure. The majority of utilities in the UK are run along footpaths on either side of the street. Figure 4.6 shows the typical positioning of mains in a two meter wide footway.

Actual placement of services will vary, and the picture is for illustrative purposes only. The picture shows typical clearance between mains necessary for access for repairs and maintenance, as well as their common depths. For example, high voltage electrical cables are buried at least 600 mm deep under carriageways and at least 450 mm under footpaths with clearance of around 300 mm from other utilities.

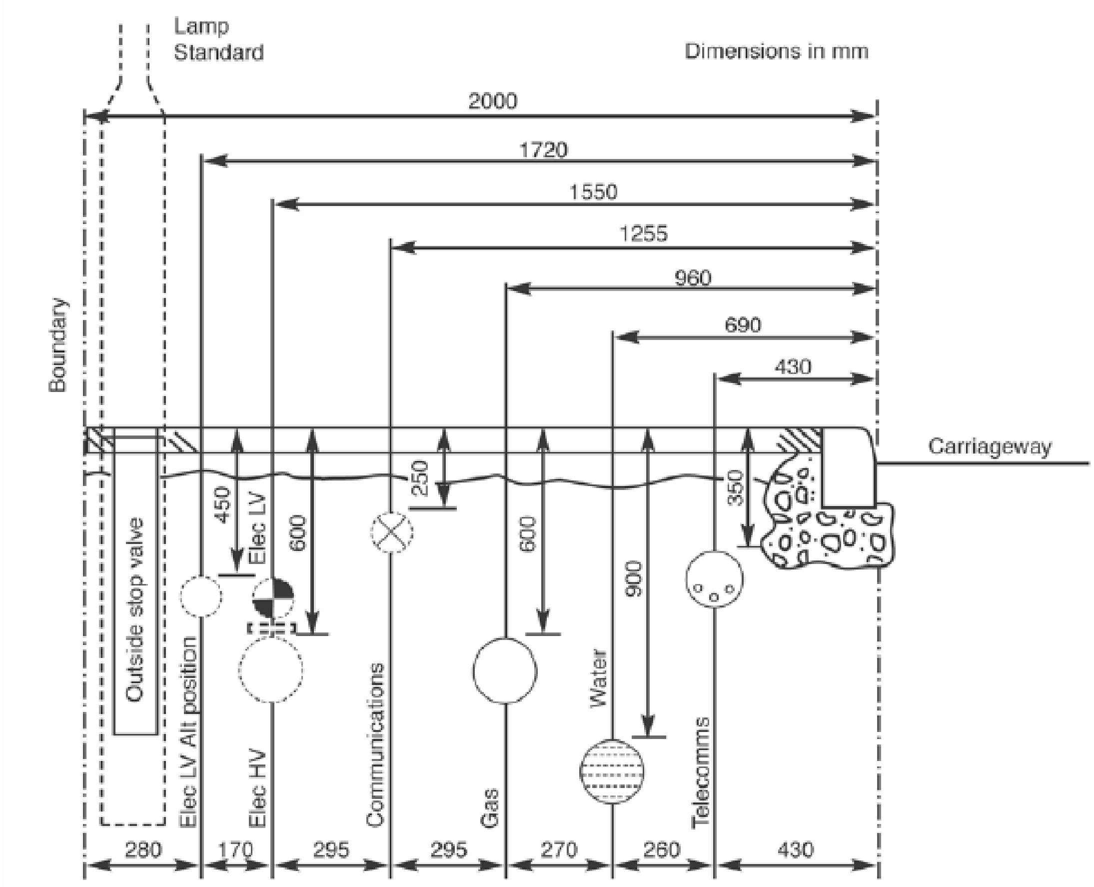

Figure 4.6: Positioning of mains in a two-meter wide footway
Source: NJUG, 2003

4.4 Distribution Route Consideration Findings

Aerial photographs of the entire Borough were the first pieces of data collected for the route assessment. The aerial photograph shown below was found in Merton's MapInfo GIS information system. The photo map was edited to display the names locations relevant to this route assessment. MapInfo has the ability to overlay this aerial photograph map layers on top of conventional maps. This is very useful, especially if there is a lack of information about vegetation, buildings, and roadways in a certain area displayed on available maps. The software allows the user to zoom in on certain areas of the map, scroll to different areas of Merton, and view the aerial photo at very high detail. The aerial photography has such high resolution that each pixel represents a ground area that is 10 x 10 cm. The farthest that a person can zoom out in MapInfo, however, is the amount of zoom shown in Figure 4.7 (area 1 km wide). The area lacking vegetation is the Willow Lane Industrial Estate.

Figure 4.7: Aerial Photograph of Willow Lane Industrial Estate

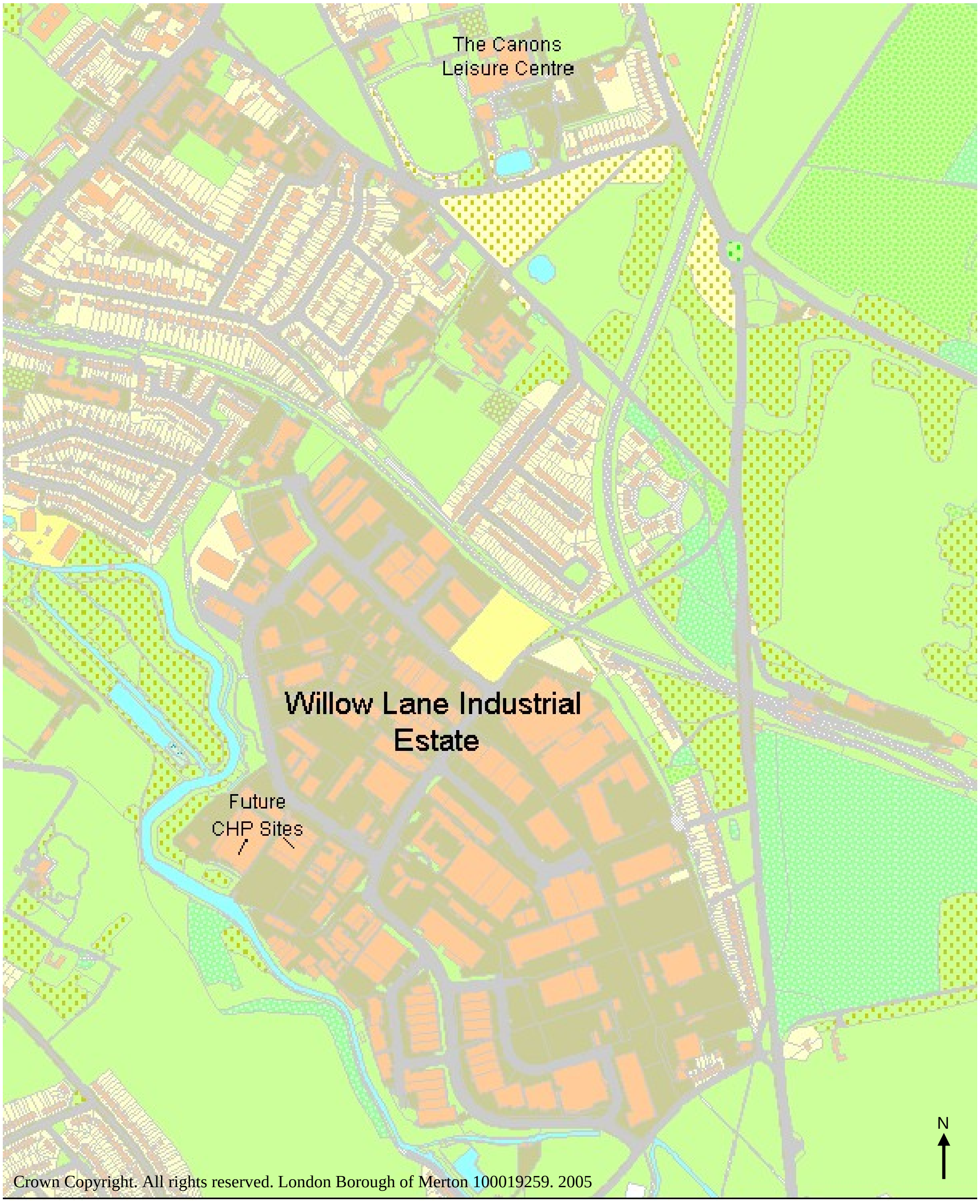

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Figure 4.8: Map of Distribution Network Area

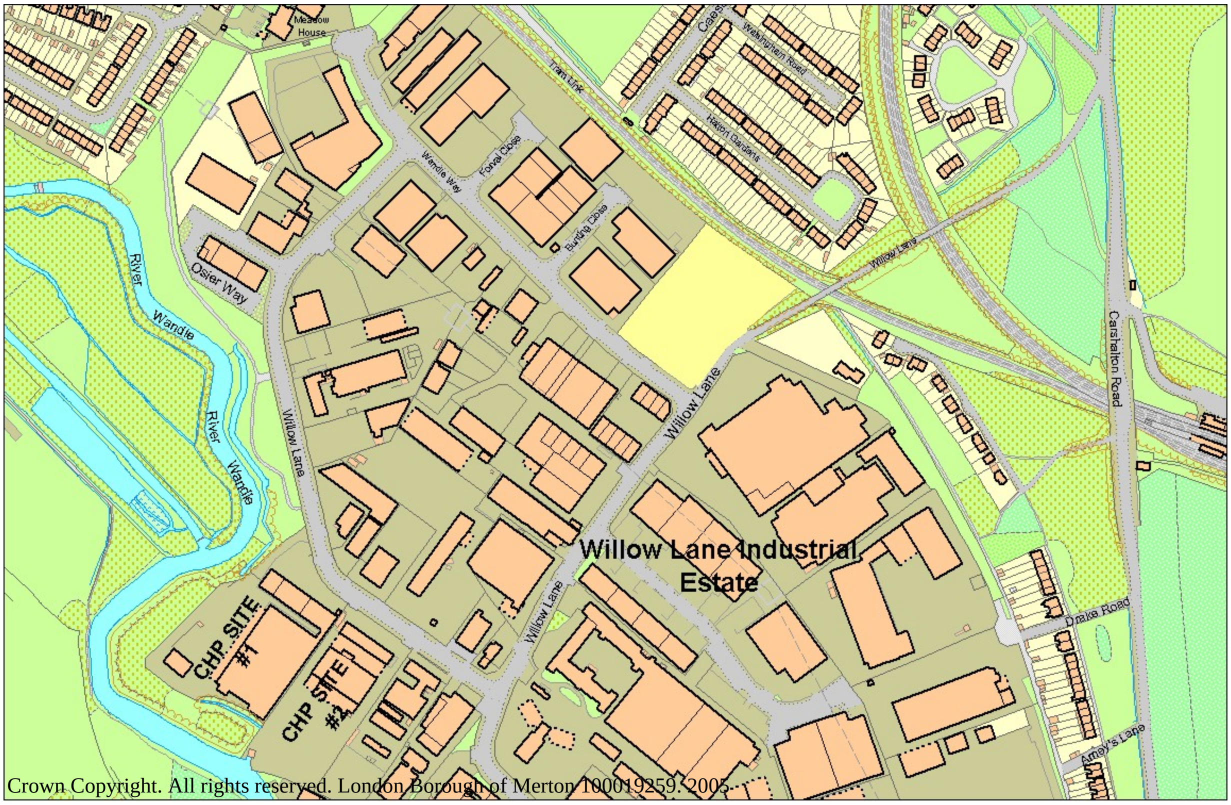

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Figure 4.9: Willow Lane Industrial Estate

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Figure 4.10: Cranmer Middle School & Wilson Hospital

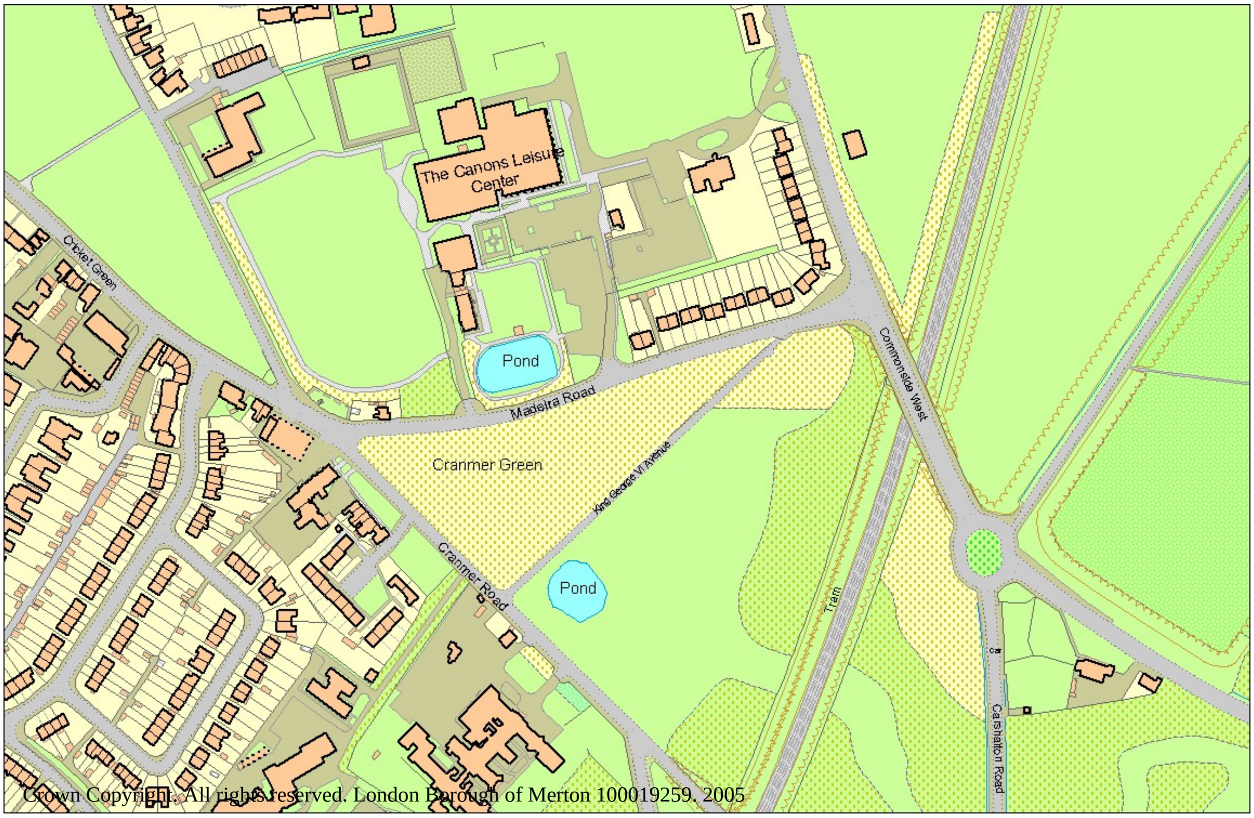


Figure 4.11: The Canons Leisure Centre & Cranmer Green

4.4.1 Buildings

The LBM's MapInfo contained the locations of buildings and other permanent above ground structures. Major buildings in the area of interest include various industrial complexes in the Willow Lane Industrial Estate, the Wilson Hospital, the Cranmer Middle School and two residential neighborhoods (see Figures 4.9, 4.10, 4.11).

4.4.2 Land Ownership

Occupancy information for properties in the Borough of Merton were found in Merton's MapInfo database in a layer called Address Finder. This layer contained occupancy data for each building and a date for when that information was last updated.

The information pulled from MapInfo, in addition to the information obtained from Merton Estates Department, indicated that all land in the Willow Lane Industrial Estate was owned or occupied by private businesses. These sources also indicated that the Cranmer Middle School and neighboring Wilson Hospital were Merton Council owned. The Canons Leisure Centre and the fields surrounding it, in addition to the land between the Canons and Madeira

Road, were also Council owned. The green corridor between the Wandle River and the Willow Lane Industrial Estate was found to be council owned.

Merton's MapInfo database also contained the location of all roadways, footpaths and bridal ways. These three types of *roads* are considered public rights of way. In Merton, buildings cannot be built on public rights of way. Utility companies most often lay their infrastructure in public rights of way and footpaths.

A tramline (railroad track) runs through the area between the Willow Lane Estate and the Leisure Centre. Merton's GIS database showed the location of the tramline track. The company who operates these tramlines is Tramlink, operated by Transport for London (TfL). It was seen that the rail splits into two on the west side of Carshalton Road Bridge. After the split, one tramline travels north along the bridge and the other tramline runs along the northern border of the Willow Lane Industrial Estate. Figure 4.12 shows the aerial view of the tramline and the split. Merton's GIS system also contained the locations of tram stations, tram lighting, and potential sites of tram improvement projects. Because of the disturbance on privately owned lines, along with the potential impact on construction methods required, railroad information is crucial when assessing a route for distribution.

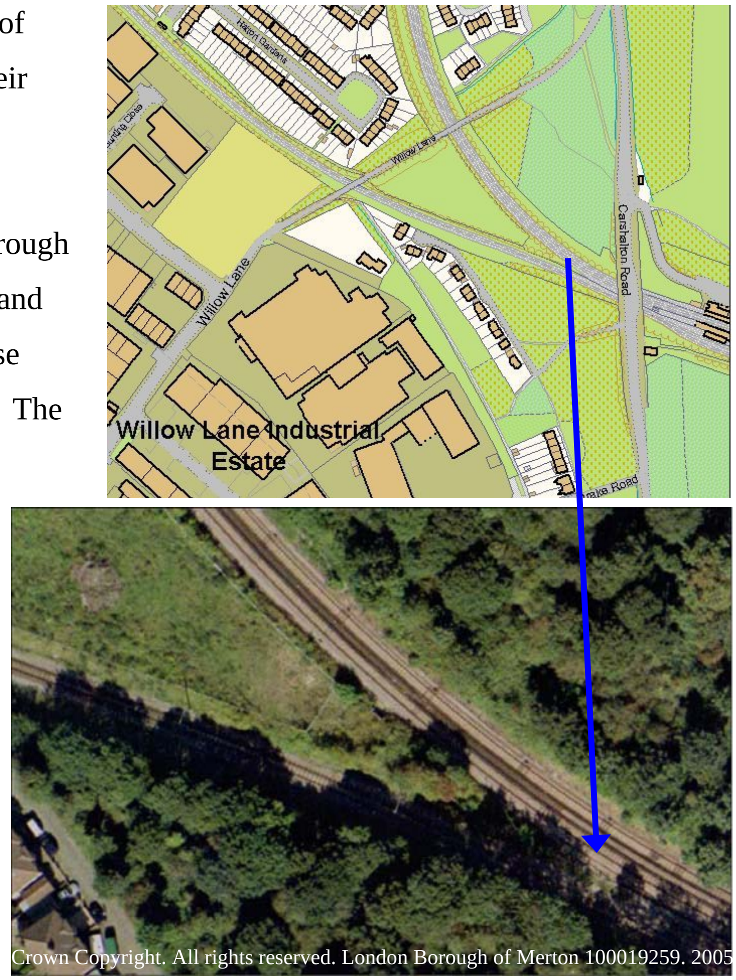


Figure 4.12: Aerial Photograph of Railroad and Tramline

4.4.3 Existing Subsurface Infrastructure

Any distribution route for a DHP scheme connecting the Willow Lane Industrial Estate and the Canons Leisure Centre will encounter subsurface gas, sewer, water, electric and telecommunication lines. The data collected describing these systems was obtained in a number of different forms, from traditional paper and digital maps to microfilm slides.

4.4.3a Electricity

There are over 400,000 km of electrical cable run underground in the UK. Electrical cables are usually buried at depths between 0.5 m and 1 m below the surface. Methods for protecting cables vary and include, but are not limited to laying cables directly in the ground, in cement-bound sand, clay pipes or ducts, or plastic pipes. For safety, buried electrical cabling sometimes has a layer of tiles, boards or plastic caution tape placed above the cables as a warning to those excavating in the area. Conduits for buried electrical cable are usually less than 0.25 m in diameter (Watson, 1987).

Electrical cables in Merton are buried underground. Maps of the electrical cables for the entire Borough of Merton were obtained from Simon Newman in the Street Management Department at the Merton Civic Centre. The maps were AutoCAD drawings on microfilm. EDF Energy-London provided Merton with the microfilm maps, which were current as of April 2004. These maps show all subsurface electrical cabling including wires running to individual residential and commercial buildings. The documentation accompanying the microfilm maps claimed that they were the most accurate representation of the actual cable locations, to EDF Energy’s knowledge.

4.4.3b Telecommunications

Buried telephone and broadband cable are typically encased in protective ducts made from clayware, PVC, or PE. Subsurface telecommunications cables are usually enclosed in ducts with a diameter of 0.09 m; however, these ducts are most often run next to other telecommunication ducts. Telecommunication ducts are most often placed 0.35 m to 0.6 m underneath footpaths although roadways are often used as well. For this reason, telecommunication lines can be laid very quickly and are more accessible then sewer, gas or water lines (Watson, 1987).

Telephone lines in Merton are buried underground. Merton’s telephone lines are maintained and operated by British Telecom (BT). Stuart Beatton, a Merton Highway Engineer, provided contact information and detailed the process for requesting cable maps from BT. According to Beatton, certain individuals in Merton’s Street Management Department have access to an online request system for maps of BT telephone line locations. It was found, however, that this online system would only produce maps showing an area that is less than 100 meters square. Procedure for requesting larger maps from BT was also provided by Beatton. Telephone line locations in the area of interest were requested from BT, however, the maps were not received by the end of this project.

The broadband supplier in Merton is Telewest Broadband. Stuart Beatton provided contact information in order to request broadband location maps. A request was sent to Telewest, however, the maps were not received by the end of this project.

4.4.3c Water Pipes

Water pipes must be buried below 0.9 m under open surface and 1.2 m under a roadway in the UK (Health and Safety Executive, 2000). Burying water pipe below this minimum depth helps prevent water pipes from freezing. Hard copy maps of subsurface water mains for the area between the Leisure Centre and the Killoughery Industrial Site were obtained from the Plan Provision Team at Thames. These maps showed the location of water mains, hydrants, and valves. Each water pipe on the map was labeled with a pipe diameter and the year of installation. The map package sent from Thames Water also contained a map key detailing water pipe classifications, types of hydrants, water meters, valves, end items, and supply assets such as pumping stations and inspection shafts. A depth table was included in the map package as well. This table gave general average depths for Thames water pipes under normal cover. Depths varied based on pipe diameter. The maps also showed T-branches coming off of the water mains. Such branches were mainly found near buildings; however, the branches stopped at a cutoff valve, well short of the buildings they were directed toward. For cases such as this, it was assumed that a water pipe ran from the shutoff value to the building even though it was not shown on the Thames Water map. It was assumed that Thames Water only showed the pipes own and maintained by the company and that Thames Water did not show private water pipes connecting these T-branches to buildings. As for accuracy of these water maps, according to Thames Water, these maps only show the "approximate position of [Thames Water] mains and associated apparatus" (Thames Water letter). For more detailed location positions, it was recommended by Thames Water that a site-specific survey be conducted by a representative from their company.

4.4.3d Sewers

Most of the underground sewer pipes in the United Kingdom are over 50 years old. Construction styles vary, but on average, 4% are made of brick or masonry, 14% are concrete and 80% are clayware. Only about 2% of sewer lines in the UK are constructed of iron, steel or plastic (Watson, 1987). They must be buried at least 0.9 m under open surface and at least 1.2 m under a road surface (Health and Safety Executive, 2000). However, sewer lines are usually buried much deeper than this to avoid other underground utilities and to achieve the gradients necessary for proper flow (Watson, 1987).

The locations of the sewer system pipe network between the Killoughery site on the Willow Lane Industrial Estate and the Canons Leisure Centre was determined using an electronic sewer map provided by Thames Water Utilities. Jason Russell, Merton’s Senior Engineer of Highways, provided the CD-ROM that contained these maps. Access to these maps required the use of a special security device called a dongle. Russell had the dongle to access these maps. Thames Water Utilities maintains the sewer system network in southeast Merton. The electronic maps showed the location of the underground sewer mains, not the locations of lines servicing private property. The map did specify whether a sewer pipe handled storm water, foul waste, or it was a combined pipe. The location of vents, rising sewer lines and abandoned pipe were also included in this map. Again, according to Thames Water, these maps only showed the “approximate position of [Thames Water] mains and associated apparatus” (Thames Water letter). For more detailed location positions, Thames Water recommended that a site-specific survey be conducted.

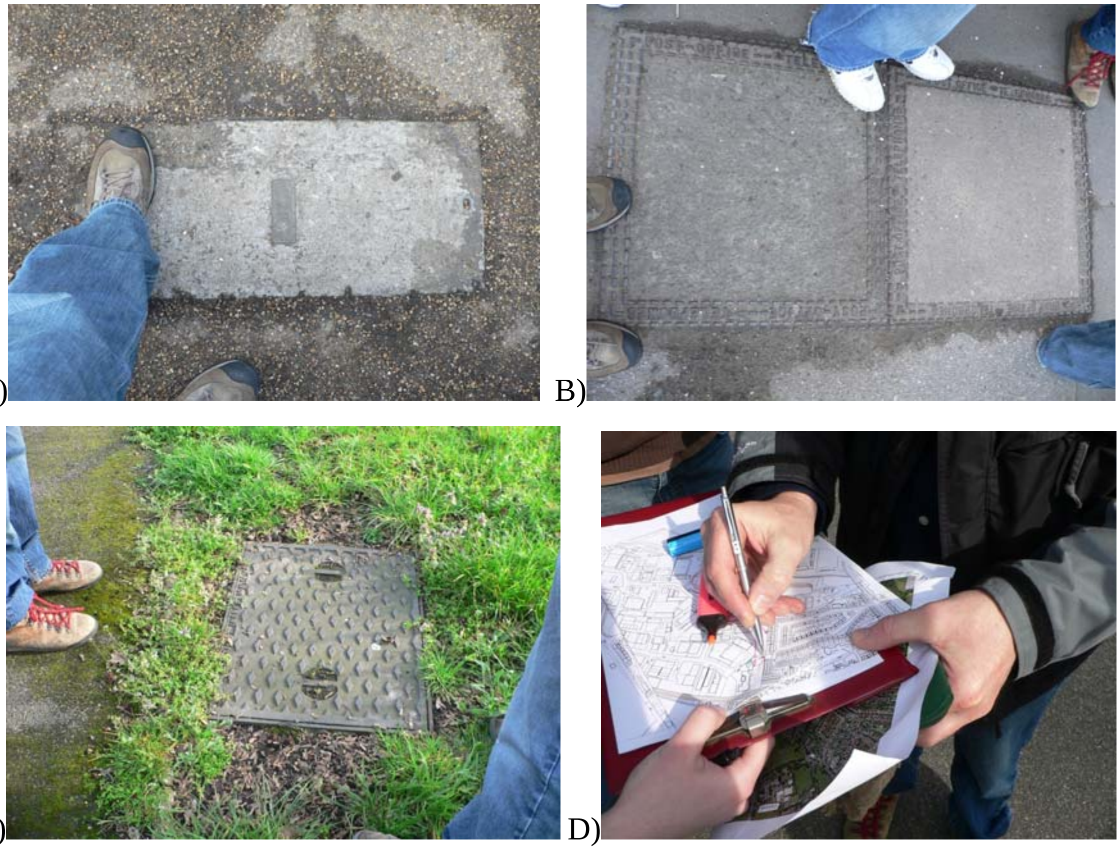
4.4.3e Natural Gas

There is over 230,000 km of subsurface natural gas line in the United Kingdom. Approximately 87% of these lines are cast iron or steel. The remaining lines are made of polyethylene (PE). Almost all service lines connecting gas mains to the user buildings are made of PE. The preferred place to lay mains is under footways or under open ground. According to the Construction Industry Research and Information Association (CIRIA), laying pipe in these locations can save 40-60% in installation costs when compared to laying pipe in roadways (Watson, 1987).

The locations of the natural gas lines servicing southeast Merton were determined using an electronic map from a British Gas Transco PLC CD-ROM. The data on the CD-ROM, provided by Jason Russell in Merton's Street Management Department, was current as of January 2005. This map showed the location of the gas mains and branch lines in the southeast corner of Merton. The gas lines located in the area between the Canons Leisure Centre and the Willow Lane Industrial Estate represented two levels of pressure classification. The first classification was intermediate pressure. Indicated on the Transco gas map using a green line (see Gas Maps, Appendix I), the map showed that there was a 24-inch intermediate pressure main running through Cranmer Green across potential routes. The second classification of gas line located in the area of interest was classified as low-pressure, indicated in red on the map (see Appendix I). Between the Industrial Estate and the Leisure Centre there was a substantial network of low-pressure gas lines, varying in diameters of 4 to 12 inches. Service lines, or lines linking gas mains to buildings, ran to almost every building within the area of interest. Unfortunately, information describing the depth of these pipelines did not exist with this electronic map. It was discovered that the location of the gas mains on the map were not to be considered exact. Transco recommended that they be contacted to pinpoint the exact location of their mains for on site location. Transco does this using a pipe locator; but also recommends that pipe locations are confirmed by hand digging.

4.4.3f Utility Summary

Utility location maps obtained for this project can be found in Appendix I. These maps showed that the subsurface utility networks in Merton occupied a considerable amount of space in the Borough's narrow roadways and footpaths. To acquire more accurate utility location information, utility access cover locations along the potential route were observed during onsite investigation.



A) B) C) D)

Figure 4.13: Locating Utility Covers On-Site
A) Gas line valve access cover B) Telephone line access cover C) Electricity cable access cover
D) Marking the location of where photographs were taken so they could be put into the GIS layer

4.4.4 Environmental Considerations

The environmental codes and regulations collected describe the area's availability for construction as well as considerations for its preservation. A variety of classifications and policies protect local environmental regions from development under the Unitary Development Plan (UDP), adopted by the Borough of Merton in 1996. A UDP coded map identifies each of the major classifications applying to each section of the Borough.

4.4.4a Land Classification

The area of Cranmer Green, which lies between Cranmer Road, Madeira Road, and King Henry VI Avenue (Figure 4.11), is the only large open space in the area under consideration and is therefore a focus of environmental concern for potential routes. The green, as well as the region surrounding the Canons Leisure Centre and The Wandle River, have a status as Conservation land, Site of Importance for Nature Conservation, Metropolitan Open Land, a

Green Corridor as well as Green Chain, and an Open Space and must be closely considered. As sited in the 2003 UDP, these guidelines impact construction and changes above ground.

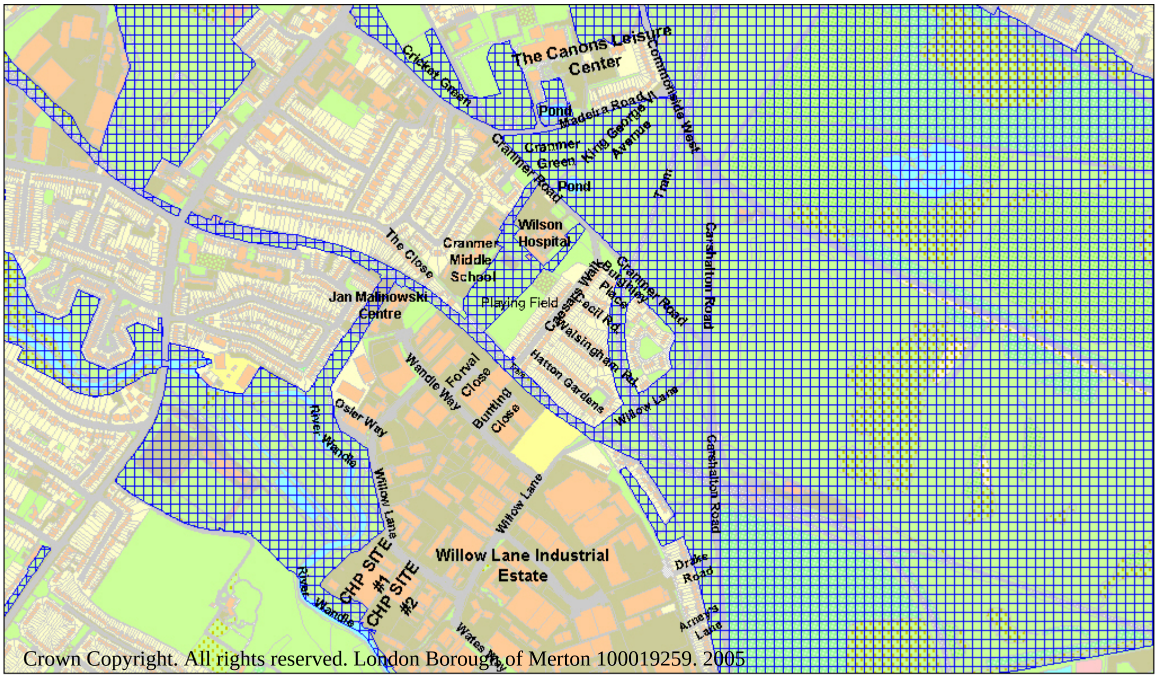


Figure 4.14: Land classified as a Green Corridor.

Conservation land, addressed by UDP policies BE.1, BE.2, BE.3, and BE.20, is an area of special interest to the community and is therefore protected. These policies restrict development, demolition, expansion, and alterations to the present state of the property. Their purpose is to maintain, as closely as possible, or improve the current appearance and atmosphere of the area. Similarly, construction and development within Local Nature Reserves and Sites of Importance for Nature Conservation, described by UDP policy NE.6, requires harm to the land be prevented through planning obligations and mitigation planning or the development to be highly beneficial to the community. The region surrounding the Wandle River is a special concern for complying with this regulation. Given our system will consist of pipes running below the surface, height and visual obstruction regulations will not apply. After installation, the site will need to be returned to the initial conditions. This will involve replanting the displaced grassy areas and removing all residual equipment and signs of construction to maintain the overall appearance of the land.

Metropolitan Open Land, addressed by policies NE.1 and NE.2, are to “enhance the health of Londoners” (Borough of Merton, 2003a, p.104), and serves to preserve areas for recreation, landscapes, and local biodiversity. The installation of piping within this area should be permitted, provided that the area is returned to as close to its original state as possible. In this case, the function and habitat the land provides will be sustained. Similarly satisfied, this project cannot damage the land's character or function (Borough of Merton, 2003a), because the land serves both as a green chain (UDP NE.3) and green corridor (UDP NE.8). Areas such as the Wandle Riverside Walk and Cranmer Green connect larger open spaces for bikers, pedestrians, and animals to safely travel through and should be preserved.

Cranmer Green and the Wandle River area are also classified as Open Space, which is accompanied by regulations constraining all development on the land (UDP L.5, L.6, L.7, L.8). The proposed piping will be traveling underground and after installation should have no impact on the land's use and appearance, therefore this action should be permissible.

The final land code regulation imposed on the potential route's area is in the Industrial Park where the CHP plant will be located. Any changes to the road network are controlled in this region, according to RN.2; however, there are no expected changes of the road network or any traffic control systems and therefore the regulation does not apply to this project.

4.4.4b. Contamination

An additional concern for this particular area is contamination. According to Merton's GIS database, the sites under consideration for CHP plant and distribution network implementation lie within a contaminated region (see Figure 4.15). Mostly likely a result of the land's industrial park, it is unknown what type of contaminants are present. Contaminants are considered to be any substance that causes harm to a person or part of the biodiversity. This is especially a concern near a river because the contaminants can seep into the water and spread more quickly. According to the Water Resources Act of 1991, it is in fact an offense to knowingly permit any pollution to enter controlled water. Before any construction or development can occur, the land must be made *suitable for use* (Venables, R., & Newton, J., & Westaway, N, 2000). Becoming *suitable* does not require that all the contaminants be removed, but the spread of them causing harm needs to be prevented. Information on the water table and the amount and type of contaminants present, along with their source and how they are affecting the land, must be determined before the site can become suitable. This study should be completed by an outside consultant, who can then assess what can be done to prepare the site for construction.

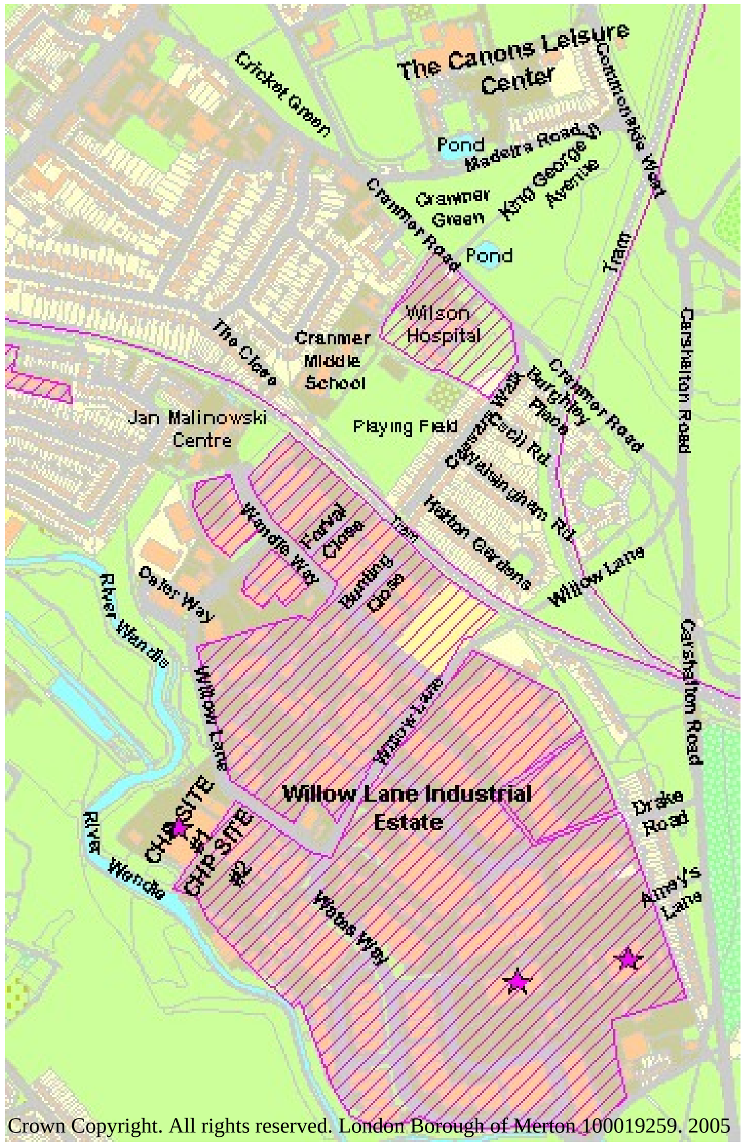


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Figure 4.15: 1970 contaminated land study.

4.4.4c Flooding

Before construction begins, the council should perform an Environmental Impact Assessment (EIA) on the site to evaluate potential impact of construction on the land, water, and biodiversity (Venables, et al., 2000). This assessment will be used by the planning department when considering if permits should be issued to allow the work. Part of the EIA will consider flooding and the potential of work to either increase or be impacted by flooding in the future. The Willow Lane Industrial site appears to be at least partially in a zone that is expect to experience flooding once every 100 years due to the Wandle River (see Figure 4.16). This location has potential problems for development in terms of meeting guideline for safe construction; however this should not be significant enough to deny permission from the Planning department.

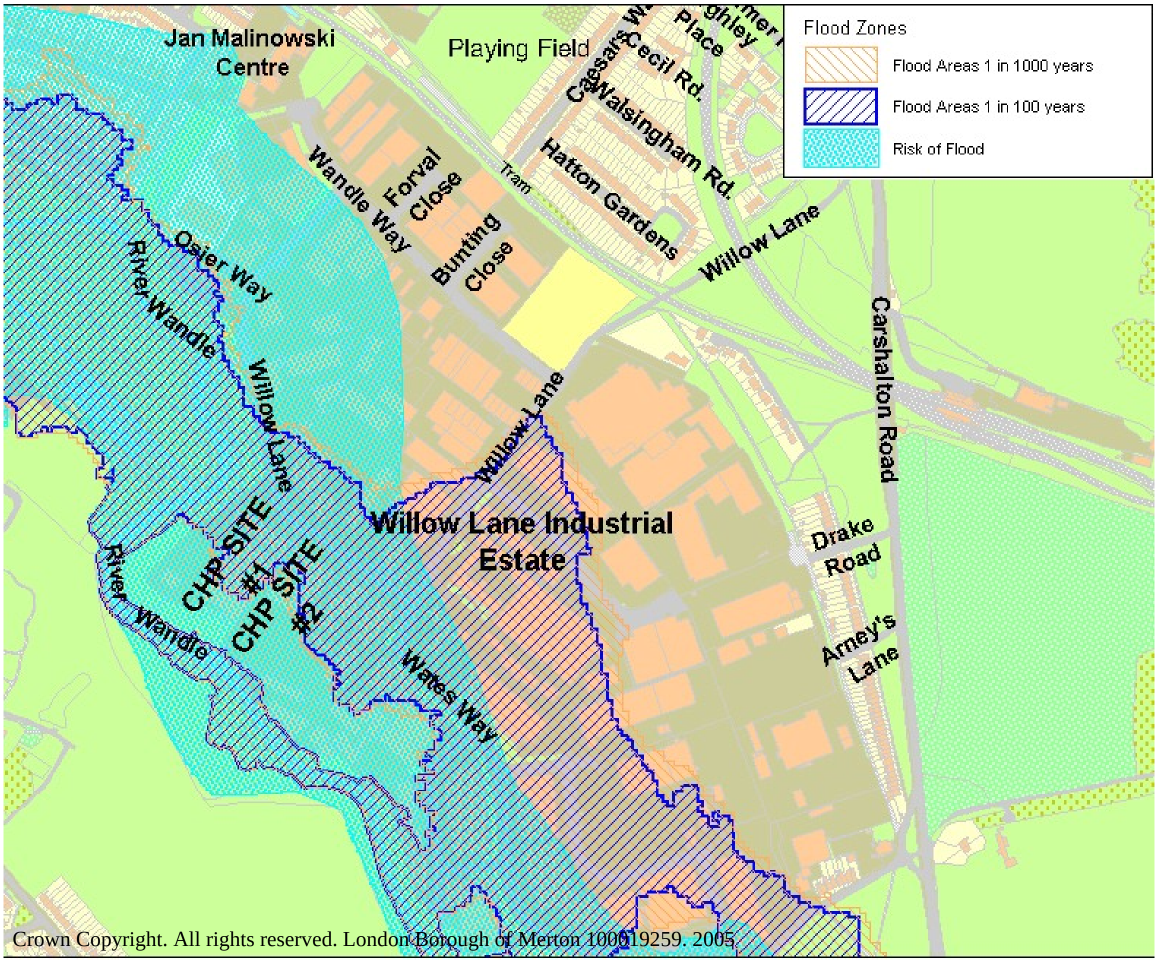

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Figure 4.16: Flood Zones based on 2004 UK Environmental Agency data.

4.4.4d Impact on Biodiversity

In addition to council guidelines for urban classification, the effect heating and electrical pipelines could have on the biodiversity of the green was important. The areas along the Wandle River and across Cranmer Green are both environmental regions, and special considerations must be included to preserve these areas. Under the Pipelines Act of 1962, the borough is obligated to restore the land back to its original or an improved condition so the land can be used as originally intended. According to The Department of Trade and Industry, long-term impact of a buried pipeline has negligible effect on the environment above after construction has occurred (1992). Following special considerations for construction around environmentally sensitive areas will preserve the land during construction and speed its regeneration. Before construction begins, a reinstatement plan should be created that outlines the procedure of replanting and restoring the site after the line is installed. This plan will allow the restoration to follow quickly, which will improve the regeneration of the area by decreasing the time it is disrupted (DTI, 1992).

An EIA report should be used to modify construction routes and methods to decrease construction costs and environmental impact (Department of the Environment, Transport and the Regions [DETR], 1999). Any project with a focus on conservation areas, especially this site running along the Wandle River, or in an industrial park, such as Willow Lane's are recommended to have such an assessment carried out to minimize disruption.

During construction, there are guidelines to follow which will help protect the areas. Before a detailed analysis of the pipeline construction can begin, the method of construction along with the codes and guidelines that apply to it must be understood. Potential obstacles, such as the established trees, should be identified and accounted for. Traditionally, the circumference of the tree is measured before excavation. This value, multiplied by a factor of four, supplies the radius away from the tree that excavation may occur with heavy equipment. Within this zone, special guidelines have been written to specify methods that cause the least harm to the tree (Department for Transport, 2002). If trenchless technology is used, the pipeline should be at a depth of 600mm within this region to avoid the majority of the major root system. If trenchless construction is not possible, then any root encountered that is more than 25mm in diameter cannot be removed and must be worked around by hand. Hand dug trenches are typically the most preferred. Above ground, the number of vehicles and equipment that drive over the root systems of a tree should be minimized to limit the roots' exposure to compression (National Joint Utilities Group [NJUG], 1995).

Measures to protect additional areas affected must be carried out as well. For example, debris and contaminants must be prevented from entering the Wandle River. One method to achieve this may be to construct a barrier or fence around the effected area during construction. After excavation, the topsoil should be stored separate from additional rubble during construction so it can be returned after the pipe is installed. When the soil is returned, the reinstatement plan created at the beginning is initiated. The soil should be compacted to settle any gaps; however, some aeration should remain for the benefit of nearby trees and root systems.

The area should also be restored to its original gradient to re-establish drainage patterns. Grass and any additional vegetation should next be planted to return the site to its original condition.

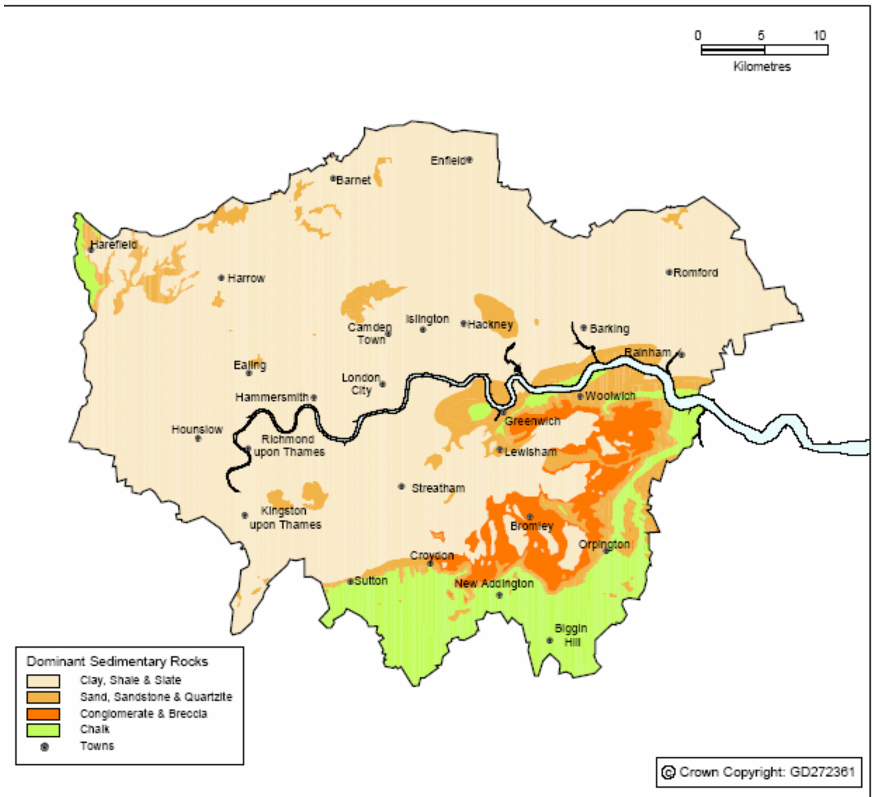
The long-term impacts from issues such as thermal pollution are negligible. David Somervell is the Energy Manager for Edinburgh University, where they have a campus wide heat, electricity and cooling network. According to Somervell, the available technology today used for pipelines typically has a very low heat loss over distance of a few degrees Celsius. These lines will have a negligible impact on the subsoil and no impact on nearby biodiversity. This technology will allow the pipelines to pass under areas of biodiversity without impacting the habitats and vegetation on the surface.

4.4.5 Geology and Archaeology

Documents and maps, such as the Contaminated Land Survey and England Rural Development Plan, were collected to provide a description of the geological subsurface along the potential route. The major soil type of the area is London clay mixed with slate and shale extending up to approximately 40m below the surface (see Figure 4.17) (Barrett, 2001). Along the River Wandle, a layer of alluvial silt and clay is present at an average thickness of five meters (Barrett, 2001). The bedrock for the London area is composed of mudstone and compacted sediment of silt and clay (British Geological Survey, 2005).

One additional consideration is the water table. The average location of the water table in the London area is 50 meters below sea level (British Geological Survey, 2005). In the section of the route along the River Wandle, the water table is expected to be closer to the surface; however, maps specific to that region would have to be obtained and a study preformed to investigate the true level. The British Geological Survey offers specific reports (GeoReports) and data on all regions of London that are available for purchase.

The potential route and the surrounding area were found to be located entirely within a high archaeological region (see Figure 4.18). The specifics of what type of archaeology present is unknown without further study by English Heritage and a report from the Greater London Archaeology Advisory Service. The type of archaeological artifacts could be industrial around the river due to its historical presence there; however, could range far back in history including Saxon times. Cramner Green is not expected to have much hidden structural archaeology because it has been recorded as a pasture and green since the 18th century (Nicholson, & Scott, 2001). In the southwest corner of the Wilson Hospital property, an example of hidden archaeology was discovered in the form of an old concrete patio during on-site inspection. Although presently covered with grass, giving the area an appearance as a harmless lawn, the concrete was visible through a portion of the grass upon closer inspection.



: Solid Geology - 1:250,000 scale Map (Source: British Geological Survey: NERC)

Figure 4.17: Geology of Greater London
Source: British Geological Survey: NERC

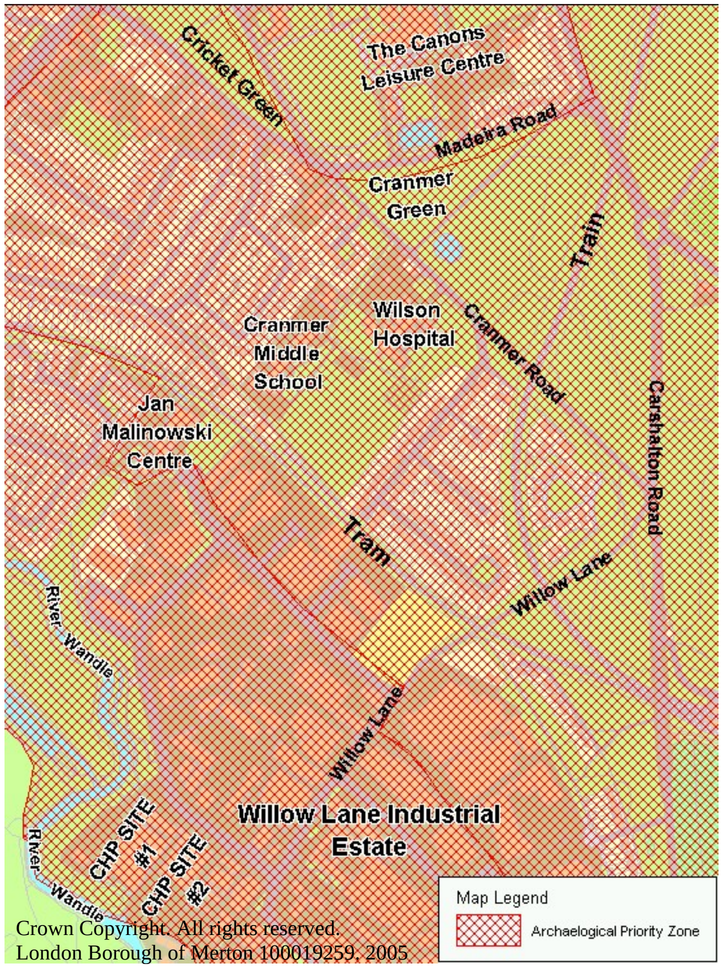


Figure 4.18: Map of Archaeological Priority Zones

4.4.6 Noise

When preparing for construction of the distribution route, considerations for reducing noise must be considered. A large portion of the route selected is located away from neighborhoods and carries less social impact; however, once the route breaks away from the industrial estate there are neighborhoods, a school, and offices, which must be accommodated. Current noise levels along these areas are influenced by major roads and railways. The level of noise created by these is expected to be high when evaluated due to high car traffic on Cranmer and Madeira Roads, as well as the two railways passing through the area and along the industrial estate.

Before construction can begin, contractors must obtain consent for construction and work, according to Section 61 of the Control of Pollution Act (1974). This regulates the noise associated with construction and methods to minimize it. A second document, BSI 5228, provides additional guidelines to minimize noise. Officially titled “Noise and vibrations control on construction and open sites”, this code has sections pertaining to this project. Part 1 describes methods of estimating construction noise and a summary of limits for construction noise. Part 2 describes the current regulations for noise and vibrations from construction, including road construction and maintenance. Currently, “The Noise Emission in the Environment by Equipment for Use Outdoors Directive 2000/14/EC” is working to rate and monitor the noise levels created by equipment during outdoor construction. This program is working towards reducing the noise disruption during outdoor construction such as the laying of this pipeline.

4.4.7 Motor Vehicle Traffic Findings

Merton Council had access to public right of ways including footpaths and other classifications of roads. Roads and footpaths are common places to install most utility infrastructure because they are public right of ways. For this reason, traffic considerations were a necessary part of this route assessment. Road closing for construction affects traffic. This is an inconvenience for the community, especially during business and commuting hours.

The area around Cranmer Green includes two main roads, Madeira Rd. and Cranmer Rd., which the pipeline will need to cross. These are not the only roads in the area or the only options for traffic flow if a detour is required. Additional roads, which could be used during a detour, include King George VI Avenue and Commonside West, which continue down to a roundabout (rotary). Refer to Figures 4.9-4.11 to reference a map of these roadways.

The only traffic volume data for the Willow Lane site was for the Willow Lane Bridge. At the time of this project, the Willow Lane Bridge was closed. Therefore, traffic volume data for the Willow Lane industrial site does not exist. Merton does not have traffic volume data for the Wilson Hospital or the Cranmer Middle School. Merton did have traffic volume data for Cranmer Road and Madeira Road. Both of these roads must be crossed by infrastructure running from the Industrial Estate to the Leisure Centre. All traffic data Merton Council had for the roads in the area of the distribution route can be found in Appendix G.

4.4.8 Surface Structures and Features

The surface structures and features between the Willow Lane Industrial Estate and the Canon’s Leisure Centre were identified using Merton’s MapInfo database and on-site observation. The MapInfo database showed the location of structures and features such as bus stop structures, bollards, cycle racks, guardrails, gates, floodlights, litter bins, planters, benches and trees. Next, on-site observation was used to observe the locations of obstacles along the potential routes. A selection of important obstacles were photographed and documented within a GIS layer in MapInfo. Additional data collected in this way was the location of utility covers, fences, and walls and the identification of land surfaces, such as pavement or dirt. See the MapInfo layer "route pictures.tab." An example of what this GIS layer represents is shown below.

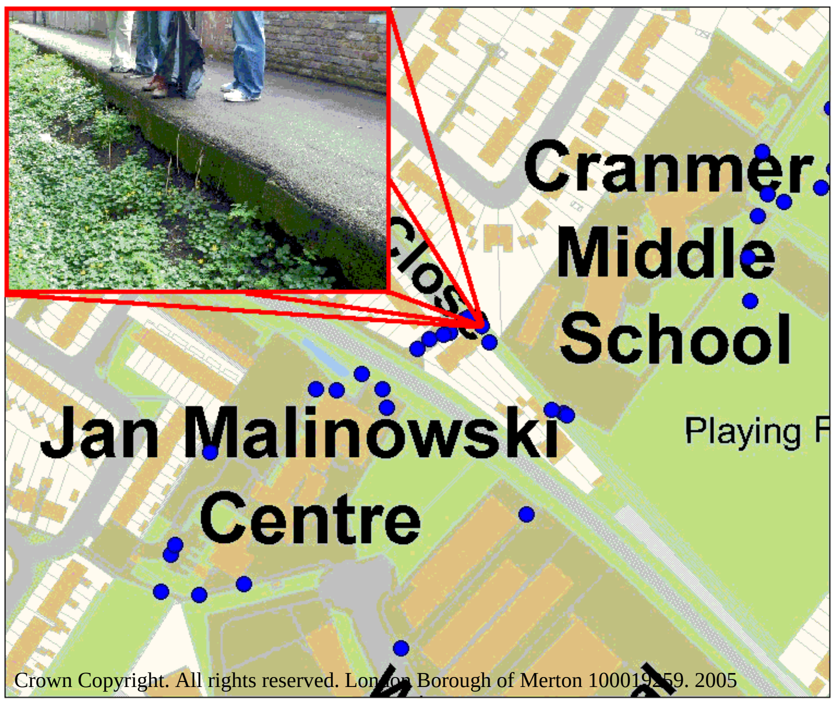


Figure 4.19: GIS layer "route pictures.tab" with photographs of surface structures and features linked to map location.

Additional examples of surface features found along the route through onsite observation are shown below.

A) B) C) D)

Figure 4.20: On-site Observation Pictures
A) Identifying Biodiversity B) A wall between the Wilson Hospital parking lot and Cranmer Rd. (view: looking from Wilson Hospital parking lot towards Cranmer Green) C) Surveying footpath in the green corridor to the west of the Willow Lane Industrial Estate D) A potential exit point out of the Killoughery industrial site into the green corridor.

4.4.9 Legal-Liability Findings

One would think that the route selection would impact the overall liability due to different construction methods and areas of high risk; however, regardless of the route selected, certain insurance policies will be required to cover liability for construction and operation. Contractors' All Risks insurance will be required to cover all assets during the construction phase, such as machinery and construction material. Public Liability insurance will be required to cover the death, injury, or illness of anyone in the general public caused by the system and any damage to property (GPG234, 2002). A table showing the specific insurance policies required for liability coverage is shown in Appendix J.

Since these insurance policies are relatively independent of route selection, the impact of legal and liability considerations on deciding the optimal route will be negligible. The Borough of Merton should be aware of its liability in constructing and operating this distribution system but this information is not a central factor when determining the distribution route(s).

5. Analysis

5.1 Introduction

The findings presented in the previous chapter are analyzed in the following sections to determine the optimal route for the CHP distribution network. The first section analyzes the size requirements for the distribution system components. This is followed by an analysis of the construction spacing requirements and recommended construction methods. Section 5.4 analyzes the findings for the distribution route considerations and using constraint mapping, identifies the optimal route for the system. The analysis is summarized in section 5.5.

5.2 Analysis of Distribution Specifications

5.2.1 Heating Pipe Size Determination

The general specifications for the district heating distribution system were presented in the Results Chapter section 4.1. A more involved analysis is required in order to determine the more specific requirements for the system. The first specification that had to be determined was the pipe size. The most effective way of determining the required pipe size is to perform a complex optimization for minimizing the total cost based on the cost of heat loss, the cost of pumping, the cost of pipes and pumps, and the cost of maintenance and repair (Phetteplace, 1995). This optimization requires difficult mathematics or computer simulation to perform and should be done by a qualified consultant. However, a very common design rule of thumb exists that is frequently used in Europe for systems in the 120°C temperature range. This is that the pressure loss in the piping should not exceed 100 Pa/m (Phetteplace, 1995).

ALSTOM's website contained a Dimension / Pressure Loss calculator that could calculate the required pipe size, flow, and pressure gradient based on operational situation, dimension, and pressure factors. By specifying a forward temperature of 120°C, a return temperature of 50°C, a total heat load of 3.7 MW, a maximum pressure gradient of 100 Pa/m, a pipe material of steel, and a pipeline length of approximately 3 km, the calculator computes a recommended pipe diameter of 125 mm. The pipeline length was estimated based on the maximum foreseeable distance to distribute heat to the Mitcham Town Centre, as well as the Canons Leisure Centre. Also note that the pipe size calculation was relatively independent of the pipeline length. A flow of 46.5 m^3/h, a forward pressure gradient of 50.8 Pa/m, and a return pressure gradient of 57.3 Pa/m were also determined for the system parameters (ALSTOM, 2005).

ALSTOM's specifications for their steel pre-insulated pipes indicated that a twin pipe could be used for this size pipe. The twin pipe system combines the forward and return heating pipes into one insulated cylinder. This significantly reduces the size trench required and improves the thermal efficiency of the pipe system. With the insulation, the outer casing diameter of the twin pipe required would be 400 mm. The twin pipe is available in 12 m or 16 m lengths (ALSTOM, 2005).

5.2.2 Heating Pipe Heat Loss and Efficiency

ALSTOM's Heat Loss Calculator was used to determine the heat loss, specific heat loss, temperature drop, and efficiency. Using the parameters previously given and specifying a pipe depth of 0.4 m, an ambient temperature of 0°C, and a soil thermal resistivity of 1°C-m/W, a heat loss of 85.1 kW was calculated. This is an efficiency of 97.7%. From the plant to the furthest load, the temperature drop would be 1.43°C. On the return, the temperature would drop 0.098°C from the load to the plant. The specific heat loss would be 28.4 W/m, which can also be used to define the thermal pollution of the pipe (ALSTOM, 2005).

The first phase of the CHP system would most likely not include the proposed new Mitcham Town Centre. In this case, the thermal load would only be around 222 kW based on the average gas heating energy consumption from 2004 data. For such a small initial load, the distribution system would not operate nearly as efficiently. However, the Leisure Centre is located only 1.5 km from the Willow Lane site so distribution losses would be less severe. Estimating a base load of 222 kW, the efficiency would be 84.3%, losing 41.2 kW of heat in the system. The temperature drop from the plant to the Leisure Centre would be 9.93°C with 0.810°C lost on the return. The specific heat loss would be 27.5 W/m. In order to compensate for the larger temperature loss when running this small load, the source temperature would have to be increased to about 133°C to deliver the water at 120°C. This would increase the heat loss to 44.6 kW or 29.7 W/m at an efficiency of 83.3%. This shows that maximizing the thermal load is essential to increasing the efficiency of the system (ALSTOM, 2005).

5.2.3 Sizing of Electrical Transmission Cables

Table 5.1 shows the current ratings for three-core cables from ABB's XLPE cable system. Since these cables are manufactured to international standards, other manufacturer's cables will have similar ratings. Three-core means that the cable includes three transmission wires in one insulated sheath. The table shows the current rating in the ground operating at both 65°C and 90°C. The cables are rated to operate continuously at 90°C but to keep losses lower and to reduce thermal instability, operation should be limited to 65°C. In order to meet the current requirement of 100 A with sufficient margin, a cross section of 35 mm^2 is required. These ratings are determined at the following conditions: ground temperature of 20°C, ambient temperature of 35°C, laying depth of 1 m, and ground thermal resistivity of 1.0 km/W (ABB Group, 2005).

Rated voltage up to 220 kV								
Cross section mm^2	Aluminium conductor				Copper conductor			
	In ground		In air		In ground		In air	
	65°C	90°C	65°C	90°C	65°C	90°C	65°C	90°C
16	74	89	60	82	96	115	78	105
25	95	115	80	110	120	145	105	140
35	115	135	97	130	145	175	125	170
50	135	160	120	165	175	210	155	210
70	165	195	145	195	210	250	185	250
95	195	230	170	230	250	300	220	290
120	220	265	200	270	285	340	255	345
150	245	295	225	300	315	380	285	390
185	280	335	255	345	355	430	325	440
240	320	385	300	400	410	495	380	515
300	365	435	335	455	460	555	430	580
400	410	490	385	525	515	625	490	680
500	465	560	445	610	580	700	560	780
630	525	635	510	705	640	785	635	890
800	585	715	585	810	705	865	715	1000
1000	645	785	655	915	755	935	785	1100

Table 5.1: Current rating for three-core cables, amperes
Source: ABB Group, 2005

In order to account for differences in these conditions, such as variation in the ground temperature, tables of rating factors are used. Rating factors are numbers that are multiplied by the current ratings found in Table 5.1 to get the new current rating based on the condition change for that rating factor. Multiple rating factors can be used until the full range of conditions is specified.

The largest constraint on the current rating is the amount of heat that can be dissipated in the ground to prevent the cable from overheating. Therefore, rating factors are specified for all the variables that affect the heat dissipation of the wire in the ground. Ground temperature is an important variable because warm soil absorbs less heat. Ambient temperature is also a factor. The installation depth is important because the heat is assumed to eventually go to the ground surface; therefore deeper cables see more total soil resistance. Installation in ducts reduces how well the heat can dissipate into the ground. Installation near other cables (or in this case, near a heat pipe) can induce greater losses in the cable. The effect is less the farther they are from each other. The soil thermal resistivity is also important because it determines how well the soil can carry away heat. This is a specialized measurement. Design assumptions can be made using handbooks such as the EPRI Underground Transmission Systems Reference Book (Summit Electric Supply, 2005). For all of these variables, rating factors are specified.

For this analysis, the following values were used for these variables. In order to meet the NJUG 9 guidelines for utilities, the installation depth will be 500 mm. The rating factor table gave a value of 1.10 for 0.5 m depth. When crossing roads, an additional 100 mm of depth will be required. The installation was assumed to not be inside a duct. If trenchless construction methods are used to cross certain areas, this may not be the case and adjustments should be made for these locations. The highest yearly temperature in London is around 35°C (Weather Channel, 2005). Since this is the temperature at which the ratings were made, the rating factor is 1. Only one transmission cable is assumed to be laid so thermal losses from other cables can be ignored. However, the effect of the heating pipe cannot be ignored and no rating factor exists for it.

In order to determine the affect of the heating pipe on sizing the electrical cable, the ground thermal resistivity and ground temperature factors are used. Ground thermal resistivity is specified in °C-m/W. Its value fluctuates widely with different soil types and moisture. A common design assumption in the US is 0.9°C-m/W (Summit Electric Supply, 2005). The cable is rated for a thermal resistivity of 1.0°C-m/W (ABB Group, 2005). For this analysis, this value will be assumed. This can be controlled by using sand for backfill that has a thermal resistivity of 1.0°C-m/W or less. The resistivity of the topsoil can be measured using specialized instrumentation.

The thermal characteristics of the heating pipe can be determined by using the heat loss calculator described in section 5.1.2. Given that the heating pipe is buried at 0.4 m, the ground resistivity is 1.0°C-m/W, the ambient temperature is 35°C, and the supply temperature is 120°C, it was determined that the specific heat loss for maximum load would be 18.2 W/m (ALSTOM, 2005). This means that for a one meter long pipe segment, the heat dissipation would be 18.2 W. Using the principles of Fourier's Law of Conduction, the temperature gradient in °C/m can be calculated from the heat flow in W/m^2 and the thermal resistivity in °C-m/W. To find the heat flow radiating out of the surface of the pipe, specified as watts per sq. meter (W/m^2), the surface area of the pipe must be determined. The surface area of a cylinder is given by $2\pi rl$ where r is the radius of the cylinder and l is the length of the cylinder. For a one meter long pipe segment where the radius is 200 mm, the surface area is 1.257 m^2. The heat flow is therefore 18.2 W over the surface area 1.257 m^2 giving 14.48 W/m^2. Multiplying the heat flow, 14.48 W/m^2, by the thermal resistivity of the soil, assumed to be 1.0°C-m/W, gives a temperature drop per meter of 14.48°C/m.

If the surface temperature of the heating pipe under these conditions can be determined, the ground temperature can be calculated at any given distance from the heat pipe. In order to estimate the surface temperature of the heating pipe, the effect of the insulation must be evaluated. The specifications for the pre-insulated twin pipe give the thermal conductivity of the polyurethane foam. This is specified as less than 0.028 W/m-°C (ALSTOM, 2005). The inverse of the thermal conductivity gives the thermal resistance, in this case 35.71°C-m/W. The pipe carrying the 120°C water will be analyzed because the return pipe actually absorbs heat from this pipe. This heating pipe is dissipating 23.9 W/m. The insulation thickness at its thinnest point around this pipe is 40 mm thick. The surface area of a 1 m long segment of this pipe, given by $2\pi rl$, is 0.393 m^2. The heat flow is therefore 23.9 W per 0.393 m^2 or 60.86 W/m^2. Using Fourier's Law, the temperature drop through the insulation is found to be 2174°C/m. Multiplying by the insulation thickness gives a temperature drop through the insulation of 86.96°C. Subtracting this from the water temperature of 120°C, the surface temperature can be estimated to be 32.4°C. Using the temperature drop per meter through the ground, the ground temperature at any point can be determined.

Fortunately, rating factors are specified for different ground temperatures. The ground temperature for which the cable ratings were determined was 20°C. Since this represents a temperature drop of 12.4°C from the surface of the heating pipe, the cable would have to be placed 0.86 m away from the heat pipe in order to be at this ground temperature. This considerably widens the excavation area. Placing the cable closer to the heat pipe may require oversizing the cable to deal with the additional heat. To check, it is assumed that the cable is placed as close as possible to the heat pipe in order to minimize the excavation area as much as possible. For a ground temperature of 35°C, which is greater than the estimated surface temperature of the heating pipe, and an operation temperature of 65°C, a rating factor is given of 0.82. Multiplying this rating factor with the previously determined rating factors and the current rating for the 35 mm^2 yields the following:

$$115A \times 1.10 \times 0.82 = 103.73A$$

This meets the required amperage of 100 A determined for the given voltage and electrical load. This shows that the transmission line should be able to operate safely at any distance from the heating pipe. For 35 mm^2 wire, the cable with insulation has an outer diameter of 43 mm.

5.3 Analysis of Construction Requirements

5.3.1 Twin Pipe System Installation Requirements

The distribution specifications determined in section 5.1 indicate that a twin pipe with two steel 125 mm pipes and an outer insulation diameter of 400 mm should be used for heat delivery. Using ALSTOM's specifications for this pipe system, the construction requirements can be determined. Figure 5.1 shows the requirements for the excavation of the trench for the twin pipe system. The minimum depth of cover for the pipe is 400 mm. This is measured from bottom of the asphalt or concrete layer or from the top of the gravel or grass layer. The pipe must be surrounded by 100 mm of stoneless sand. Therefore, the trench must be dug another 100 mm below the pipe's resting depth to be filled in with sand. The total minimum trench depth is 900 mm. The pipe must have 100 mm of clearance on either side for the stoneless sand, setting the minimum trench width at 600 mm. Figure 5.1 also shows the warning tape that must be buried over the pipe.

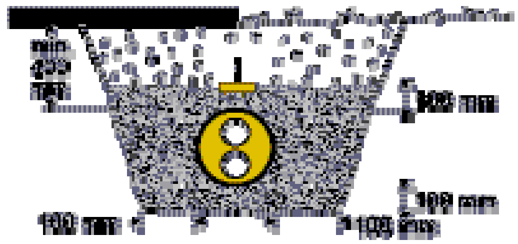


Figure 5.1: Excavation of Trench
Source: ALSTOM, 2005

An additional 250-300 mm must be excavated at joints to ensure enough working space for welding and installing muffs. Figure 5.2 shows a preinstalled muff which requires an extra 1000 mm clearance. While possibly saving construction time, this space additional requirement for preinstalled muffs should be considered when the construction plan is made. Figure 5.3 shows the different types of muffs that can be used for joining straight sections.

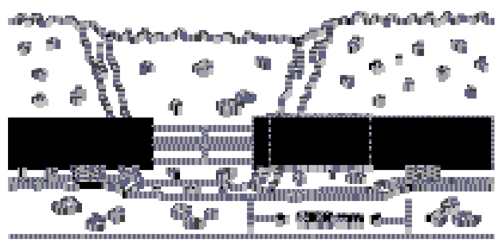


Figure 5.2: Excavation for Preinstalled Muff
Source: ALSTOM, 2005

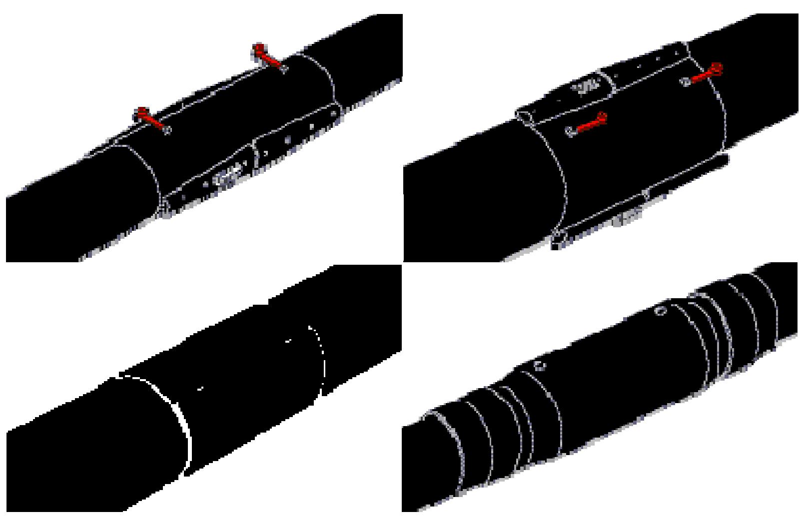


Figure 5.3: Top: 2-part Muff, 3-part Muff, Bottom: Band Muff, Preinstalled Muff
Source: ALSTOM, 2005

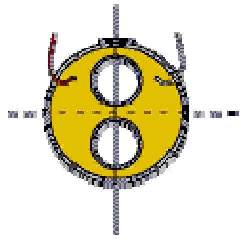


Figure 5.4: Twin Pipe Position
Source: ALSTOM, 2005

Figure 5.4 shows the necessary position for the twin pipe system. One pipe must always lie above the other pipe vertically as shown. The leak-detection alarm wires must lie at the top of the joint.

Pipe bends (Figure 5.5) are available at angles of 15° to 90° in 15° intervals. Alternatively, pipe curves (Figure 5.6) can be ordered in 12 m or 16 m lengths at 2° intervals to optimize the system and improve project economy. The construction plan should consider which joints to use along the route and their effect on the total system performance.

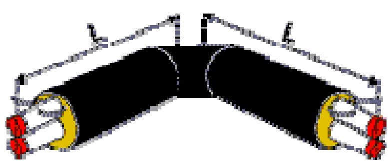


Figure 5.5: Twin Pipe Bend
Source: ALSTOM, 2005

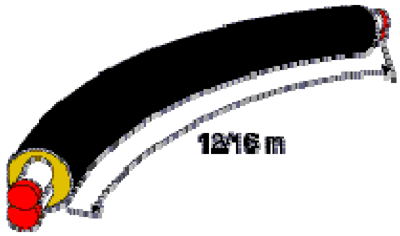


Figure 5.6: Twin Pipe Curve
Source: ALSTOM, 2005

The twin pipe system is also suitable for easy future expansion of the heat distribution network by using hot tapping. Hot tapping allows the installer to connect a new pipeline to the existing pipeline while it is operating. Figure 5.7 shows the hot tapping valve (1) that is used to connect the pipe to another twin pipeline. Hot tapping can also be used to create branches with smaller diameter flexible piping.

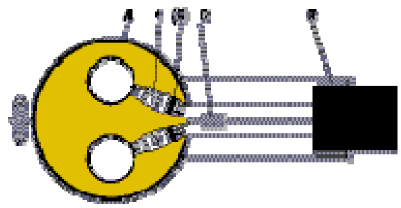


Figure 5.7: Hot Tapping of Twin Pipe
Source: ALSTOM, 2005

5.3.2 Electrical Transmission Cable Installation

In section 5.1.2, the size of the electrical transmission cable was determined and the clearance from the heating pipe was found to not be a concern. However, NJUG 9 recommends 300 mm of clearance from other utilities in order to easily access the high voltage line. Since the heat pipe requires a trench width of 600 mm for 100 mm of clearance on each side of the pipe, the required clearance from the electrical cable of 300 mm will expand the trench width by another 200 mm to one side. Additionally, the transmission line is 43 mm in diameter so another 100 mm should be added for laying the line. This brings the total minimum trench width to 900 mm. Since the electrical cable should be buried at 500 mm depth (or 600 mm under roadways), no additional depth beyond the minimum 900 mm for the heat pipe is required.

When using trenchless methods under railways, roads, or other infrastructure, a duct will have to be installed and the cable pulled through the duct. The duct should be at least twice the diameter of the cable. Additional clearance from the heat pipe will be required because the electrical cable will not dissipate heat as well from inside a duct (ABB Group, 2005).

5.4 Analysis of Distribution Route Considerations

Following the methodology for analyzing distribution route considerations, the first pieces of information placed on the map were the locations of the Killoughery Industrial Estate on Willow Lane with its property boundaries and the location of the Canons Leisure Centre and its property boundaries (see Figure 5.8). The area between these two sites defined the area of interest for this route assessment.

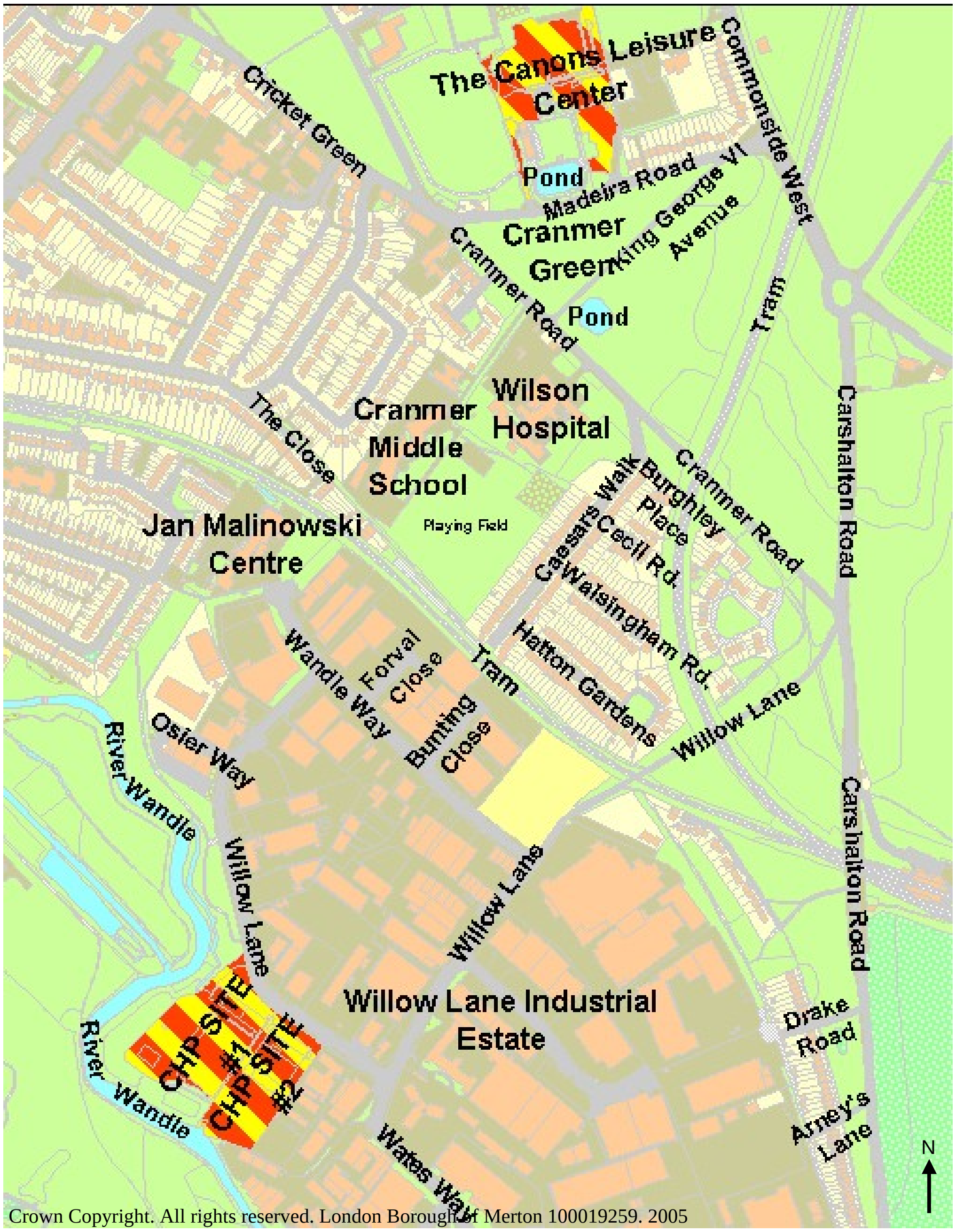


Figure 5.8: Constraint Map with Killoughery Site (CHP Site 1 & 2) and the Canons Leisure Centre

5.4.1 Buildings

The first layer placed on the constraint map was the location of buildings (see Figure 5.9). It was immediately determined that the area between the two sites was crowded with industrial and residential buildings. Clearly, it was necessary to avoid a number of buildings. However, it was also obvious that there was a good amount of open spaces where no buildings were present. The first set of buildings the distribution network would have to be routed around was the industrial site buildings. The next set of buildings to avoid was the buildings in two residential neighborhoods. One neighborhood was to the northwest of the industrial estate and the other was to the northeast of the industrial estate. Two other large buildings were located between these residential neighborhoods. These buildings were the Cranmer Middle School complex and the Wilson Hospital buildings. In addition, a housing complex to the east of the Canons needed to be avoided, as did the Merton Heritage Centre historical building directly south of the Canons. A map showing the location of these buildings between the Killoughery Industrial Site and the Leisure Centre is shown. The buildings are shaded on the map in brown.

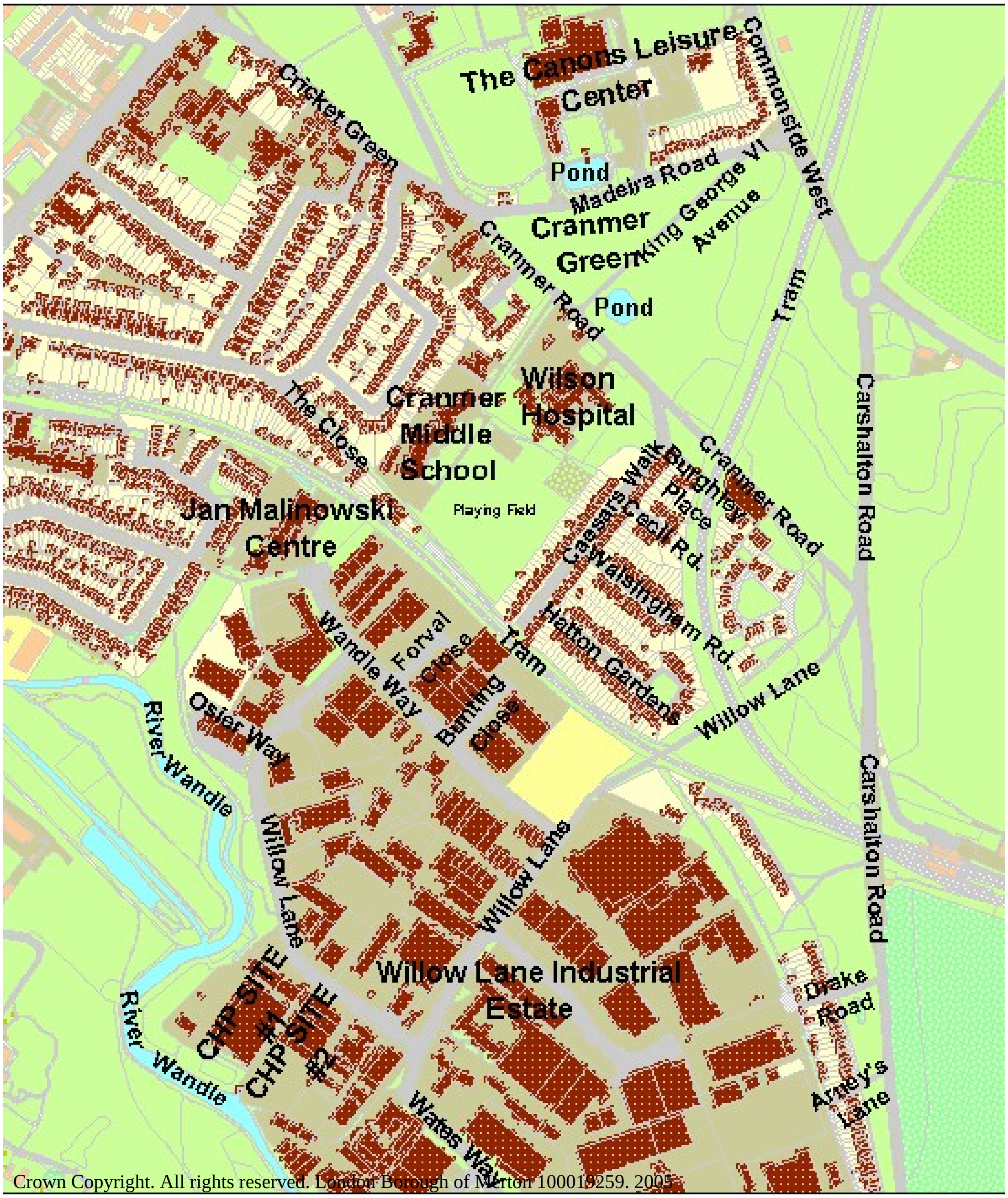


Figure 5.9: Constraint map with all buildings in the area of interest highlighted in brown.

5.4.2 Land Ownership

The next layer placed on the constraint map was property ownership and boundaries (see Figure 5.10). This information was added to the constraint map by color coding properties classified as privately owned and controlled, Merton Council owned and controlled, and public right of ways.

To break up this part of the analysis into more manageable sections, the area of interest was divided into three analysis areas. These three areas were the Willow Lane Industrial Estate, the area between the Industrial Estate and Cranmer Road and the area between Cranmer Road and the Canons Leisure Centre. Detailed maps of these three sections follow. Using the methodology described in Chapter 3, all land privately owned, controlled, or otherwise occupied by parties other than the Merton Council were classified as land areas to avoid. Classification of properties in this way eliminated a large amount of land through which to run the CHP distribution network.

The first area analyzed incorporating property ownership and boundary data was the Willow Lane Estate. As seen in the map below, private companies occupy all properties in the Willow Lane Industrial Estate.

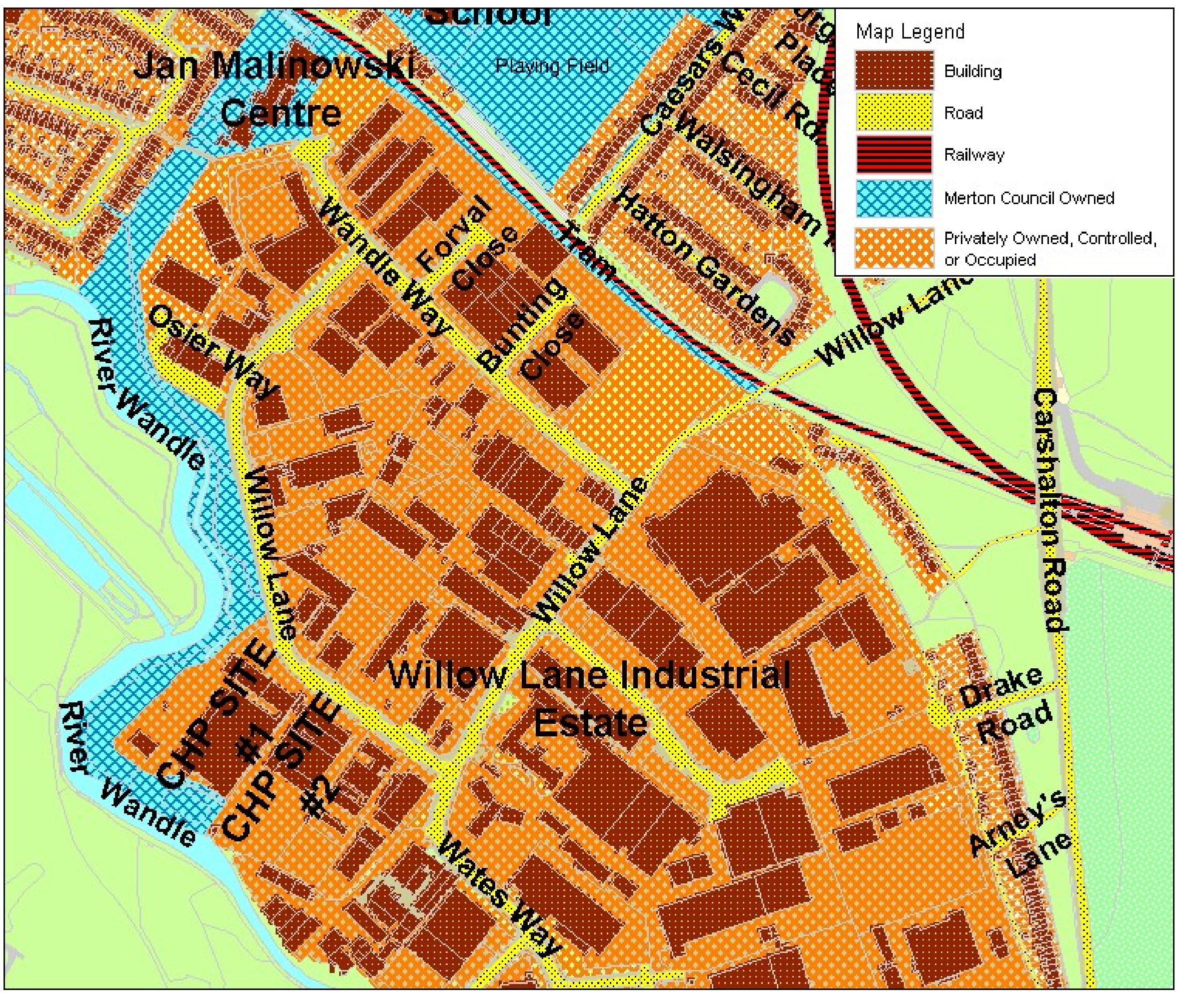


Figure 5.10: Constraint map showing Willow Lane Industrial Estate shaded according to property classifications

The roadways and sidewalks running through the industrial estate were public right of ways. To the west of the industrial estate is land classified as a green corridor. This land is owned and controlled by Merton Council. The Jan Malinowski Centre, although not part of the industrial estate, is located at the northern corner of the industrial estate. The Malinowski Centre is owned and operated by the Merton Council Housing and Social Services Department. Analysis of this area showed that there were two options for running heat and electricity infrastructure from the Killoughery site out of the Industrial Estate toward the Leisure Centre.

One option was to run the infrastructure under the roadways in the industrial estate. Roadways that could be utilized to do this included Willow Lane, Wandle Way, Osier Way, Forval Close and Bunting Close. These roads ran toward the north of the Industrial complex in the direction of the Leisure Centre. Using these roads for the distribution network left one clear point of opportunity for exiting the industrial estate. This point of exit is at the Willow Lane Bridge (see Figure 5.11). At the time of this route assessment, Willow Lane Bridge was closed to motor vehicle traffic because the bridge was deemed to old to carry heavy vehicles such as trucks. This route area was shaded in red on the constraint map.

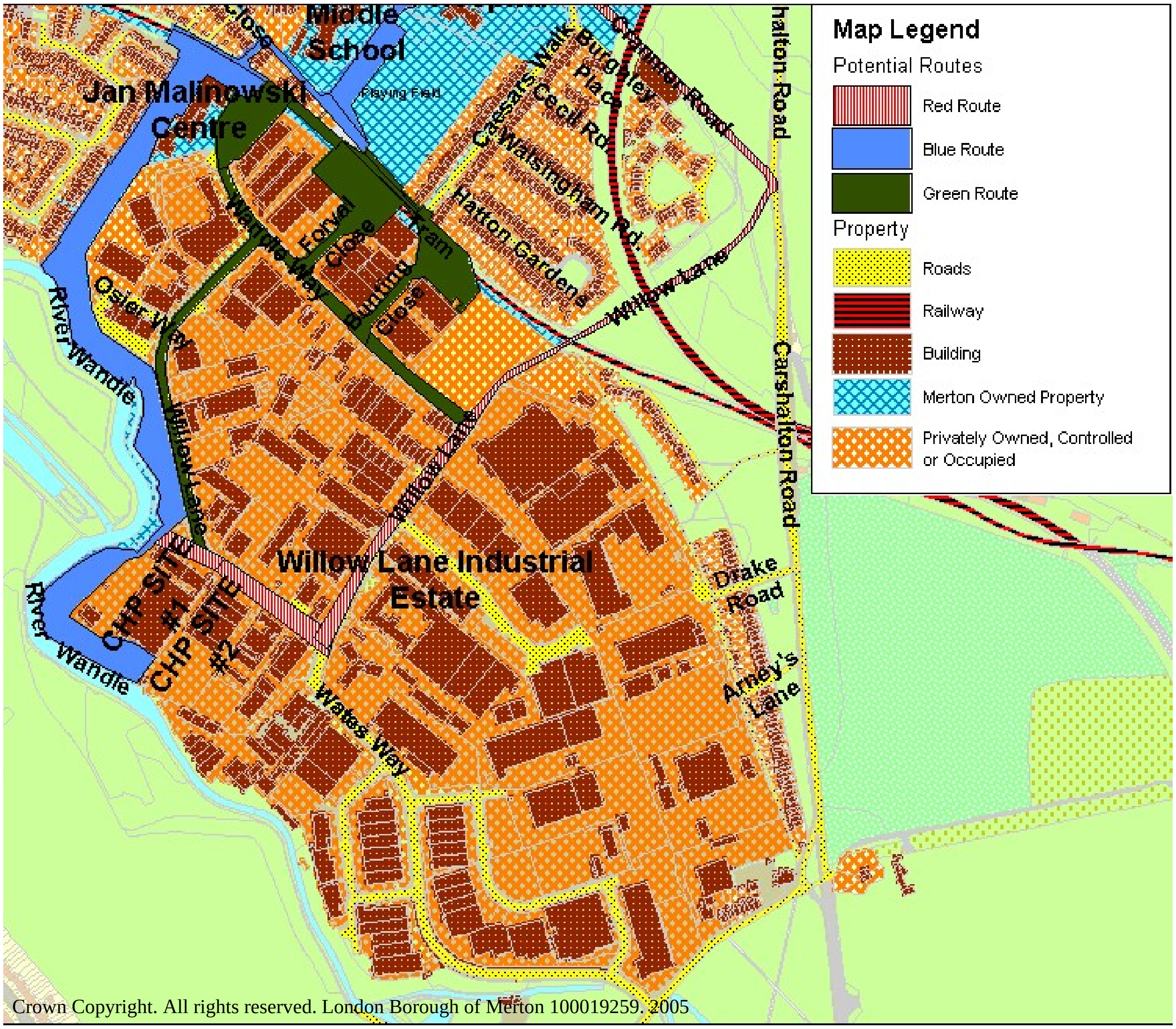


Figure 5.11: Constraint map showing all possible routes identified based on building locations and property ownership.

Three other exit points existed at the end of Wandle Way, Forval Close or Bunting Close. This area was shaded with green on the constraint map. However, using these exit points required running across property occupied by private companies. Again as stated in the Methodology, Merton Council wished to avoid crossing privately owned, controlled or otherwise occupied land at all costs. Because of this, these routes were marked as last resort possibilities in the case that all other exit points proved more difficult.

Another road option existed as well. This option was to run southeast out of the industrial estate. However, choosing this path would mean first running the route in the opposite direction of the Leisure Centre and then out of the only vehicle entrance to the industrial estate since the Willow Lane Bridge was closed. Then, pipe and cables would have to be run up Carshalton Rd. to Cranmer Rd. where they would then be run up to Cranmer Green. Choosing this option adds almost 1 km onto the route length. It would also require construction through the high traffic volume areas of the Willow Lane Industrial Estate entrance and Carshalton Rd. For these reasons, at this stage of placing data on the constraint map, this option was moved to the bottom of possible routes based on additional route length, added material and construction expense as well as traffic considerations.

Another option found for exiting the industrial estate was to run the distribution route through a green corridor between the western border of the Willow Lane Estate and the River Wandle. The potential area in the green corridor through which the distribution pipes and cables could be run is marked in blue on the constraint map (see Figure 5.11). This route would allow the infrastructure to be run from the Killoughery Industrial site, through a small section of brush, and then along a dirt footpath to the Jan Malinowski Centre at the northern point of the industrial estate. The route would be run through the open space on the west side of the Centre. This area is also shaded blue (see Figure 5.11).

It is clear that after adding property ownership to the constraint map, the CHP distribution network could exit the industrial estate through either roadways or a green corridor. At this point in the analysis, the possible areas through which this distribution network could be run are clearly marked on the map in Figure 5.11. The green corridor option is shaded in blue. The primary roadway option is shaded in red on the constraint map and the secondary roadway options are shaded in green.

The next area analyzed was the section of land between the Willow Lane Industrial Estate and Cranmer Rd. The major constraint on the northern border of the industrial estate is a railroad line operated by Tramlink. This tramline is not owned or operated by Merton Council. As seen in Figure 5.12, only two public right of ways cross the tramline tracks in the area of interest. These crossing points are over the Willow Lane Bridge and Carshalton Rd Bridge.

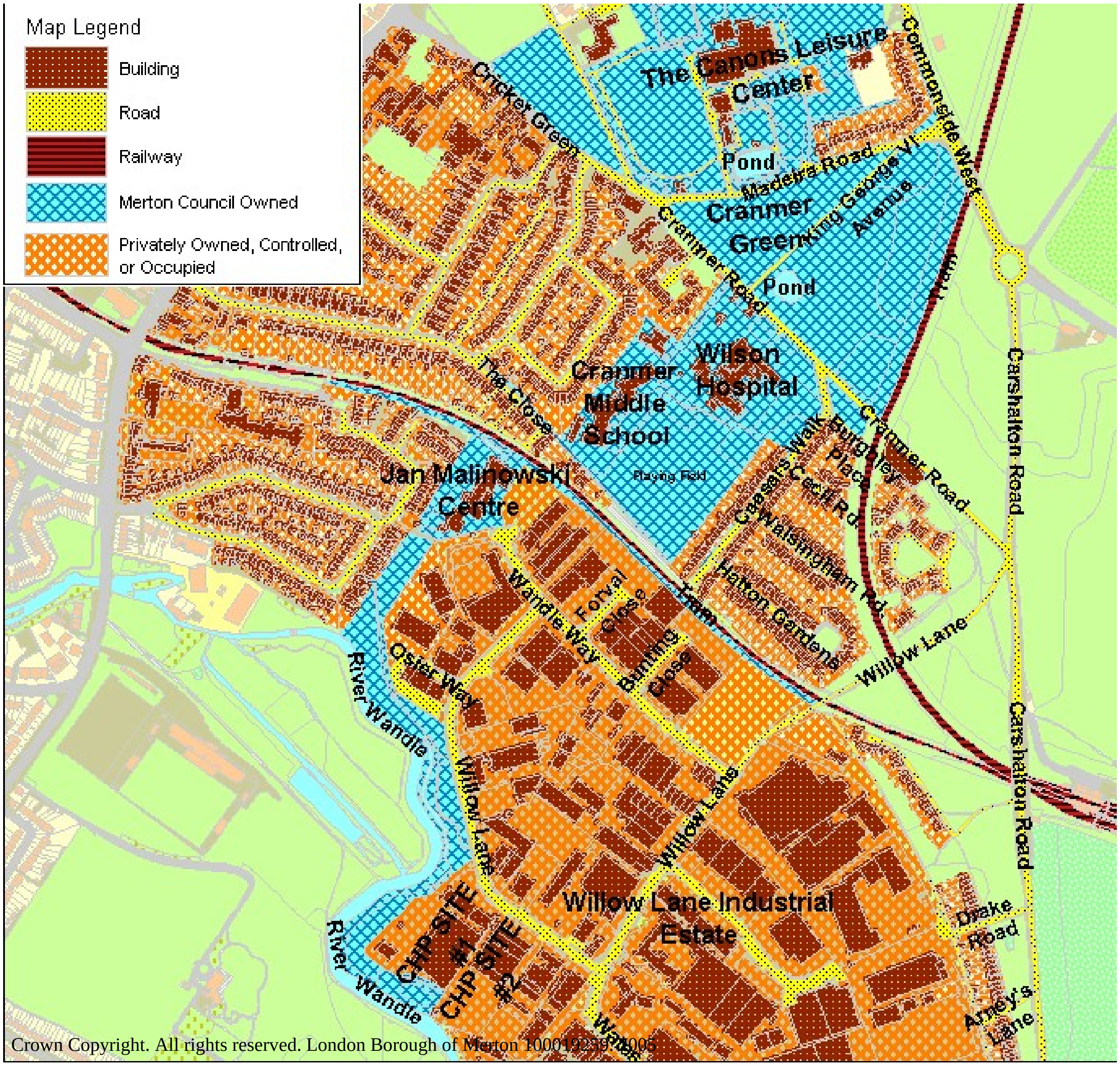


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Figure 5.12: Constraint map for entire potential route area with buildings and property ownership data

If the Willow Lane Bridge is used to exit the industrial estate, crossing the tramline is not a problem. However, based on the fact that the Willow Lane Bridge has been closed for structural integrity reasons, installing the distribution route in a structurally failing bridge poses a major risk. It is also unknown at this time when the bridge will be replaced. The Carshalton Rd. Bridge could only be used if the CHP distribution network was routed up Carshalton Rd. but this option was previously eliminated.

The other option for crossing the tramline was to go underneath the railroad tracks. Potential methods for installing distribution pipes and cables under operational railroad tracks are detailed in the construction section of the Results Chapter (see section 4.3.1). Instead of crossing the railroad tracks on the red route in Figure 5.11 by using the Willow Lane Bridge, it was determined that the pipes and cables could be run under the tracks next to the bridge. If the blue route was used, the route would also have to cross under the tramline after it exited the Malinowski Centre property.

However, taking into consideration private property, the constraint map shows only two feasible places on the north side of the tramline where the distribution route could cross. One of these is at the end of Close Rd. The other is Willow Lane on the north side of the Willow Lane Bridge. Since Willow Lane Bridge ruled out was a crossing point, the risks associated with crossing underneath the tramline at these two locations were the same for both routes. For this reason, the tramline crossing did not make one route more favorable than the other. It should be noted though that the risks associated with crossing the tramline still needed to be addressed for construction purposes.

With the tramline crossed, it was determined that Cranmer Green would be the common node where these two possible route areas would meet. Therefore, it was seen that to continue defining the red area from Willow Lane Bridge, the route would need to be run north to the intersection of Cranmer, Willow and Carshalton roads. Then the route would have to be turned northwest on Cranmer Rd. and brought to Cranmer Green (see Figure 5.13). To continue defining the blue route, the next public right of way after the tram crossing would be the Tramway Path, accessed by going across Close Rd. Then it was seen that to avoid the two major residential areas mentioned earlier, the route would have to go through the Cranmer Middle School (CMS) land and possibly the Wilson Hospital properties. Merton Council owns and controls both of these properties (see Figure 5.13).

The constraint map showed that the route with the fewest property and building obstacles was through the playing fields of CMS. It also showed that north of the playing fields, the route could either be run along the CMS driveway or through the Wilson Hospital parking lot.

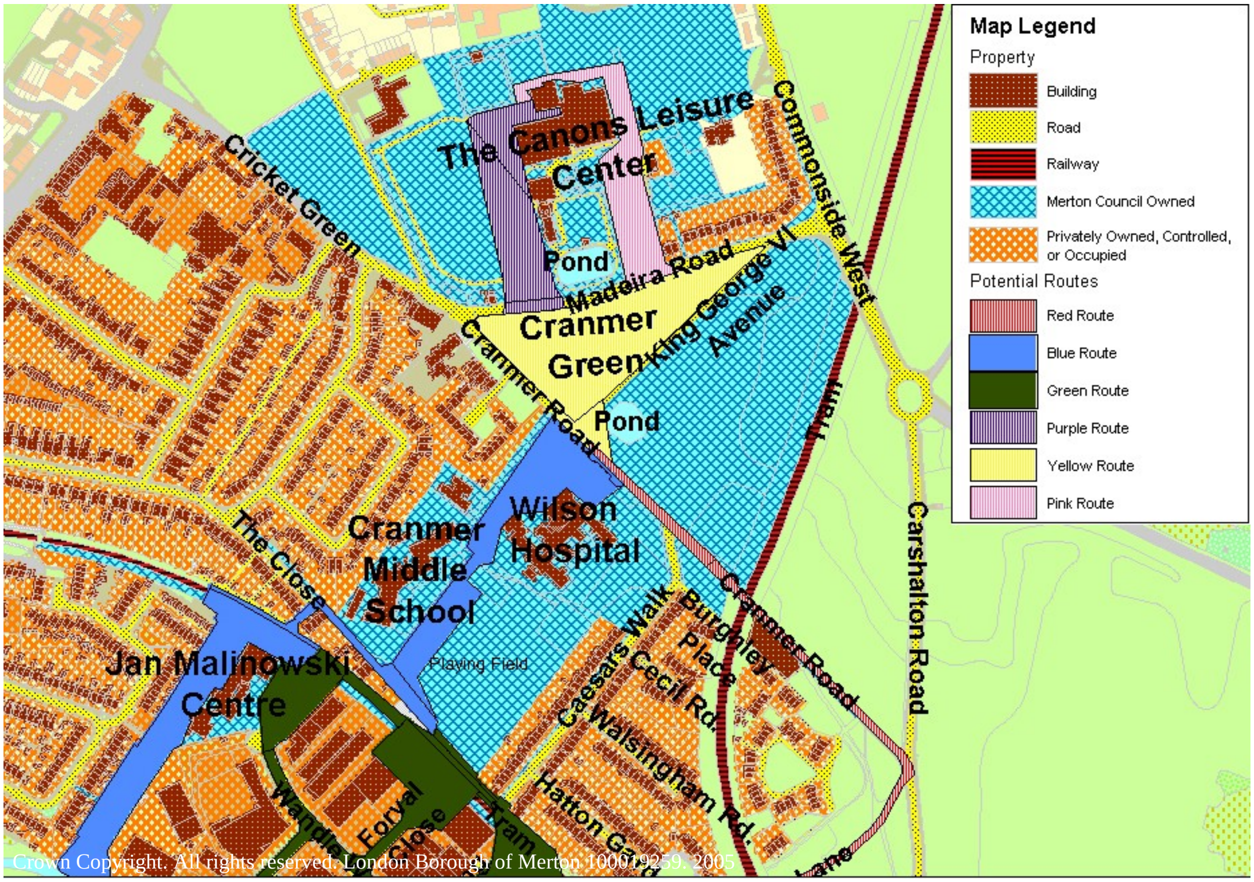

Figure 5.13: Constraint map showing building & property data with potential route areas identified between Willow Lane Industrial Estate and the Canons Leisure Centre.

The final area analyzed was between Cranmer Rd. and the Canons Leisure Centre. The area through which the distribution network could be routed is not overly constrained in this section by buildings or property ownership. The constraint map shows that Cranmer Rd., Cranmer Green, Madeira Rd., and the entrance points to the Canons Leisure Centre property on the north side of Madeira Rd. are all Merton Council owned property or public rights of way. The possible areas for the distribution route to the power rooms at the Leisure Centre are indicated on the constraint map in purple and pink (see Figure 5.13).

5.4.3 Existing Subsurface Infrastructure

At this point, two possible distribution routes had been identified between the Industrial Estate and Cranmer Green. Two other routes from Cranmer Green to the Canons Leisure Centre had also been identified.

The next category of information added to the constraint map was existing subsurface infrastructure (see Figure 5.14). The locations of the existing underground utilities were added to the constraint map. An examination of the utility locations along these routes showed a high concentration of existing utilities buried underneath roadways and footpaths. It was also clear that any route between Willow Lane Estate and the Canons Leisure Centre would be required to cross existing utility lines multiple times. See Appendix I for detailed utility company asset location maps.

The utility company maps only show pipes and cables owned and operated by the utility companies. In most cases, these maps do not include the location of non-utility company cables or pipes. For example, for water pipes in Merton, Thames Water runs a branch with a shutoff value off of their water main to the boundary line of a property they are supplying water to. It is up to the property owner to install pipe that connects their building to the Thames Water branch. For this reason, when the following sections describe areas as 'free of subsurface utilities,' this assumption was only based on utility company asset location maps, the locations of utility access covers found through on-site observation, and inferences as to where utility lines might run. Using the water company as an example again, it was also inferred that there was a private water pipe between a building and the Thames Water owned service branch coming off the main line. These inferences were included on our constraint map. Still, there is medium risk of finding unmarked utility infrastructure in areas around buildings such as privately owned pipes and cables running to objects such as light posts. There is a very low risk of finding unmarked buried pipes and cables in green corridors where there are no buildings.

According to the disclaimers on the utility company asset location maps, accuracy of maps could not be guaranteed. For this reason, on-site verification of utility locations is required. Because of the expense and difficulty of accurately locating and avoiding underground utilities, it was determined that it would be best to avoid running the distribution route in close proximity to as many existing subsurface utilities as possible. Based on this, the red and blue route areas were ranked according to the risks associated with running next to and across subsurface utilities.

The asset location maps for sewer, water and gas infrastructure were used to place the locations of these pipes on the constraint map. Due to the complexity of the electrical utility maps, their detailed locations were not added on the constraint map. However, it was noted that electrical cabling ran through all roadways along the potential routes. Since the electrical cable locations were so close to the utilities added in detail to the constraint map, this knowledge was deemed sufficient for assessing utility crossings. Telephone and broadband cable locations were not put on the constraint map either. This is because asset location maps for these utilities were not received from BT or Telewest by the end of this project. However, these cables were assumed to be located in the same places as the other utilities.

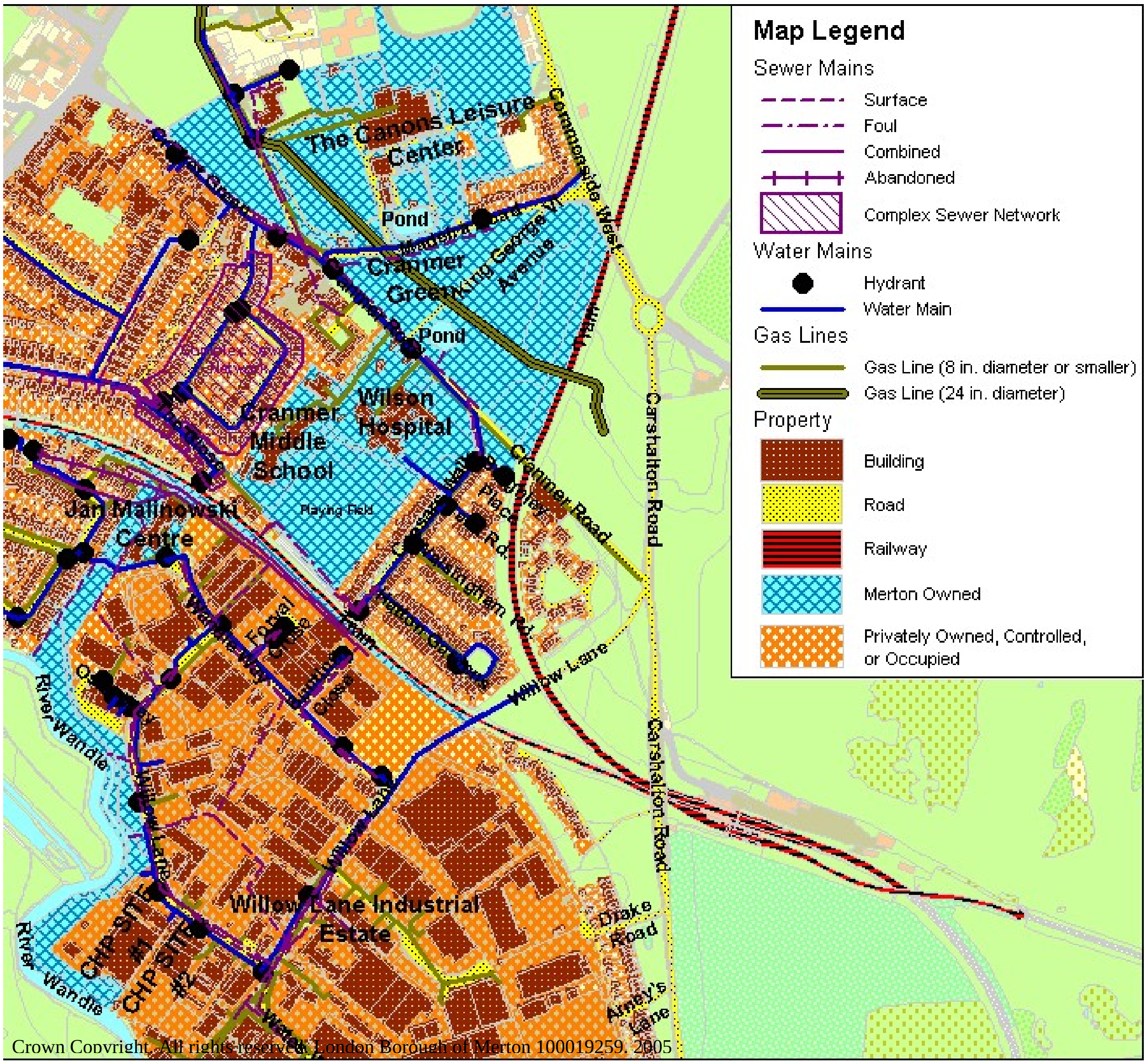

Figure 5.14: Constraint map with sewer, water and gas lines overlaid.
(Note: electrical lines are not shown on this constraint map. See Appendix I for detailed electrical company maps)

The entire red route ran along roadways and footpaths packed with an extensive network of existing subsurface utilities. However, there were much fewer areas in the blue route where the distribution network would run through an area crowded with subsurface infrastructure. The constraint map analysis for the blue route revealed that the area of land classified as a green corridor on the west side of the Willow Lane Industrial Estate was free of underground utilities. This gave initial preference to the green corridor (blue route) over running though the roadways crowded with underground infrastructure in the industrial estate (red route). Also, the blue route had only five places where it crossed buried utilities. There were many more utility crossings along the red route.

Moving further north on the blue route, water and sewer lines had to be crossed on the southern border of the Malinowski Centre. Also, analysis showed that there was only one 12" gas main between the Malinowski Centre and the tramline. The route would cross more utilities on Close Rd. However, the analysis showed that the tramway path and CMS playing fields were free of subsurface utilities. In addition, analysis of the western side of the Wilson Hospital parking lot indicated that it was free of underground utilities. On-site inspection of the parking lot showed no utility covers in this section. The other route option was to use the CMS driveway. However, this driveway had telecommunications, gas and water pipes running through it. Based on this utility information, it was determined that there would be less risk running a route through the western edge of the Wilson Hospital parking lot.

The next area to consider was the location between Cranmer Road and the Canons Leisure Centre. The utilities in this area were again confined to the roadways, with exception of a 24-inch intermediate pressure gas main running through Cranmer Green between King George VI Ave. and Madeira Rd. North of the green, the utilities under Madeira Rd. had to be crossed. There are two paths for running pipes and cables into the utility room at the Leisure Centre from Madeira Rd. The Canons power room was located on the northwest side of the Leisure Centre. The shortest route leading to the power rooms at the Canons was to enter along the driveway and/or field on the western side of the Leisure Centre. This path is colored purple on the constraint map. The second path available was to run the distribution infrastructure along the driveway and parking lot on the east side of the Leisure Centre. This route is colored pink on the constraint map. However, based on analysis using the constraint map, it was determined that there were much fewer subsurface infrastructure obstacles through the field on the western side of the Leisure Centre.

At this point in the constraint mapping analysis the combination of the blue route and purple route was determined to be the most favorable for the CHP distribution network. This was based on utility constraints and associated risks, as well as building locations and property ownership.

5.4.4 Environmental Considerations

The potential route selected during the process above passes through regions of open space as well as green corridors among other classifications. Given the constraints described above along with the considerations for the protection of these lands, the route selected remained the best route for distribution between Willow Lane and the Leisure Centre. These regions were free of major structures and excessive utility conflicts which allows simple access to the land for excavation. The classifications for the Cranmer Green restrict development on the property; however this project is subsurface and will not disturb the function or skyline above ground. For visual impact after construction, "provided that sufficient care is taken during construction and reinstatement, there should be no long-term significant residual effect on soils, drainage, natural vegetation or agricultural crops" (DTI, 1992, p12). Impact on the local habitats is similar for all regions across the green as well because the majority of the land is open with no special habitat locations. The area of Cranmer Green containing a pond, classified as a conservation area, was not under consideration, and therefore did not pose an obstacle. Any paths across the Cranmer Green or beside the Wandle River have approximately equal risk and did not influence the selected route.

5.4.4a Thermal Pollution

The information gathered regarding thermal pollution, eliminated it as a concern which impacted route selection. The heat loss through the pipe was determined in the analysis of the heating pipe specifications in section 5.2.2. Using Fourier's Law of Conduction as described in section 5.2.3, a rough estimate was made for the effect on ground temperature caused by the heating pipe when operating at full load. Figure 5.15 shows the estimated ground temperature at the surface of the pipe, 20 cm away, 40 cm away and 60 cm. By 60 cm, the ground temperature is not affected by the heat pipe and at the ground surface the temperature rise is only about

2.6°C. This approximation determined that the thermal pollution could be considered negligible. This agrees with David Somervell's counsel. This consideration had no impact on the final route selection.

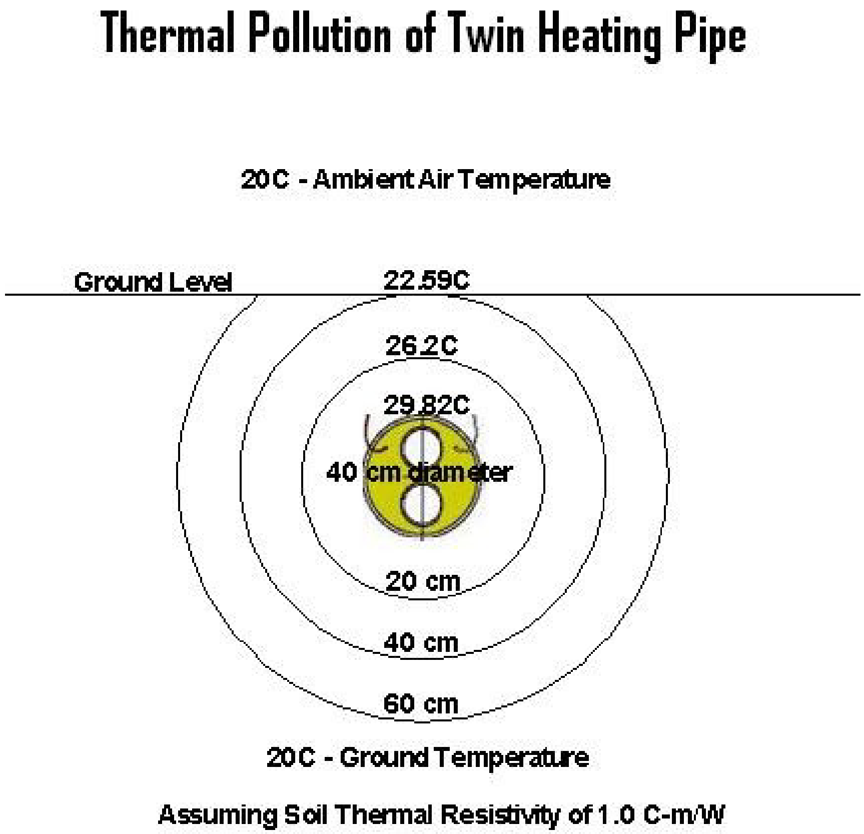

Figure 5.15: Thermal Pollution Estimate for Twin Heating Pipe

5.4.4b Contamination

Regions of the preferred route, specifically the land of the Wilson Hospital were classified as contaminated zones as of 1970. Parts of Willow Lane Industrial Estate are also considered contaminated but these parts have already been avoided in this route assessment. Contaminated zones complicate construction because the sites need special preparation before construction can begin, therefore requiring additional time and money. An assessment of the site must be completed by a consulting firm. The assessment must include details on the type and extent of contaminants present as well as a risk assessment for construction. Once the type of contamination has been established, the required action can be identified to manage them. Treatment of the site may be required in order to minimize the risk of releasing contaminants.

Burying pipelines have fewer regulations which could impact construction because they are entirely underground and contained. Contaminants such as hydrocarbons which could deteriorate the pipes would need to be removed; however many other contaminants such as heavy metals could most likely be left undisturbed. The risk of these additional steps was not as large as the risk associated with the alternate route considered above and therefore did not have a large impact on the selection of the distribution route. The Wilson Hospital could be avoided if necessary once the details on contamination are known.

5.4.4c Flooding

The sites under consideration for the distribution route also include regions classified as flood zones from the Wandle River, occurring once every 100 years. The majority of the chosen sites for the CHP plant within the Willow Lane Industrial Park were located inside the flood region, and therefore avoiding the flood zone completely was not possible. A small island region was found with in the property from the Willow Lane Industrial Park in the MapInfo database to be above the flood levels within the industrial park; however, this did not affect the distribution route which needed to leave the property. The flood zone had the potential to drastically change our route; however after considering alternate routes along streets it was determined that the blue route was again the preferred option.

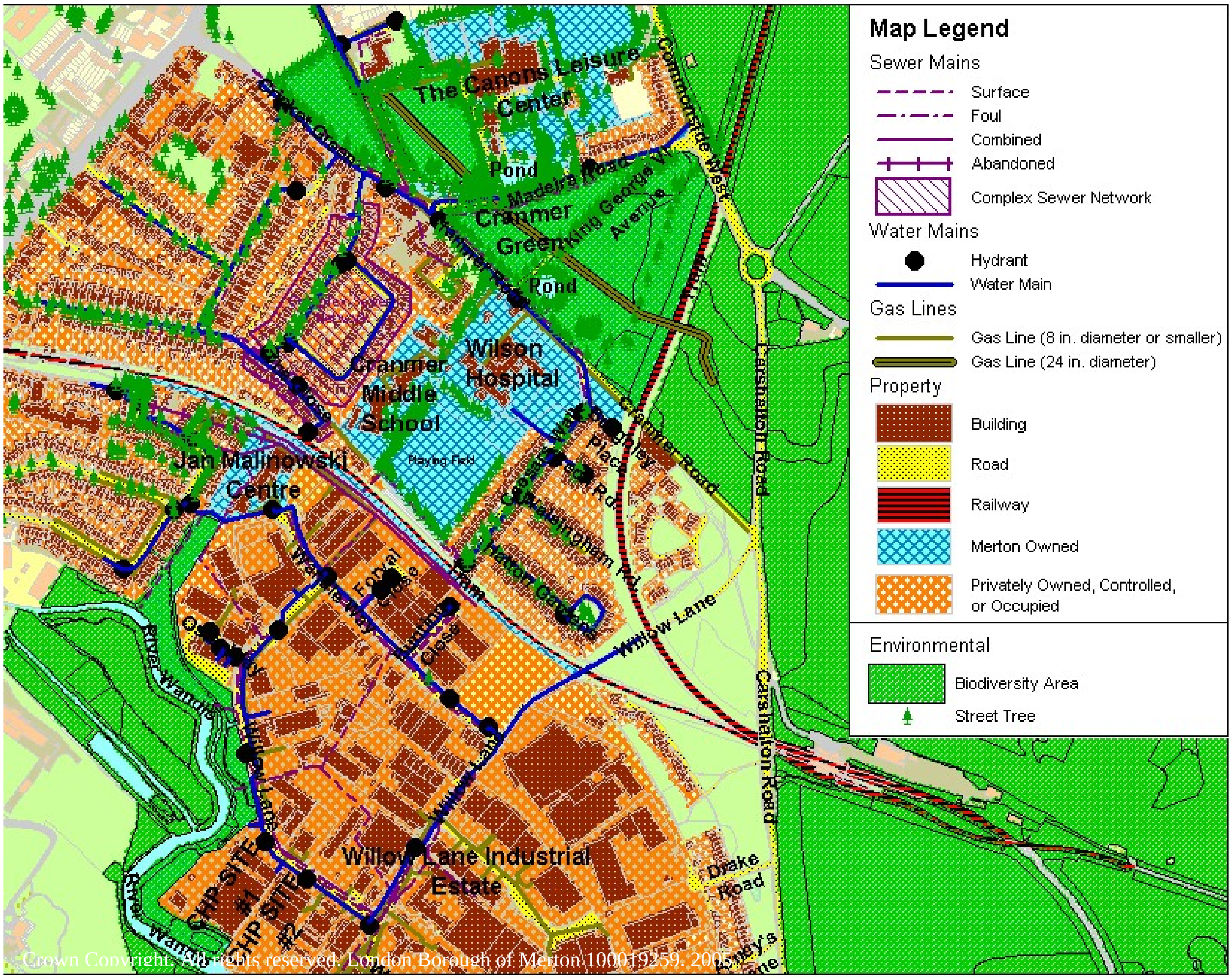

Figure 5.16: Map showing Environmental considerations

5.4.5 Geology and Archeology

5.4.5a Geology

The geology of Merton is favorable to construction because it is mostly soft London clay which is easier to excavate than a rocky soil type. Any location along the potential routes would contain this clay subsurface. Therefore, it did not have an impact on the selected route. This thick clay prevents contamination of ground water by preventing contaminants from passing through easily. Pending a further assessment by the British Geological Survey, no obstacles were found based on the route's geology.

5.4.5b Archaeology

The entire region under consideration is classified as an archaeological priority zone. Therefore, the route selection did not depend heavily on avoiding archaeological zones. Some sites can be speculated to contain more artifacts and obstructions that others, but many, such as the Willow Land Industrial Site cannot be avoided. On-site analysis both before and during construction will provide information on obstructions such as the concrete patio discovered behind the Wilson Hospital. The route was modified to avoid this area and travel up the side parking lot avoiding as many current utility lines as possible. Final details of the assessment cannot be completed until a report from English Heritage is obtained describing the regions along the route.

5.4.6 Motor Vehicle Traffic

All of the possible routes found either cross or run along roadways. For this reason, the effects of construction and maintenance on traffic patterns must be considered. The key road crossing for the blue route was at Cranmer Rd. The red route ran along Willow Lane and Cranmer Rd. All routes crossed Madeira Rd. Merton's traffic survey data from 2003 and 2004 indicated that these roads carried steady traffic volumes. Appendix G contains all of Merton's traffic data that pertain to the roads in the potential distribution route area. Taking Cranmer Rd. for example, during a week in June 2003, weekday traffic in the northbound lane averaged 4241 vehicles per day. Weekday southbound traffic volume during this same period averaged 2973 vehicles per day. According to a speed survey in 2004, vehicles traveling on Cranmer Rd. average speeds of 35 mph (miles per hour).

One traffic consideration for this route assessment was what impact infrastructure installation would have on blocking entrances to buildings or entrances to neighborhoods. Also analyzed were traffic patterns that might have to be detoured due to infrastructure installation.

Restrictions on access points to residential areas and businesses caused by route construction and maintenance were factored into the route assessment. Along the red route, construction in the Willow Lane area had a very high potential of causing disruption to industrial estate businesses. Blocking entrances to these sites for construction purposes would be more than an inconvenience to these businesses; it would be economically harmful. On the south side of Cranmer Rd., there was a residential neighborhood entrance. This entrance was the only access point to the neighborhood. If the method of installing the infrastructure past this roadway required blocking the neighborhood entrance, this would block access to more than 150 houses. There were two more individual entrances to houses along this narrow stretch of road that also had the potential to be blocked by infrastructure installation.

A distribution route running through the blue area would only require two crossings at Cranmer Rd. and Madeira Rd. If either of these roads had to be closed off to allow for infrastructure installation, they could be closed in areas that would avoid blocking any entrance points to the Wilson Hospital, the Cranmer Middle School or the Canons Leisure Centre. The CMS driveway should be avoided on the blue route because it is the only access point to the school. If it was closed off for construction, vehicle access to the school would be eliminated. Installing infrastructure through the Wilson Hospital parking lot would reduce the number of available spaces temporarily. However, on-site observation during the weekday at the hospital indicated that the parking lot is mostly empty along the western side. Therefore, the impact on traffic in this area is small. The blue route is again favored over the red route based on potential for blocking access points during construction and maintenance.

Detour routes were considered next. Adequate detour routes existed if road closures were needed at the specific crossing point for the blue route on Cranmer Rd. As seen on the map in Figure 5.17, running infrastructure across Cranmer Rd. in the blue area would occur between the school entrance and the hospital entrance ways. King George VI Ave. could be used as a one way detour route since it is only wide enough for traffic moving in one direction. However, Madeira Rd., Commonside West and Carshalton Rd. could also be used in a detour route. Carshalton Rd. was found to be by far the busiest road in the area. A June 2003 volume survey found that average daily traffic volumes during the weekday on this road were approximately 13,800 vehicles traveling north and 12,800 vehicles traveling south on Carshalton. However, if either Cranmer or Madeira were closed for construction, Carshalton Rd. would need to be used for a detour route.

The red route could use the same roads for similar detour routes during construction. However, because the red route runs on Willow Lane and Cranmer Rd., the red route would require large sections of road to be narrowed or closed during installation. Based on the limited amount of traffic survey information available, a more detailed analysis of the impact on traffic patterns due to road closures should be conducted.

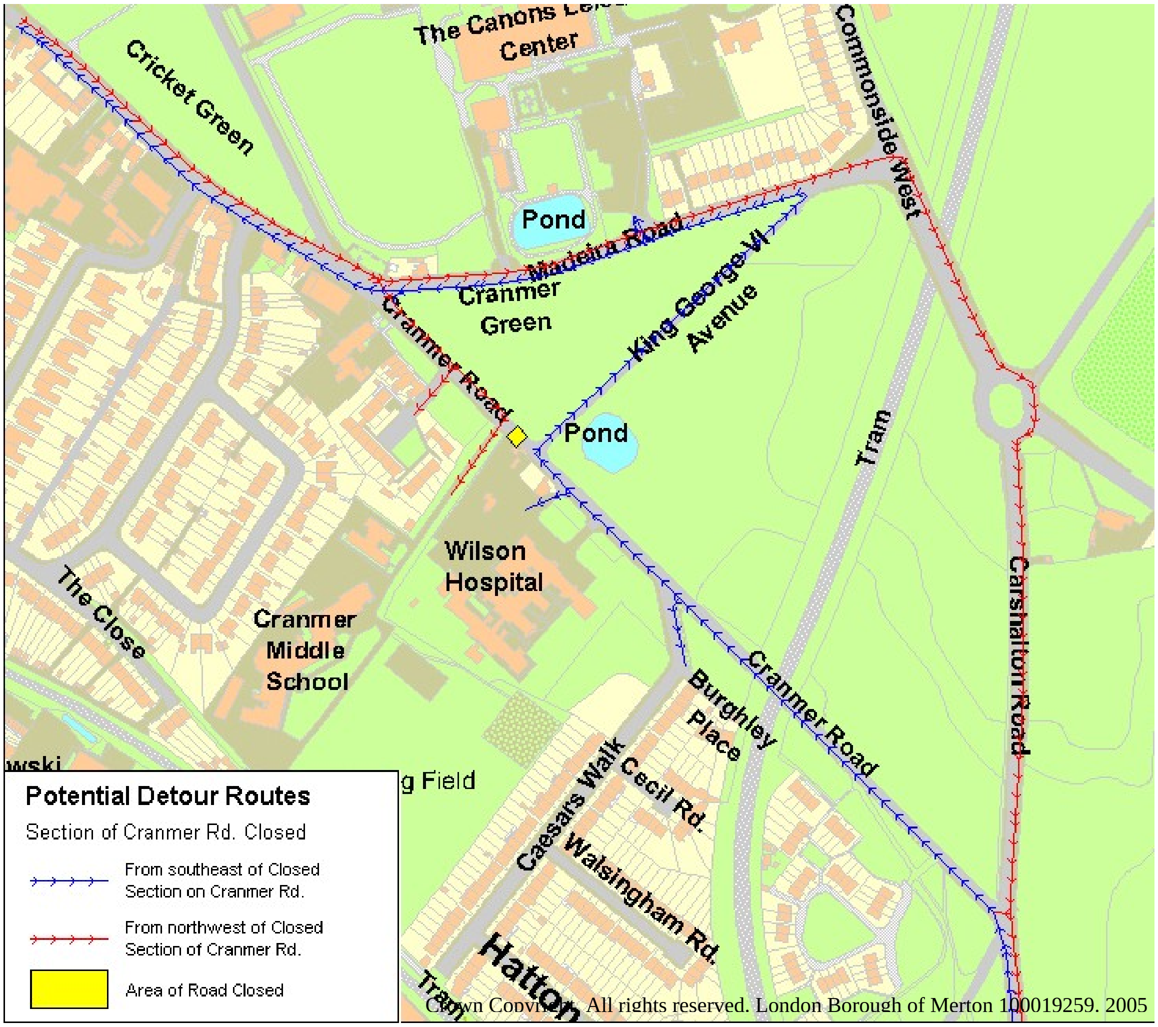

Figure 5.17: Closed section of Cranmer Rd. (yellow) and traffic detour routes if construction method chosen for installation required closing the road at this crossing point. The road crossing was identified using the constraint map.

Moving on, a crossing at Madeira Rd. would take place across from the west side driveway into the Canons Leisure Centre (purple route). Blocking this driveway would not inhibit access to the Canons Leisure Centre because the eastern entrance off of Madeira Rd. provides access to the same areas as the western drive. Again, the same roads used for detour routes for a Cranmer Rd. crossing could be used for a Madeira Rd. crossing. Preferred detour routes are shown in Figure 5.18.

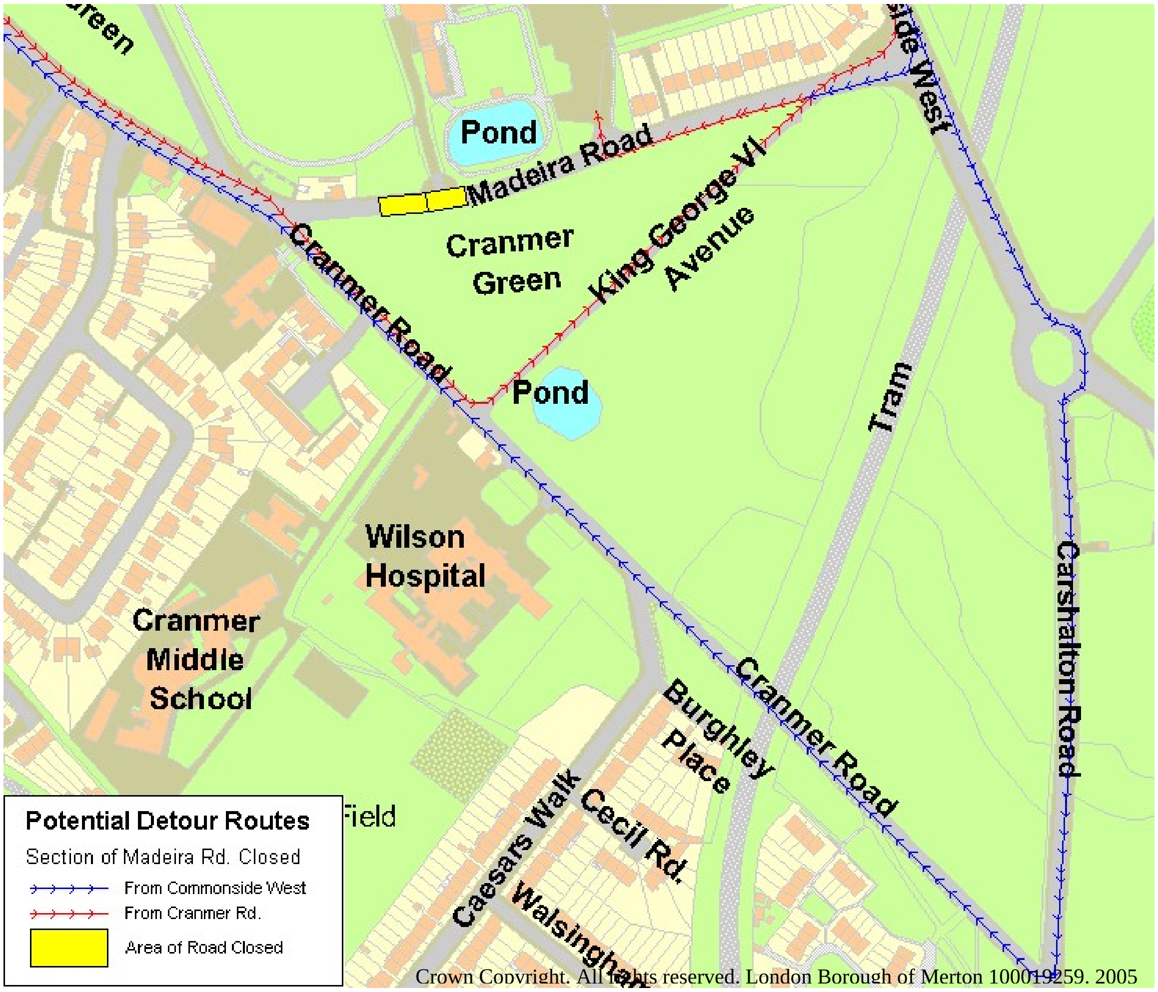

Figure 5.18: Closed section of Madeira Rd. (yellow) and traffic detour routes if construction method chosen for installation required closing the road at this crossing point. The road crossing was identified using the constraint map.

Depending on construction techniques used, it would be possible to avoid road closures completely by tunneling underneath both Cranmer and Madeira at sufficient depths to avoid any existing subsurface infrastructure. Since the utility depths at these locations are not accurately known, it would be necessary to first conduct a 3-D mapping survey of the specific crossing points. A cost analysis, including the indirect cost of diverting traffic, should also be performed to determine the preferred construction method at these locations.

5.4.7 Surface Structures and Features

The location of surface structures and features was the final category of information added to the constraint map. In this analysis, these features were considered a low priority. Still, the surface features that were determined to be most important such as ponds, large gardens, protected trees and light posts were identified as obstacles for the distribution route to avoid.

Surface features along the blue route were considered and analyzed first. The footpath in the green corridor to the west of the industrial estate was free of obstructive surface features. The route would have to go under a fence on the south boundary of the Malinowski Centre and avoid a garden in the northwest corner of the property. The route would also have to cross under a fence to enter the CMS playing fields and go through a small section of wooded area to enter the Wilson Hospital parking lot. To exit the parking lot, the route would have to cross under a 6 ft tall by 1 ft deep brick wall. Difficulty in running under these walls and fences will be minimal based on numerous construction methods available for performing these types of crossings.

Aside from avoiding trees in these areas, there were not any significant surface features or structures that required drastic alterations to the proposed route areas. The addition of environmental and traffic considerations as well as analysis of surface features and structures further narrowed the potential distribution route area. These considerations further identified the blue and purple route as the best path for the distribution route.

5.5 Distribution Route Summary

The CHP specifications and construction analysis showed how much space the infrastructure would need to be installed. It also showed that significant cost savings could be obtained by trenching through open spaces and avoiding roads and subsurface infrastructure.

Next, the constraint mapping analysis identified four specific route areas after building locations, property ownership and locations of existing underground utilities were added to the map. The analysis was completed based on all the considerations mentioned in the corresponding sections and showed that the blue, yellow, and purple routes were preferred. Further analysis of environmental, geological and archeological considerations revealed that the use of the blue, yellow, and purple route was indeed feasible. Next, the analysis of traffic and surface features further narrowed the area of the blue, yellow, and purple routes. Finally, the route was cross checked with the CHP distribution system specifications and the construction requirements and this confirmed that the blue, yellow and purple route combination was the best option.

6. Conclusions & Recommendations

After completing the analysis, a preferred distribution route was evident. This chapter will present the distribution system specifications and the construction requirements for infrastructure installation. Recommendations follow that explain the additional work required to design the distribution system and make a construction plan for installing the distribution system. The optimal route is presented and the risks associated with this route are assessed. Finally, recommendations are given on how to minimize these risks during the implementation of the distribution system.

6.1 CHP Distribution System Specifications

The Results chapter section 4.2 and Analysis chapter section 5.1 explain how the distribution system specifications were defined for this assessment. These specifications are as follows:

- Total Heat Load of 3.9 MW, Total Electrical Load of 3.2 MW for the Canons Leisure Centre and the proposed redevelopment of Mitcham Town Centre with a safety factor of two
- Medium temperature hot water system operating at up to 120°C and 16 bar
- Steel carrier pipes with polyurethane insulation and a high-density polyethylene (HDPE) casing
- Standard pipe size of 125 mm diameter, twin pipe system, outer casing diameter of 400 mm
- Efficiency greater than 95% when fully loaded
- Heat loss of 28.4 W/m at full load (0°C ambient)
- Electrical transmission lines operating at 11 kV, 100 A, 65°C
- Clearance from heat pipe at least 300 mm
- Three-core aluminum XLPE cable, 35 mm^2 conductor cross-section
- Outer diameter of three-core cable, 43 mm

6.1.1 Recommendations for Load Assessments

The desktop survey that was done to obtain these basic system specifications revealed the need for more research to accurately define the distribution system requirements. Essential will be identifying potential loads and performing in-depth load assessments. Computer simulation can be done for buildings yet to be constructed to determine their energy usage requirements. Existing buildings can be assessed by obtaining energy usage records from utility companies or by profiling the existing usage over a certain period of time. An accurate load demand profile is essential for beginning to size the CHP plant and its distribution system.

Another consideration when making load assessments will be the implementation of a domestic hot water system and an absorption chilling system. These have potential to increase the thermal load to make better use of the thermal output of a CHP. Absorption chilling is especially beneficial because its highest demand will be in summer when heating systems are typically not run.

Thermal storage solutions should also be considered to accommodate the peak and off-peak heat demand. Excess hot water can be stored in the thermal reservoir at times when heat demand is low. The hot water storage can then be drawn upon when the CHP is not running or when the thermal demand is beyond what the CHP can deliver while producing maximum electricity.

Another possibility for utilizing excess hot water from electricity generation would be to connect certain sites with heating only in order to better balance the CHP plant output with the thermal and electrical loads.

6.1.2 Recommendations for CHP Plant Identification

Once the annual demand profile is determined, a rigorous assessment must be made to identify the most suitable CHP plant to meet the demand. The pyrolysis plant represents a unique opportunity both to provide inexpensive fuel for a CHP and to manage Merton’s waste stream in a cost-effective and environmentally friendly manner. The CHP plant design should therefore be based on how the methane can be used to produce as much power as possible. Initial load assessments showed the thermal load to be only slightly larger than the electrical load. Since typical CHP plants produce much more heat than electricity and electricity can be sold for much higher returns than heat, a highly electrically efficient CHP plant should be designed. This may mean purifying the methane produced by pyrolysis so that it is suitable for direct methane fuel cells. Other options include purifying the methane for powering gas turbines and combined cycle engines.

6.1.3 Recommendations for Distribution System Assessment

While a rough distribution system assessment was performed for this project, a much more thorough analysis will be required. The system temperature should be reassessed for compatibility with the various thermal loads. The system temperature should be high enough to work with efficient ABS chillers and heat exchangers. A variable system temperature should be considered to help improve efficiency with seasonal changes in heat usage. The system temperature range will help to determine the pipe material and insulation thickness necessary for the system.

An important consideration will be the connection method to the distribution system. Indirect connection is preferred for large networks with various heat loads as pressure and temperature can be regulated for each load. The distribution system will have to be compatible with a variety of heating systems serving residential, commercial, and retail facilities. It will also be necessary to meter each of the clients in order to determine their exact heat and electrical usage for billing. A major consumer side design factor will be the return water temperature. A lower return temperature will improve the efficiency of the system and allow the CHP to deliver more heat.

The pipe size is a major consideration because it will greatly affect both the heat loss through the distribution system and the cost of the system. The pipe size should be determined through a cost analysis factoring in the cost of heat loss, the cost of pumping, the cost of pipes and pumps, and the cost of maintenance and repair.

Once the pipe material, pipe size, and thermal loads are known, the pressurization can be analyzed to determine the pump requirements of the system. The pumping costs will be a major component of the operational costs and should be minimized as much as possible while meeting the technical requirements of the system.

A complex analysis will also be required for the electrical distribution system. Electricity can be sold to consumers for as much as three times that which the electricity company will pay when backfeeding the power grid. However, the cost of laying and maintaining the transmission network will have to be made up from the additional income earned by selling directly to consumers. The plant selected must be able to produce a large amount of electrical energy in order for this cost to be regained in a reasonable length of time. To make this decision, the additional cost of laying the electrical transmission network needs to be determined including the cost of transformers and substations. A competitive electricity rate should be worked out with the consumers in a contract for a minimum number of years.

Another issue would be if the CHP is not able to meet the peak electrical load. A plan for how the infrastructure will supply the peak load should be determined. Some possibilities include purchasing electricity off the national grid, incorporating peak load generators, or supplementing the electrical system with renewable energy generation technology. Renewable energy technologies such as solar panels or ground source heat exchangers could also be employed to maintain the water temperature in the district heating network. An in-depth background of some of these renewable energy sources can be found for reference in Appendix B.

6.2 Construction Specifications and Conclusions

The specifications for construction determined from the analysis in section 5.2 are as follows:

- Heat pipe buried with 400 mm minimum of cover
- 100 mm of stone-free sand around heat pipe
- Clearance of at least 300 mm between heat pipe and transmission line
- Transmission line buried at least 450 mm under footways and 600 mm under carriageways
- Total minimum trench depth of 900 mm
- Total minimum trench width of 900 mm

6.2.1 Recommendations for Trenching

An interesting observation is that the additional 335 mm of trench width required for laying the transmission line also satisfies the additional 250-300 mm required for welding and installing muffs in the trench. Therefore, the trench can be dug to the required width and depth and the pipe sections placed in the trench. Then the pipe sections can be fitted, welded, and muffed in the trench before pressure testing and heat pre-stressing. Next, the trench can be backfilled with stone-free sand which meets the soil thermal resistivity requirements up to the required depth of the transmission line. Then the transmission line can be laid with the appropriate clearance from the heat pipe and backfilling can continue until the heat pipe is covered by at least 100 mm of the sand. Finally, the topsoil can be replaced and grass replanted and other surface features restored.

6.2.2 Recommendations for the use of Trenchless Technology

Trenchless construction methods should be pursued for crossing major infrastructure, such as railways, roads, and existing subsurface infrastructure. While typically more expensive than trenching methods, when factoring in the cost of reinstating roads, disrupting traffic, and avoiding subsurface infrastructure, it could represent significant cost savings. Trenchless methods also tend to take less time, generate less noise, and reduce environmental disruption. This could help ensure public support for the project. An assessment should be made at each of the areas along the route that cross major infrastructure to determine if trenchless methods would be advantageous.

6.2.3 Recommendations for Safe Digging

In order to ensure that the route excavation is done in a safe manner, a number of guidelines explained in section 4.3 must be followed. The CDM Regulations stipulate that an appropriate health and safety plan must be created and approved before any construction can begin. *Avoiding Danger from Underground Services* offers essential guidelines from the planning stage to the actual construction that help to ensure the safety of the workers and the general public. The most important measure for ensuring safe digging is accurately locating all existing subsurface infrastructure. All utility companies operating in the area must be notified of the project. When surveying the route as well as when performing the actual construction, locator devices should be used for finding subsurface transmission lines, pipes, ducts, and cables. Special care must be taken when digging near known utilities such as hand digging rather than using mechanical excavators or power tools.

When using trenchless methods, tracking devices should be used to make sure that the bore or mole does not go off course into any subsurface utilities. The best assurance of project safety is proper planning which must start early in the design phase.

6.3 Distribution Route Conclusions

The CHP specification analysis and the construction analysis combined with the constraint mapping analysis clearly presents the optimal area through which to run the CHP distribution network. This optimal area is shaded turquoise inside the blue, yellow and purple areas in Figure 6.1. The red line in this map indicates the recommended route for the CHP distribution network.

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Figure 6.1: The optimal area through which to run the CHP distribution network is shown shaded in turquoise (inside the blue, yellow and purple areas). The red line indicates the recommended route for the CHP infrastructure. See Appendix E for larger map.

The red line on the map is the optimal route; however, as mentioned in the Analysis Chapter, there are still risks associated with this route area. Some of these risks are high enough to warrant further investigation. Five categories were used to clearly summarize and present these risks. These categories are Built Environment, Transport, Subsurface, Environmental and Public, Planning & Policy/Regulation. This summary method is used by the European Union LETIT Project (Local New Energy Technology Implementation) to help local authorities communicate energy project risks to their respective communities. The five main categories were divided into subcategories. The level of risk determined in the analysis for each of these subcategories was quantified using a risk scale of 1-5, where 1 is negligible risk and 5 is irresolvable risk. The subcategory risks for each main category were then averaged. The calculated risk for each category is displayed in Figure 6.2. The detailed data structure driving this risk chart can be found in Appendix D.

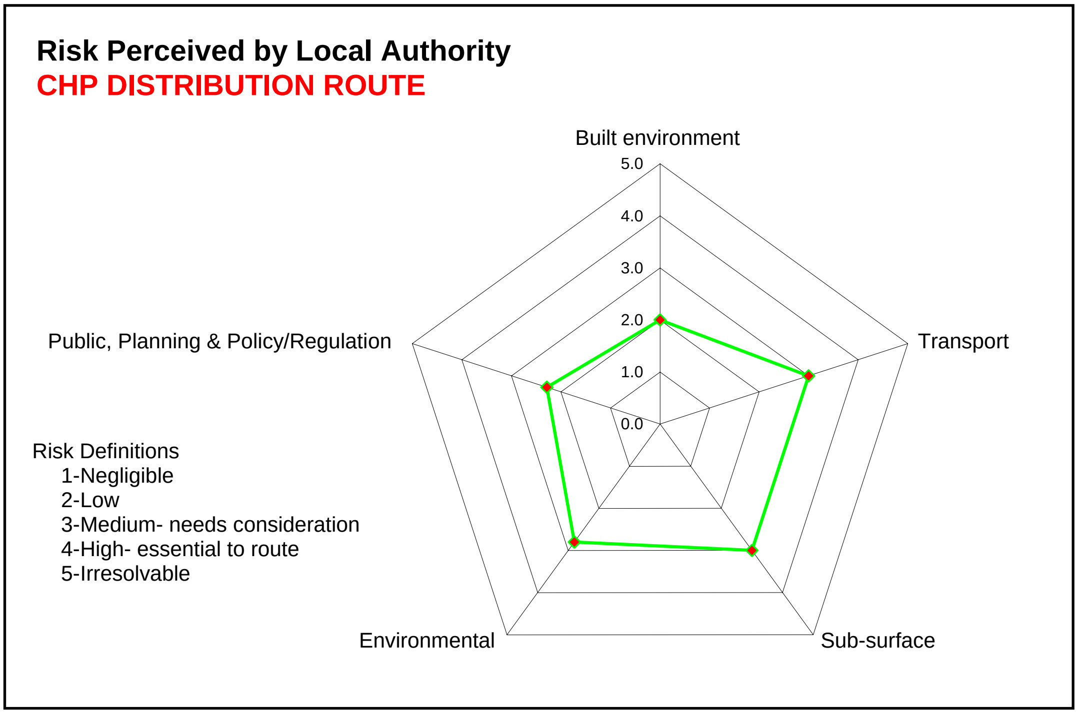


Figure 6.2: Risk perceived for the CHP Distribution Route between the Willow Lane Estate and the Canons Leisure Centre based on the route assessment analysis.

The chart shows that all risk categories are at or below risk level 3. The following recommendations explain how these identified risks can be minimized.

6.3.1 Recommendation to Conduct Detailed Utility Mapping Surveys

Where utility company asset location maps show that it is necessary to cross utility lines in a certain area, it is recommended that a more precise method of determining the locations and depths of these underground utilities be utilized. The points along the distribution route where these more precise measures should be taken include all locations where multiple utility pipe and cable crossings will occur. Examples include the crossing at Close Rd., Cranmer Rd. and Madeira Rd. Once a detailed knowledge of utility depths in these locations is obtained, the construction method for installing infrastructure through these locations can be determined. Once the depths and detailed locations of the utilities are known, decisions can be made on construction method. This knowledge will determine where it is possible to trench using mechanical excavators and what sections should be hand dug. It will also show whether the CHP distribution pipes and cables can be snaked through existing lines at their recommended burying depths, or if it will be required to install the infrastructure below the existing utilities. If this is the case, then trenchless technologies can be considered.

Suggested methods for obtaining this detailed location and depth data include using a ground mapping radar survey in these specific areas. Another option is to tap the knowledge base within the utility companies themselves. Based on research conducted for this project, there are individuals within these utility companies who have detailed knowledge of asset locations and depths for very specific areas. The difficulty lies in finding these sources because this knowledge is not necessarily recorded electronically or in print.

6.3.2 Recommendation for Crossing Tramline

This distribution route must also be run under a tramline. The tram company that operates on these lines is Tramlink. Tramlink operates under the Transport for London system (TfL). Tramlink will not allow their rail service to be disrupted by CHP infrastructure installation. For this reason, it is recommended that Merton Council does not approach Tramlink for permission to install infrastructure under their tramline until a detailed plan for doing distribution route construction under the tramline without disruption to Tramlink service is complete.

6.3.3 Recommendation for Marketing Route

The route chosen will run the CHP distribution system through the property of the Malinowski Centre, the Cranmer Middle School and the Wilson Hospital. Having the distribution network in close proximity to these buildings raises the possibility of connecting these buildings to the CHP heat and electricity network. Therefore, it is recommended that the route chosen for the CHP distribution network be sold as having the future potential to provide a cheaper source of heat and electricity to these Merton Council owned buildings.

6.3.4 Recommendation to Continue Pursuing Best-Practice Information

The Borough of Woking is currently operating a fully functional district heat and electricity distribution network scheme. Woking's scheme is a well functioning system. Since Woking is one of the first Boroughs to implement a DHP system in the UK, it has a vast knowledge base from which Merton could draw. The problem is that Woking is protective of its knowledge related to its DHP network. As Merton moves closer to implementing a DHP scheme, UK resources with experience in this area such as the Borough of Woking, the city of Aberdeen and the city of Southampton should continue to be tapped by the Merton Council for information that will help reduce the risks and costs associated with this project.

6.3.5 Recommendations for Environmental Assessment

In order to complete the environmental assessment, further data must be collected describing the sites along the selected route. Merton Council should have an Environmental Impact Assessment (EIA) completed about the route, specifically Cranmer Green and the region along the river. The assessment will provide detailed descriptions of the current environment and the impact construction could have on the biodiversity, including habitats, vegetations, animals, and basic archaeology. This knowledge will allow the Council to better understand what the pipeline would disrupt if it was constructed there. It is also a requirement before permits can be obtained for construction. To ensure the specific requirements of the sites along the route are understood, English Nature (or its Merton equivalent) should be contacted to request the guidelines and exact requirements of the areas.

An additional study must be completed to investigate the contamination located within the Wilson Hospital. If necessary, this location should be cleaned and 'made suitable' for construction. The study must clarify the contaminants present along with how these could be removed. An estimate for the cost of this removal would be beneficial from this consultant as well.

In order to best preserve the environment during this project, it is recommended a reinstatement plan for restoration of the sites be created so the land can recover more quickly after construction. This plan should include details for backfilling the excavated trench and repairing vegetation for all effected areas including replanting grass and restoring drainage. An established plan can be implemented as soon as construction is complete and disruption time to the environment will be minimized.

Overall vehicle movement should be minimized to protect the open ground. The weight of the vehicles and equipment leave marks along their paths and compresses the ground, disturbing habitats beneath the surface as well as drainage. This is especially true when the soil is wet such as after rain, or along the Wandle River where soil is typically softer. The season in which construction and restoration is completed has an impact as well. Work completed during the winter could have a worse impact on the environment due to the movements of trucks along the grassy surfaces. The ground is harder during the winter, but could have a worse impact on root systems below ground as the surface is compressed (DTI, 1992). The protection of animals should be considered as well, given that construction during breeding season could have a negative effect on the population. The EIA study discussed above should identify the preferred seasons for construction.

Further investigation and discussion is needed with the Environmental Agency to formally address the concern of flooding within 100 years. The Environmental Agency department should be contacted to discuss the possibility of construction within a classified area and add any necessary precautions to the system's design.

6.3.6 Recommendations for Noise Survey

To better accommodate residents and businesses that will be impacted by construction, a few additional steps are required. Before construction, a noise assessment should be completed to help determine ambient noise. This will help determine the noise impact caused by construction. The British Standards Institute (BSI) document describing methods and guidelines for reducing noise pollution should be obtained. This can only be purchased directly from BSI and should be obtained and referenced before construction begins. An additional consideration is the impact construction noise will have near buildings such as the Jan Malinowski Centre. This site in particular should be considered for the interruptions construction will cause on the children and staff at the school.

6.3.7 Recommendations for Archaeological Survey

The EIA will include a section describing the basic archaeology for the areas along the potential route; however, English Heritage should be contacted to conduct a site specific assessment. English Heritage would provide a more detailed report describing the history of the site's use and structural remains that could be present below the surface. For example, hidden concrete slabs would change construction methods and equipment required and should be considered for an accurate estimate of construction cost and duration.

6.3.8 Recommendations for Geological Survey

To describe subsurface details including the exact water table (particularly near the Wandle River), a study is required for specific sites along the route to determine potential obstacles. The British Geological Survey offers a GeoReport, which identifies the conditions of a specific site including soil type, bedrock, depths of soil layers, and water table among other topics. A detailed geological assessment required by Merton would include a description of the subsurface layers and depths as well as water table information along with other information. This report would cost £376 (BGS, 2005). If water table information is located through the Environmental Agency, then a standard geological assessment would suffice and cost £235 (see Appendix K). The water table near the Wandle River is of particular interest due to its expected high level. The information will be important when determining depths and paths for the pipeline leaving the Willow Lane Industrial Site.

6.3.9 Recommendations for City Knowledge

Much of the information collected to make this route assessment came from Merton's GIS database. The City Knowledge concept has been proposed as a better way of collecting and managing information using a distributed GIS database. This project would have benefited if more of the information collected had already existed in the GIS database. Examples include subsurface infrastructure, traffic data and land ownership. Although this information existed, it was stored in a variety of formats. For this project, much of this information had to be manually inputted into the GIS mapping software to perform the analysis. A distributed GIS database utilizing the City Knowledge concept would ideally contain more up to date information in a compatible format. This would have reduced the amount of time spent researching, gathering and inputting data necessary to complete this project.

As a result of this project, many recommendations have been made for gathering more detailed information about the recommended route. If the City Knowledge concept were in use, this data would automatically be placed in the GIS database in order to be reused by other projects in the future. This has the potential to drastically improve information management in the London Borough of Merton.

6.4 Conclusion

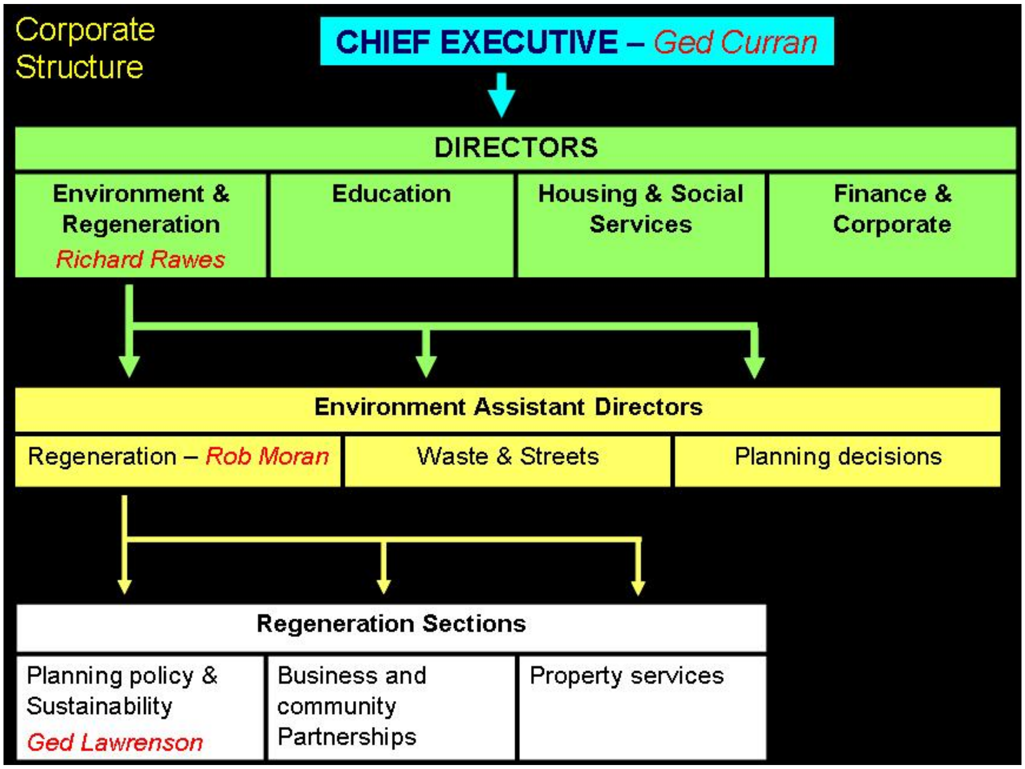
Following these recommendations will help the Borough of Merton implement the first phase of a district heat and power system. As this system expands, it has the potential to significantly reduce the Borough's greenhouse gas emissions. It will also serve as a replicable model for other communities seeking to provide a cheaper source of heating, cooling, and electricity while lowering their emissions. The widespread adoption of these sustainable energy technologies can help slow the rate of global climate change preserving the environment for generations to come.

Appendix A: The London Borough of Merton and WPI

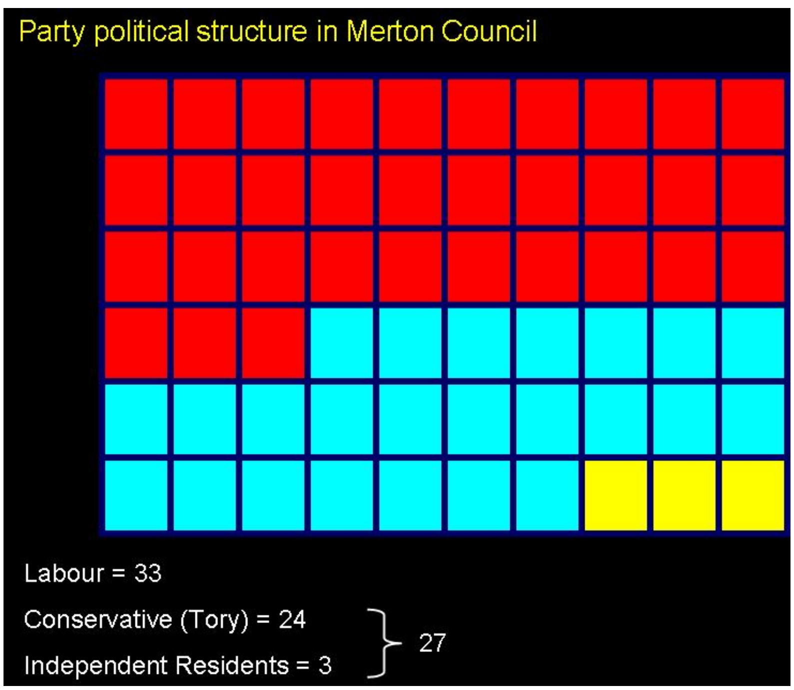
The Borough of Merton is located in southeast London and is one of 39 boroughs comprising the city. The towns of Merton, Morden, Mitcham, and Wimbledon merged to form the borough in 1965 and had a population of approximately 190,000 people as of 2003 (Borough of Merton, 2003c). Local governing responsibilities and services are managed by Merton Council, which consists of 60 councilors. Its goal is to "Make Merton a great place to live, work, and learn" (Borough of Merton, 2003c, p v). The Council is supported by six departments within the Merton Civic Centre: Chief Executive, Corporate Resources, Customer Services and Development, Education, Leisure and Libraries, Environment and Regeneration, and Housing and Social Services who work to develop and maintain the affairs of the Borough. These bodies work collectively to manage and improve education, construction and development of the area, and the environment and parks of Merton, as well as many other aspects of a community.

Relations between Merton Council and WPI began in 1996 and the Council has acted as one of the largest project sponsors for WPI's London Center, with more than 30 projects already completed. Past projects have included studies on a variety of social and environmental topics including social surveying studies, environmental assessments, feasibility studies for proposed designs, and a wide range of additional subjects. Teams complete preparation work on campus and come to London during C (Jan.-Mar) or D term (Mar.–May) for seven weeks to complete their work.

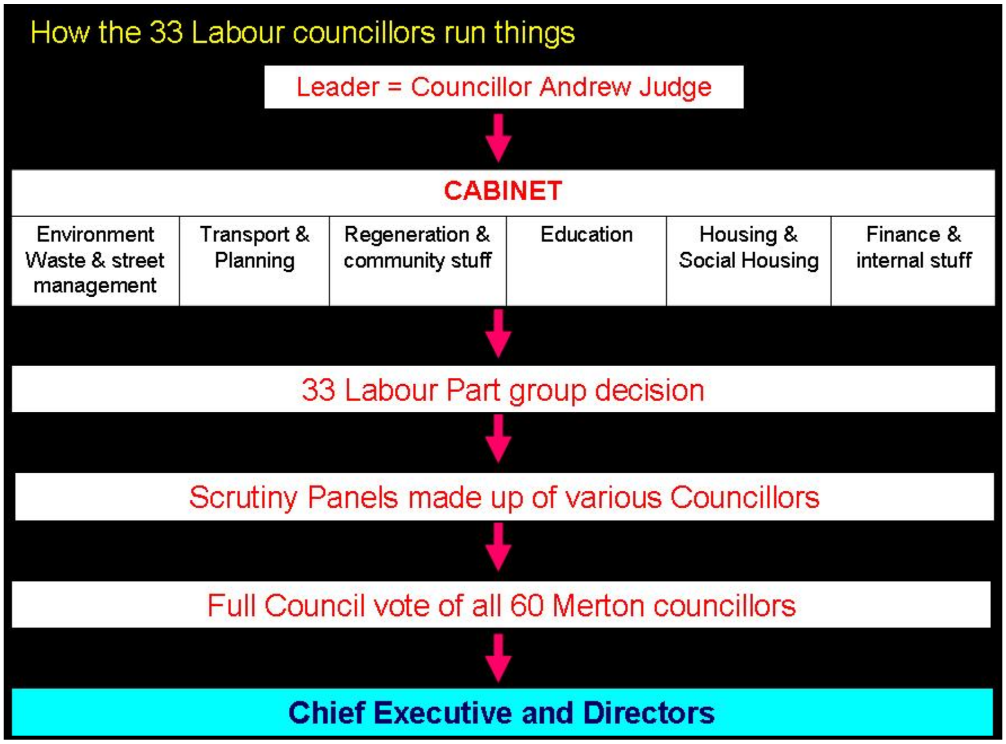
Our team worked with the Environmental and Regeneration Department towards their goal of reducing carbon emissions. The department as a whole works to maintain and improve Merton's environment and economy through regeneration projects, services, and local partnerships (Environment and Regeneration, 2005). In response to the Kyoto Protocol and guidelines issued by the UK government, Merton is seeking to reduce its quantity of carbon dioxide emissions and improve the borough. Adrian Hewitt, Principle Environment Officer and liaison for this project, is the lead behind the proposed project reducing emissions and has a long history working with WPI research teams. One of the areas he has worked on is identifying methods and systems to move Merton towards more environmentally conscience and renewable energy sources. This most recent IQP further develops the move towards decreasing carbon emissions by helping to implement a new combined heat and power system. (For details and description of CHP see the above report.)



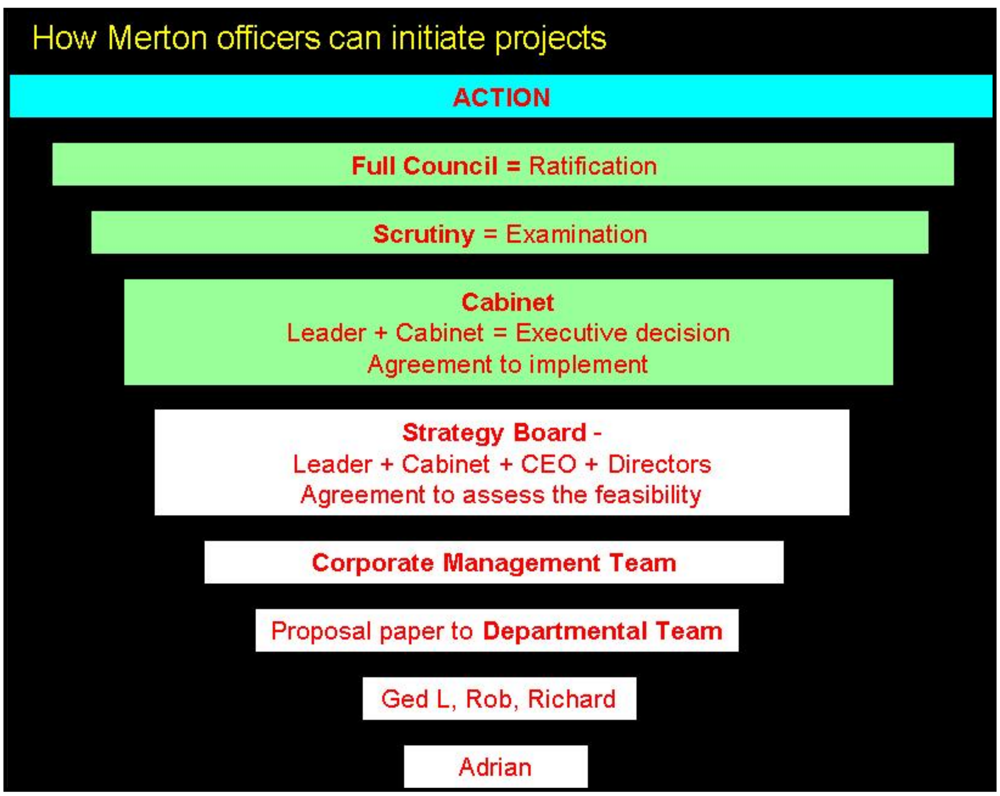
Source: Adrian Hewitt



Source: Adrian Hewitt



Source: Adrian Hewitt



Source: Adrian Hewitt

Appendix B: Alternate Forms of Heat and Electricity Generation

As the DHP system expands, renewable sources of energy such as solar, wind or geothermal can be integrated into the DHP system along the distribution network to provide additional power to the network. Also, solar or geothermal technology could also be used maintain water temperature in heat pipes throughout the DHP network.

1. Solar Power

The Sun is the source of all of the life on this planet. It was not understood until recently that the power of the Sun could be captured and used to generate heat and electricity with the versatility of fossil fuel energy generation. In the 1970s a steady push began towards the development of cleaner energy sources due to rising fossil fuel costs and a heightened concern for the environment. As a result, solar power generation was born.

There are two major types of solar power plants that are used, thermal and photovoltaic. Thermal solar plants are used near the equator, where there is a surplus of concentrated direct irradiation. This irradiation is needed to produce heat, which is then converted into electricity (Winter, Sizmann, Vant-Hull, 1991). Thermal solar plants have the potential to act as a combined heat and power plant, producing both heat and electricity. However, the UK does not receive high volumes of direct irradiation, and therefore thermal solar plants are ineffective in this area.

Photovoltaic solar plants are the other type of use of solar power. They differ from thermal solar plants in that they can use both direct and diffuse irradiation. This means that these plants can be placed almost anywhere in the world where there is sunlight. They operate by producing direct current at a low voltage and convert it into alternating current at any voltage. A photovoltaic solar unit could be used along heat pipe distribution lines to supplement a CHP plant.

2. Wind Power

Another green energy source that has been used for years is wind power. As early as the twelfth century, windmills were erected to capture the power of the wind and to perform tasks. In Europe, windmills became commonplace, with 100,000 mills by the beginning of the twentieth century (Asmus, 2001). Today, structures with similar components to the early windmills are used to generate electricity instead of completing tasks. In 2001, however, wind power was found to be providing only 0.1 percent of global power consumption totals (Asmus, 2001). Serious concerns about reliability and sustainability of wind power systems will need to be addressed before we will see a real rise in wind power usage. These problems are meeting the power needs of the clients using the wind power and having effective backup systems for when the wind is calm. Because of these drawbacks, the developers in the UK would have trouble relying on wind power as a main source of power for users. Wind power technology could be used to reduce the power load on a CHP plant when the wind is at high enough velocity for generation.

3. Geothermal Heat Pump

One of the most reliable sources of energy on this planet is the heat that is located underneath the Earth's surface. That thermal energy is a resource just waiting to be tapped. In a recent study of the global potential for geothermal power, "the results indicated that 70 GW, or roughly nine times the existing installed capacity, could be produced with current technology" (Williamson, Gunderson, Hamblin, Gallup, Kitz, 2001).

The way that the heat located within 10 kilometers below the Earth's surface is utilized is a complex one. Generally, researchers look for pools of hot water (200° C) underground to tap for steam (Williamson, Gunderson, Hamblin, Gallup, Kitz, 2001). This steam is then rapidly transferred to the surface and run through a turbine, which activates power generators. Geothermal has proved to be a reliable and clean source of energy generation, but faces many challenges for its usage. Buildings that have used other methods of heat generation are often incompatible with geothermal technology (Aery, et. al, 2003). Developers have also had problems with implementing geothermal at multiple-level sites. While there are setbacks to using geothermal technology to heat buildings independently, it is possible for it to be incorporated into a DHP distribution network to maintain water temperature through heat pipes.

Appendix C: Methodology Constraint Mapping Layering Example

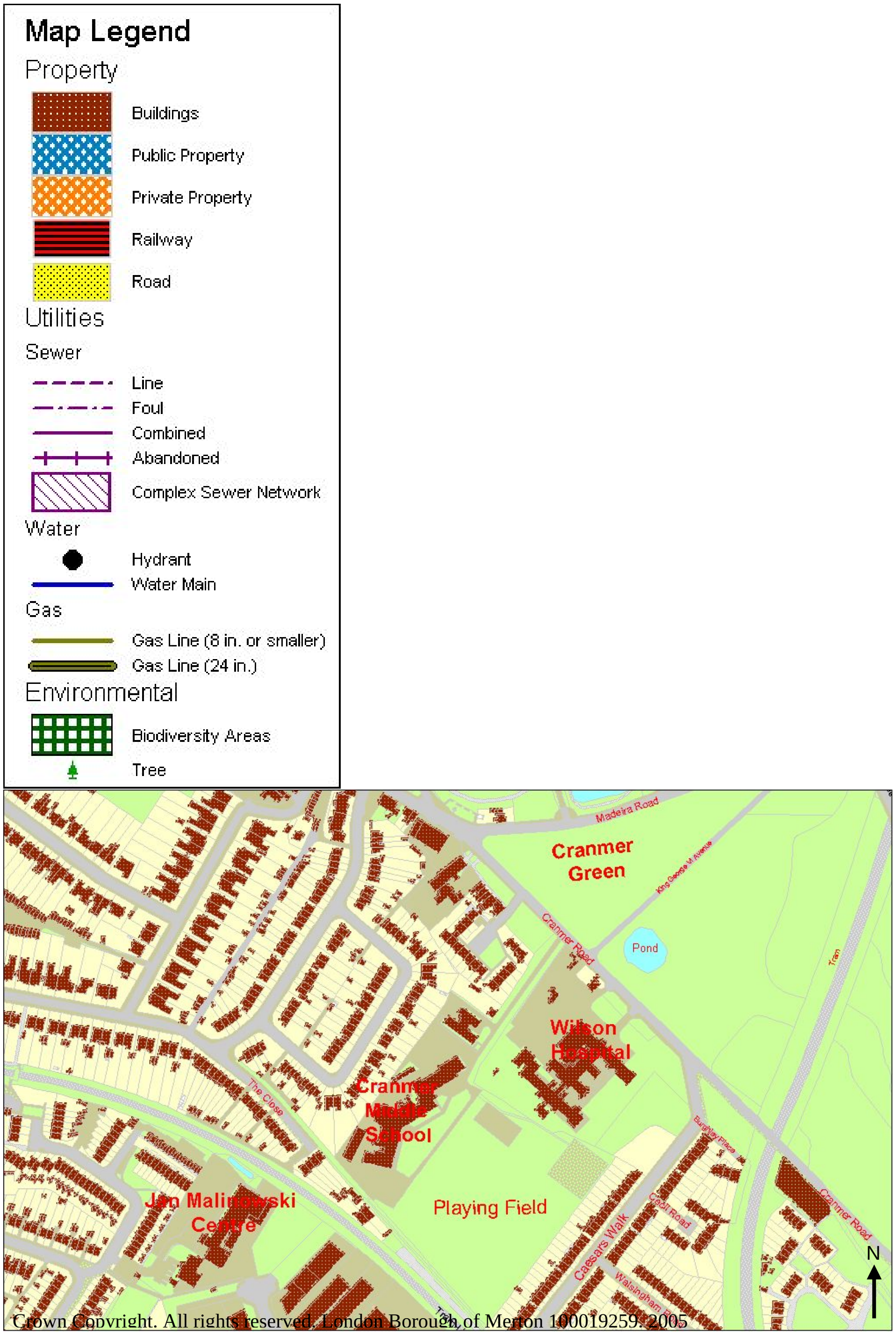


Figure C.1: Map including layer showing Buildings

Figure C.2: Map including layer showing Land Ownership

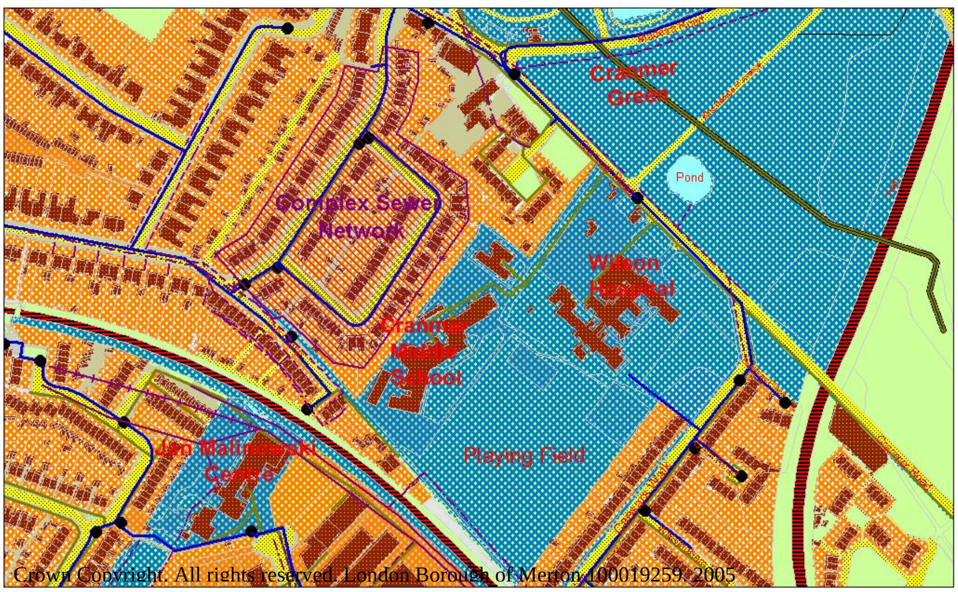


Figure C.3: Map including layer showing Existing Subsurface Infrastructure

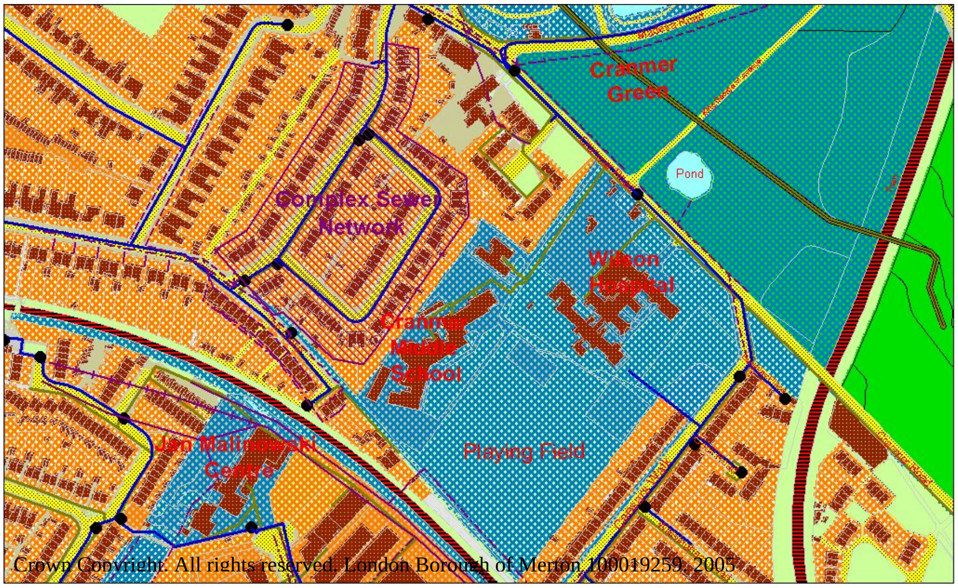


Figure C.4 Map including layer showing Environmental Area

Figure C.5: Map including Surface Structures/Features
(only the tree layer is shown to avoid clutter)

Appendix D: Pyrolysis CHP Distribution Network Risk Assessment

This risk assessment for the pyrolysis CHP distribution route is based on the European Union LETIT (Local New Energy Technology Implementation) risk assessment model. This model has been modified for use with this specific route assessment. The detailed data structure driving the risk chart in section 6.3 is shown below.

Type of energy	Technology		Risk Perceived by Local Authoritory - DISTRIBUTION									
			Built environment	mark	Transport	mark	Sub-surface	mark	Environmental	mark	Public, Planning & Policy / Regulation	mark
Heat & Electric	Pyrolysis CHP DISTRIBUTION	Qualitative description	Geology	3	Railroads	4	Electicic	3	Biodiversity	3	Conservation Areas	4
			Building structures (individual)	1	Roads	3	Gas	3	Trees	2	Council Owned & Controlled Property	2
			Built environment (area)	2	Access points to buildings	2	Water	3	Open space	2	Private/Lease property	1
			Built environment - surfaces	2	Road closures detour	3	Sewers	3	Flood Zones (risk of flooding)	3	Public Right of Ways	1
			Walls	2	Access during engineering	3	Telecommunications	3	Contaminated Land	3	Disruption	3
			Fences	2							Planning	2
			Street Furniture	1							Regulation	2
			Archeology	3								
		Quantitative		2.0		3.0		3.0		2.6		2.1

RISK DEFINITIONS

1 - negligible

2 - low

3 - medium- needs consideration

4 - high- essential to route

5 - Unresolvable

Appendix E: Recommended Route for the Distribution Network

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Recommended route for CHP distribution network shown by red line

Appendix F: Topics Matrix

Topics Matrix

CHP Specs
Route Determination
Construction

Topic	What we need to know	What we have (Document, Data, Information)	Where we will find/where we have found data		Priority of Information needed	Likelyhood of Locating Listed Information	Accuracy of Information Obtained (Percentage)
			Located at London Borough of Merton Civic Centre	External Source			
Existing Infrastructure	Electricity	Electricity Line Maps (microflim)	Simon Newman	Seaboard EDF			
	Telephone		Stuart Beatton in Street Management	British Telecom			
	Broadband		Stuart Beatton in Street Management	Telwest Broadband			
	Water Pipes	Thames Water Maps	Does not have data	Thames Water			
	Sewer	Thames Water CD	Gary Shaw 13th floor	N/A			Pretty High Accuracy
	Natural Gas	Transco PLC CD	Jason Russel 12th floor (street management)	N/A			50-60% accuracy of location
Public Right of Ways (roads)	Traffic	Excel Data (Traffic Volumes & Average Speeds) (\\ntserver_es1\users\trafficsurveydata)	Declan Stegner 13th floor	N/A			2003 & 2004 data
	Surface	On-site observation	On-site observation				

	Street Location & Names	MapINFO	Gary Shaw 13th floor	N/A			Accurate
Environmental	Unitary Development Policy (UDP)	Adopted Plan 2003	Adrian Hewitt	N/A			
	Trees	MapINFO, NJUG 10	Gary Shaw 13th floor	Archival searches			Accurate
	Water Table	Britain beneath our feet- GIS http://www.bgs.ac.uk/britianbeneath/guide.html	Does not have data	British Geological Survey			
	Flood Zone	MapINFO / EA maps from website	Gary Shaw 13th floor	Environmental Agency			Accurate
	Biodiversity	DTI Guidelines for Environmental Assessment, Environmental Impact Assessment, NJUG 10	Environment Dept. Rose & Dave/Chris Martin Boyle	Archival searches			
	Conservation Areas (open spaces)	UDP Map	Phil Ryder 11th floor PrcplDesignPlanner	N/A			Accurate
	Geology	British Geological Survey: Britain beneath our feet/England Rural Development Program report/Contaminated Land Regime Strategy report/	contaminated land report (Louise Halloran)	British Geological Survey online resource/ ERDP from Defra website			
	Archeology	archaeological zone classifaction map	GIS MApInfo layer (Lone Le Vay)	for further detail, contact English Heritage			

CHP distribution specifications	Pipe Material	ALSTOM, Logstor, Perma-Pipe, GPG234	N/A	Mike King, Archival searches			
	Size	ALSTOM, Optimal Design of Piping Systems for District Heating	N/A	Mike King, Archival searches			
	Transmission Lines	ABB XLPE Specifications	N/A	ABB.com			
	Depth	NJUG 9	Jason Russel 12th floor (streets)	Mike King, Archival searches			
	Enclosure/Insulation	ALSTOM, Logstor, Perma-Pipe, GPG234	N/A	Mike King, Archival searches			
	Water Circulation?	GPG234	N/A	Mike King			
	Water Temperature	GPG234	N/A	Mike King			
	Pressure	ALSTOM, GPG234	N/A	Mike King			
	Transformers	N/A	N/A	James Nelson, EE, APC			
	Distance Constraints	ALSTOM	N/A	www.flowsystems.alstom.com			
	Loads	Leisure Centre Energy Consumption, Mitcham Town Centre Design Brief, ECG087	Adrian Hewitt	Archival searches			
	Renewable Energies	Background Research	Adrian Hewitt	Archival searches			
	Exchangers/Absorption Chillers	GPG234	N/A	Mike King			

Construction	Methods	Trenchless and Minimum Excavation Techniques, Trenchless Construction for Underground Services, Pipeline Construction	Jason Russel 12th floor (streets)	Archival searches			
	Codes and Guidelines	Avoiding Danger from Underground Services, Specification for the Reinstatement of Openings in Highways	Jason Russel 12th floor (streets)	N/A			
	Equipment (spacing needed)	ALSTOM, Logstor, Perma-Pipe	N/A	Mike King, Alan Jones			
	Clearance between other utilities	Avoiding Danger from Underground Services, NJUG 9	Jason Russel 12th floor (streets)	Archival searches			
	Placing Transmission Lines Next to Broadband/data lines?	NJUG 9	Jason Russel 12th floor (streets)	Archival searches			
	Time/Duration		N/A	contractor			
	Disruption (social & environmental)	Trenchless and Minimum Excavation Techniques, Trenchless Construction for Underground Services, Pipeline	Jason Russel 12th floor (streets)	Archival searches			

		Construction					
Cost	Material	ALSTOM, Logstor, Perma-Pipe	N/A	Mike King, Alan Jones			
	Construction	Estimate	N/A	Alan Jones, BP Power			
	Maintenance	Maintenance of large district heating components, Maintence of district heating pipeline systems	N/A	Mike King			
	Liability	GPG234	Sharon Lauder Legal Department	Mike King			
	Insurance	GPG234	N/A	Mike King			
Land Ownership	Property Lines	MapINFO	Gary Shaw 13th floor / Tony Skilbeck Estates Dept. 12th floor	N/A			
	Address Info	MapINFO	Gary Shaw 13th floor / Tony Skilbeck Estates Dept. 12th floor	N/A			
	Ownership	Estates Dept.	Tony Skilbeck Estates Dept. 12th floor	N/A			
Social	Noise	Civil Environmental Handbook, SiteNoise, RoadNoise & RailNoise Issues, DTI Noise Emission Directive	Jason Russel 12th floor (streets)	Archival searches			

	Blocking entrances to businesses & residential areas	On-site observation	On-site observation	N/A			
	Traffic Detour Routes	MapINFO	Gary Shaw 13th floor	N/A			

Top Priority!! We do not have this information yet but it is the top priority to go after	**Have Information**
We do not have the information yet	**In process of contacting sources - limited response need more data from additional sources**
Have some information, but could use more information	**Have not commenced search for this information**
Have Information	**Information not available**
	Information not obtainable in project timeframe

Appendix G: Merton Traffic Data from 2003 & 2004

Site No: 27154012			Grid Reference: TQ50377,68681						
Site 12, Cranmer Road, Merton (L/C 12)									
Vehicle Count Report			Week Begin: 05-Jun-04			Channel: Northbound			
Time	Sat	Sun	Mon	Tue	Wed	Thu	Fri	5-Day	7-Day
Begin	05/06/2004	06/06/2004	07/06/2004	08/06/2004	09/06/2004	10/06/2004	11/06/2004	Av	Av
00:00	43	43	23	29	26	28	28	27	31
01:00	21	23	8	12	4	10	12	9	13
02:00	9	23	11	11	8	9	4	9	11
03:00	16	11	11	9	11	8	14	11	11
04:00	21	7	23	29	16	23	22	23	20
05:00	41	15	78	91	93	99	93	91	73
06:00	79	38	330	317	328	316	301	318	244
07:00	143	73	339	341	330	361	352	345	277
08:00	185	111	316	338	332	357	348	338	284
09:00	198	125	238	247	270	262	317	267	237
10:00	211	186	232	254	243	253	241	245	231
11:00	219	195	216	230	230	228	223	225	220
12:00	212	235	248	228	248	229	226	236	232
13:00	190	204	256	253	253	277	243	256	239
14:00	175	173	215	213	233	223	227	222	208
15:00	188	157	198	207	193	245	231	215	203
16:00	164	175	231	223	227	233	233	229	212
17:00	209	151	253	234	239	249	263	248	228
18:00	193	152	175	180	223	192	180	190	185
19:00	159	149	157	158	187	152	198	170	166
20:00	132	138	116	144	123	128	152	133	133
21:00	87	128	90	94	104	113	107	102	103
22:00	80	78	60	73	68	95	88	77	77
23:00	73	65	53	50	41	53	60	51	56
12H,7-19	2287	1937	2917	2948	3021	3109	3084	3016	2758
16H,6-22	2744	2390	3610	3661	3763	3818	3842	3739	3404
18H,6-24	2897	2533	3723	3784	3872	3966	3990	3867	3538
24H,0-24	3048	2655	3877	3965	4030	4143	4163	4036	3697
Am	11:00	11:00	07:00	07:00	08:00	07:00	07:00	-	-
Peak	219	195	339	341	332	361	352	345	306
Pm	12:00	12:00	13:00	13:00	13:00	13:00	17:00	-	-
Peak	212	235	256	253	253	277	263	260	250
COUNT ON US				Created at 17:49:07 on 5 Jul 2004					

Site No: 27154012			Grid Reference: TQ50377,68681						
Site 12, Cranmer Road, Merton (L/C 12)									
Vehicle Count Report			Week Begin: 05-Jun-04			Channel: Southbound			
Time	Sat	Sun	Mon	Tue	Wed	Thu	Fri	5-Day	7-Day
Begin	05/06/2004	06/06/2004	07/06/2004	08/06/2004	09/06/2004	10/06/2004	11/06/2004	Av	Av
00:00	53	51	35	27	31	47	36	35	40
01:00	25	44	18	20	20	11	17	17	22
02:00	21	31	6	11	14	9	13	11	15
03:00	19	24	13	11	9	12	10	11	14
04:00	28	16	9	15	15	17	20	15	17
05:00	27	28	27	37	27	35	38	33	31
06:00	52	37	87	83	86	77	82	83	72
07:00	70	50	123	136	114	134	117	125	106
08:00	114	60	119	150	157	128	138	138	124
09:00	117	85	137	129	148	167	142	145	132
10:00	149	114	153	159	148	155	149	153	147
11:00	158	104	156	171	137	163	137	153	147
12:00	156	134	181	158	168	153	185	169	162
13:00	128	132	196	185	180	198	198	191	174
14:00	144	111	164	181	201	210	206	192	174
15:00	131	111	194	231	237	195	208	213	187
16:00	141	129	214	202	210	197	180	201	182
17:00	133	141	187	198	211	184	187	193	177
18:00	137	96	164	186	190	191	165	179	161
19:00	134	116	135	166	171	135	153	152	144
20:00	101	118	118	139	125	128	132	128	123
21:00	75	85	88	110	96	112	90	99	94
22:00	78	61	91	76	87	105	101	92	86
23:00	86	59	51	57	55	69	70	60	64
12H,7-19	1578	1267	1988	2086	2101	2075	2012	2052	1872
16H,6-22	1940	1623	2416	2584	2579	2527	2469	2515	2305
18H,6-24	2104	1743	2558	2717	2721	2701	2640	2667	2455
24H,0-24	2277	1937	2666	2838	2837	2832	2774	2789	2594
Am	11:00	10:00	11:00	11:00	08:00	09:00	10:00	-	-
Peak	158	114	156	171	157	167	149	160	153
Pm	12:00	17:00	16:00	15:00	15:00	14:00	15:00	-	-
Peak	156	141	214	231	237	210	208	220	200
COUNT ON US			Created at 17:49:08 on 5 Jul 2004						

Site No:25312011								Site Reference: 25312011	
			11 - Carshalton Road (Mitcham Jun at Ped Crossing)						
Vehicle Count Report				Week Begin: 04-Jun-03				Channel: Northbound	

Time Begin	Wed Jun-04	Thu Jun-05	Fri Jun-06	Sat Jun-07	Sun Jun-08	Mon Jun-09	Tue Jun-10	5-Day Av	7-Day Av
0:00	109	110	125	156	220	99	101	109	131
1:00	55	55	86	117	151	68	51	63	83
2:00	53	52	50	77	104	37	37	46	59
3:00	52	57	59	74	69	56	53	55	60
4:00	108	136	148	92	71	144	131	133	119
5:00	365	363	385	197	91	338	327	356	295
6:00	952	960	950	329	163	896	1009	953	751
7:00	1079	986	988	581	264	944	981	996	832
8:00	942	913	912	690	382	881	956	921	811
9:00	900	804	879	705	485	822	830	847	775
10:00	783	756	799	777	665	743	776	771	757
11:00	765	779	791	816	738	759	685	756	762
12:00	744	747	866	784	710	784	781	784	774
13:00	747	773	790	759	689	810	838	792	772
14:00	736	808	753	652	639	738	746	756	725
15:00	722	825	768	585	599	788	795	780	726
16:00	918	891	792	629	656	901	872	875	808
17:00	944	978	857	664	647	967	1029	955	869
18:00	722	782	814	685	634	750	749	763	734
19:00	658	609	727	640	589	613	626	647	637
20:00	548	535	542	537	483	448	499	514	513
21:00	437	476	453	438	445	386	403	431	434
22:00	287	378	316	303	304	279	330	318	314
23:00	217	219	268	275	221	171	212	217	226
12H,7-19	10002	10042	10009	8327	7108	9887	10038	9996	9345
16H,6-22	12597	12622	12681	10271	8788	12230	12575	12541	11681
18H,6-24	13101	13219	13265	10849	9313	12680	13117	13076	12221
24H,0-24	13843	13992	14118	11562	10019	13422	13817	13838	12968
Am	7:00	7:00	7:00	11:00	11:00	7:00	6:00	-	-
Peak	1079	986	988	816	738	944	1009	1001	937
Pm	17:00	17:00	12:00	12:00	12:00	17:00	17:00	-	-
Peak	944	978	866	784	710	967	1029	957	897

TRAFFIC WATCH (UK) LTD

Created at 14:23:09 on 7 Jul 2003

Site No:25312011

Site Reference:25312011

11 - Carshalton Road (Mitcham Jun at Ped Crossing)

Vehicle Count Report

Week Begin: 04-Jun-03

Channel: Southbound

Time Begin	Wed Jun-04	Thu Jun-05	Fri Jun-06	Sat Jun-07	Sun Jun-08	Mon Jun-09	Tue Jun-10	5-Day Av	7-Day Av
0:00	149	126	153	221	278	114	134	135	168
1:00	89	72	92	165	179	69	70	78	105
2:00	47	60	72	100	144	38	65	56	75
3:00	64	69	72	105	127	45	49	60	76
4:00	83	85	101	96	76	66	91	85	85
5:00	161	144	153	135	96	156	153	153	143
6:00	378	387	391	224	162	378	380	383	329
7:00	645	723	685	364	166	726	662	688	567
8:00	683	716	720	513	235	710	736	713	616
9:00	603	607	601	604	335	624	625	612	571
10:00	610	609	683	762	474	612	617	626	624
11:00	708	696	738	802	665	627	658	685	699
12:00	687	720	766	808	717	636	687	699	717
13:00	717	752	828	841	802	739	701	747	769
14:00	766	807	872	778	660	821	887	831	799
15:00	955	946	827	672	646	896	955	916	842
16:00	980	995	1041	699	616	1004	1033	1011	910
17:00	1024	1008	1076	660	644	943	924	995	897
18:00	923	888	898	722	598	842	942	899	830
19:00	757	762	757	584	616	671	945	778	727
20:00	571	605	747	550	509	529	630	616	592
21:00	474	473	453	401	425	439	455	459	446
22:00	390	395	402	393	290	318	362	373	364
23:00	269	297	340	342	210	192	254	270	272
12H,7-19	9301	9467	9735	8225	6558	9180	9427	9422	8842
16H,6-22	11481	11694	12083	9984	8270	11197	11837	11658	10935
18H,6-24	12140	12386	12825	10719	8770	11707	12453	12302	11571
24H,0-24	12733	12942	13468	11541	9670	12195	13015	12871	12223
Am	11:00	7:00	11:00	11:00	11:00	7:00	8:00	-	-
Peak	708	723	738	802	665	726	736	726	728
Pm	17:00	17:00	17:00	13:00	13:00	16:00	16:00	-	-

Peak	1024	1008	1076	841	802	1004	1033	1029	970

TRAFFIC WATCH (UK) LTD

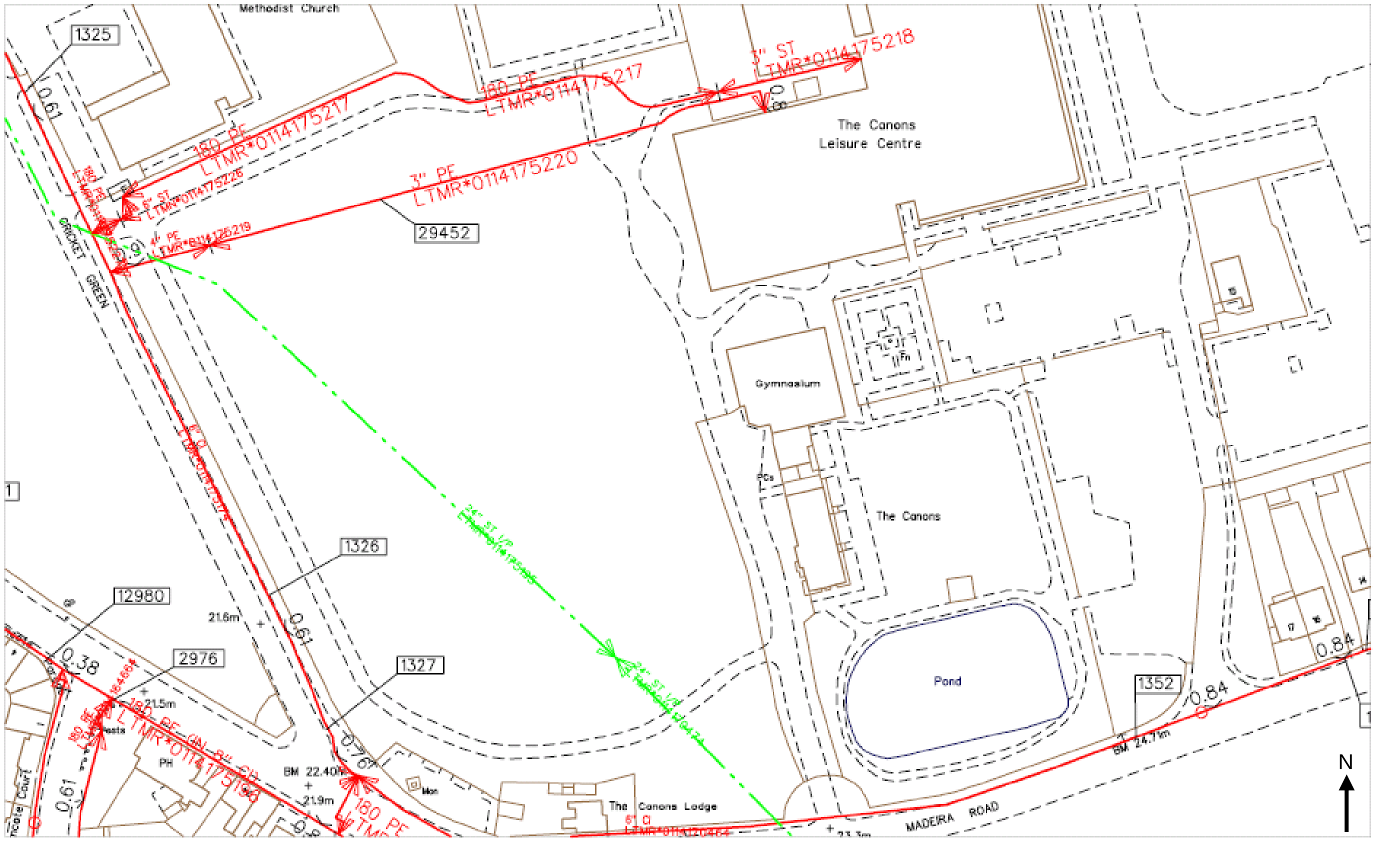
Created at 14:23:09 on 7 Jul 2003

Appendix H: Building Loads

Building Classification Building Types	Data Source	Fossil Fuel kWh/m2/year	Electricity kWh/m2/year	Area Data Source	Area m2	Heat Load kWh/year	Electrical Load kWh/year	Total kWh/year	Heat Load kW	Electricity Load kW
Retail				Urban Design Brief	17,500					
Supermarket	Supermarkets from Toolkit	200	915	Estimate	8,000	1,600,000	7,320,000	8,920,000	183	836
Retail/A3 units	Clothes shops from Toolkit	75	250	Estimate	7,500	562,500	1,875,000	2,437,500	64	214
	Fast-food restaurant from Toolkit	480	820	Estimate	2,000	960,000	1,640,000	2,600,000	110	187
Community Facilities	Average from following:	279.25	73.5	Urban Design Brief	8,500	2,373,625	624,750	2,998,375	271	71
Library	Typical Libraries from ECG87	210	46							
Health Centre	Sports facility without a pool from Toolkit	215	75							
Fitness Centre	Typical Dry sports centre from ECG87	343	105							
Bookshop										
Café										
Childcare Facilities	Typical Day centres from ECG87	349	68							
Residential	Whole house energy consumption table	217	38	Urban Design Brief	40,000				991	174
Houses										
Town Houses										
Flats	Based on 65 sq m flats									
Car Parks				Sum of:	12,000					
Multi-Storey	Car parks - multi storey from ECG87	0	15	Urban Design Brief	10,000	0	150,000	150,000	0	17
Open	Car parks - open from ECG87	0	1	Estimate for 100 open spaces	2,000	0	2,000	2,000	0	0
Leisure Centre	Leisure Centre 2004 Energy Usage from DHP site info table	364	143	Roy Clarke estimate	5,355	1,948,252	768,283	2,716,535	222	87
	Typical Leisure Pool Centre from ECG78	1321	258	Roy Clarke estimate	5,355	7,073,955	1,381,590	8,455,545	808	158
	Good practice Leisure Center Pool from ECG78	573	164	Roy Clarke estimate	5,355	3,068,415	878,220	3,946,635	350	100
	Typical 25 M Swimming Pool Centre from ECG78	1336	237	Roy Clarke estimate	5,355	7,154,280	1,269,135	8,423,415	817	145
	Good Practice 25 M Swimming Pool Centre from ECG78	573	152	Roy Clarke estimate	5,355	3,068,415	813,960	3,882,375	350	93
	Typical Combined Centre from ECG78	598	152	Roy Clarke estimate	5,355	3,202,290	813,960	4,016,250	366	93
	Good Practice Combined Centre from ECG78	264	96	Roy Clarke estimate	5,355	1,413,720	514,080	1,927,800	161	59
Totals						7,444,377	12,380,033	19,824,410	1,840	1,586

Appendix I: Utility Maps

Gas Maps – Source: Transco CD-ROM



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Plant Owner = Transco or the relevant Gas Distribution Network MAPS Viewer V4.10.1

This plan shows those pipes owned by Transco plc or the relevant Gas Distribution Network in their roles as a Licensed Gas Transporters (GT). Gas pipes owned by other GTs, or otherwise privately owned, may be present in this area. Information with regard to such pipes should be obtained from the relevant owners. The information shown on this plan is given without warranty, the accuracy thereof cannot be guaranteed. Service pipes, valves, syphons, stub connections, etc. are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Transco plc, the relevant Gas Distribution Network, or their agents, servants or contractors for any error or omission. Safe digging practices, in accordance with HS(G)47, must be used to verify and establish the actual position of mains, pipes, services and other apparatus on site before any mechanical plant is used. It is your responsibility to ensure that this information is provided to all persons (either direct labour or contractors) working for you on or near gas apparatus.

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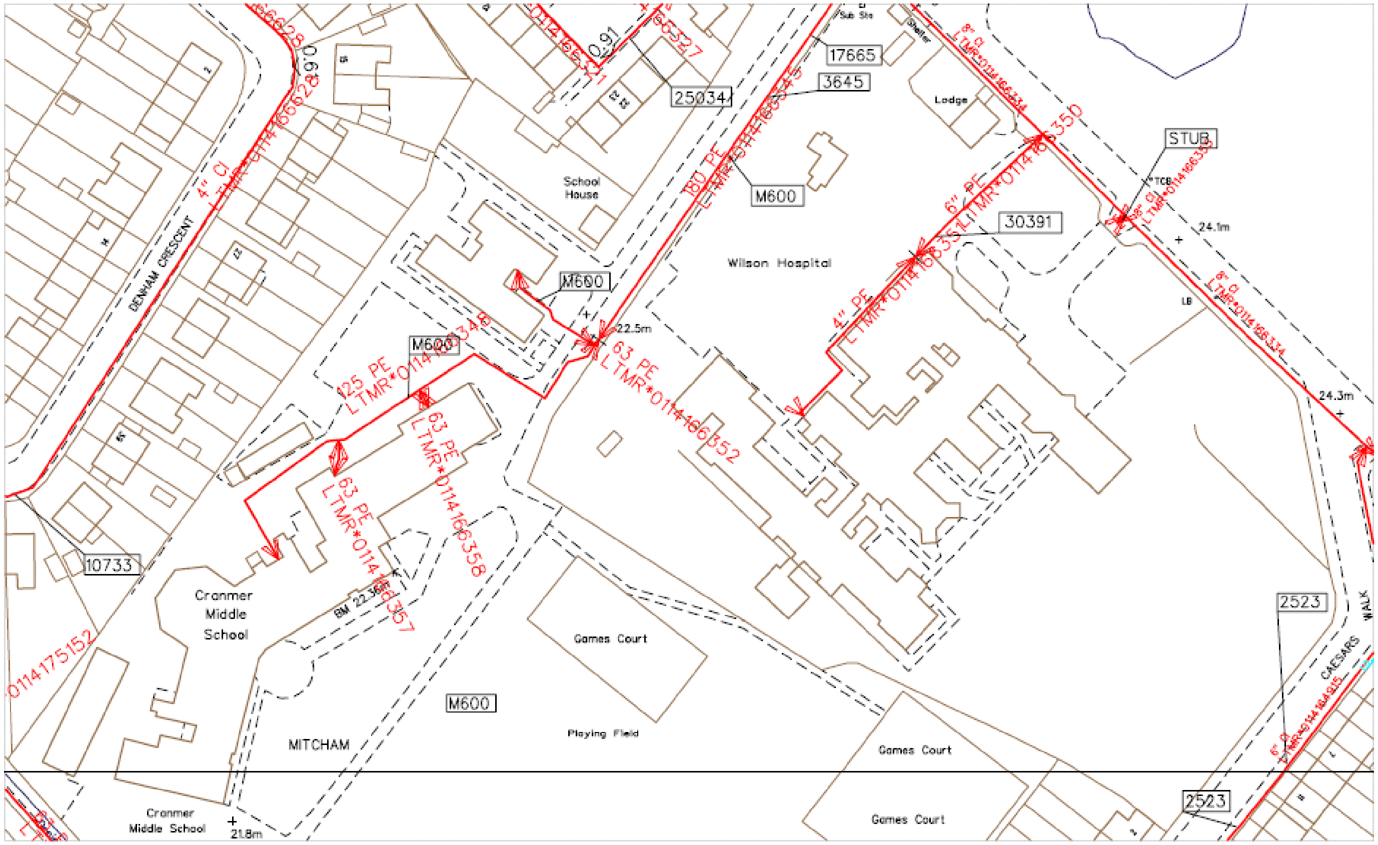

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Plant Owner = Transco or the relevant Gas Distribution Network MAPS Viewer V4.10.1

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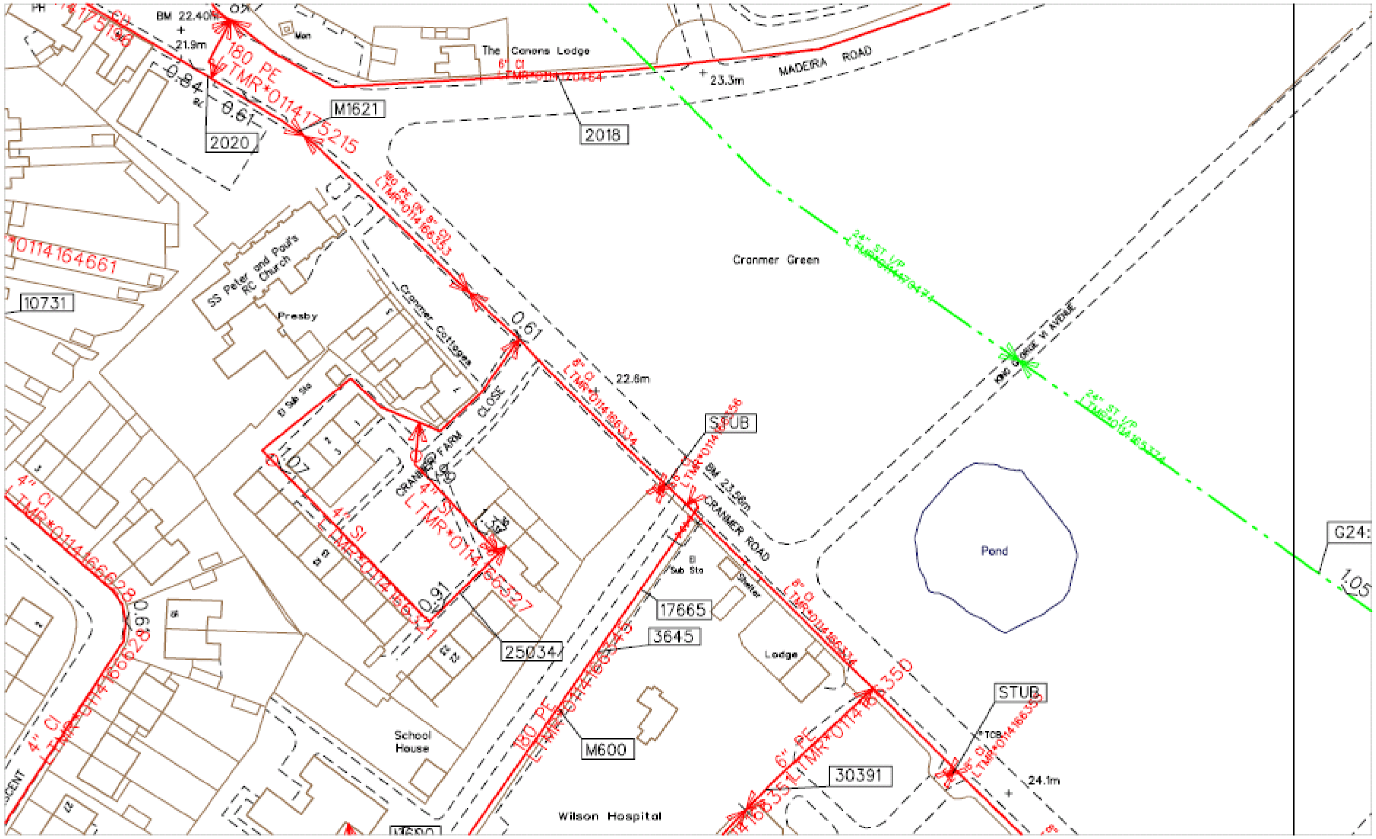

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Plant Owner = Transco or the relevant Gas Distribution Network MAPS Viewer V4.10.1

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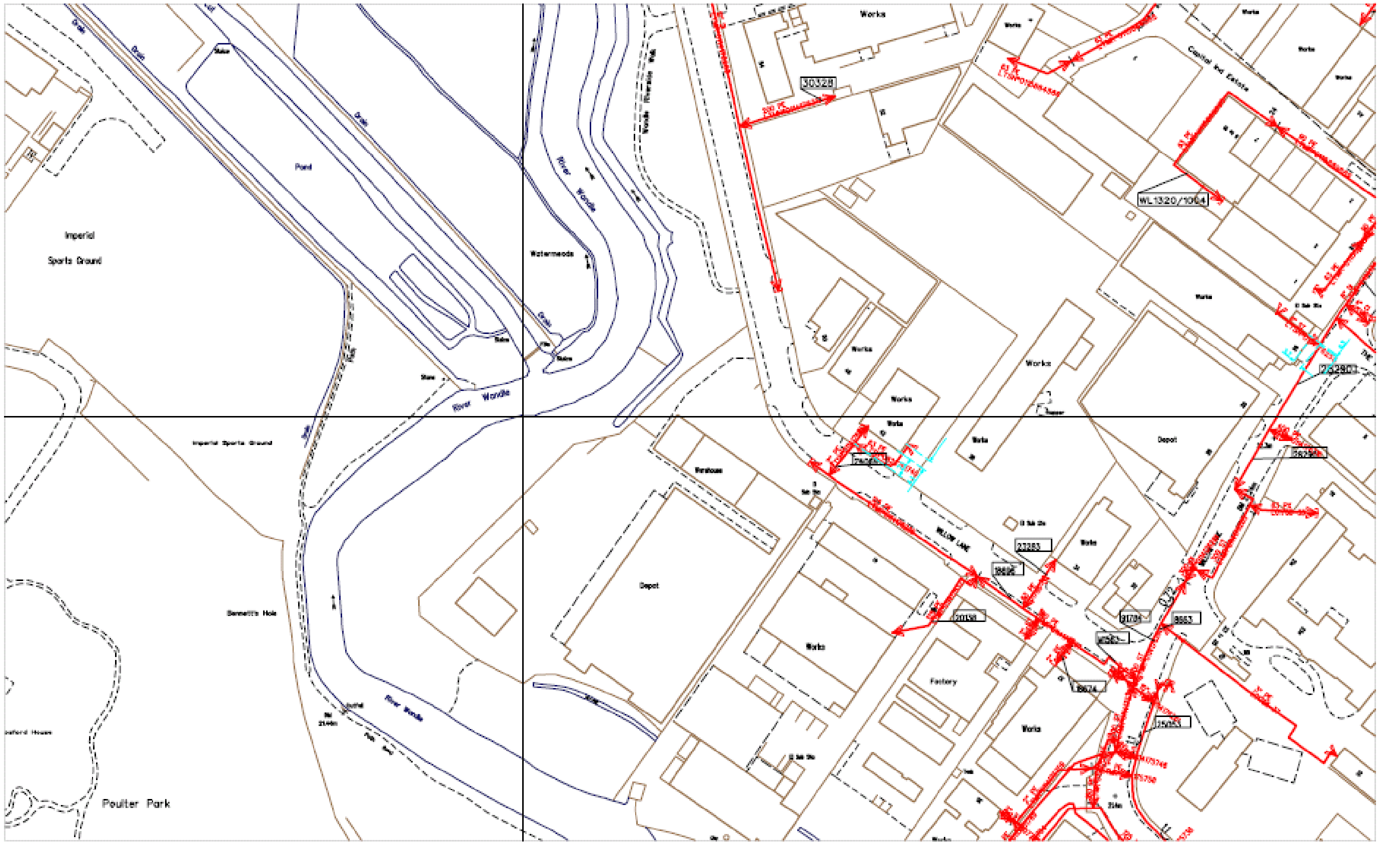

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Plant Owner = Transco or the relevant Gas Distribution Network   MAPS Viewer V4.10.1

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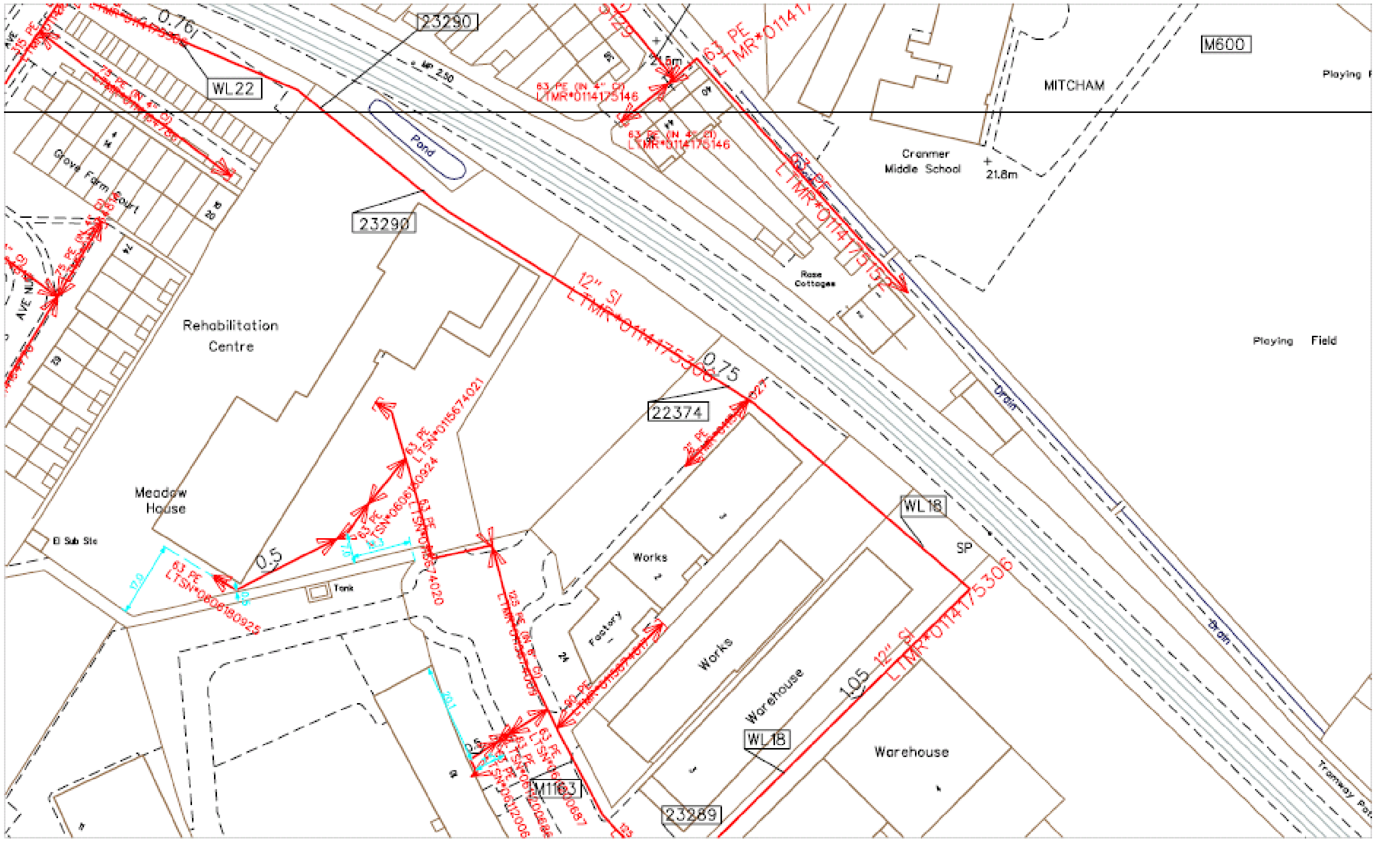

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Plant Owner = Transco or the relevant Gas Distribution Network MAPS Viewer V4.10.1

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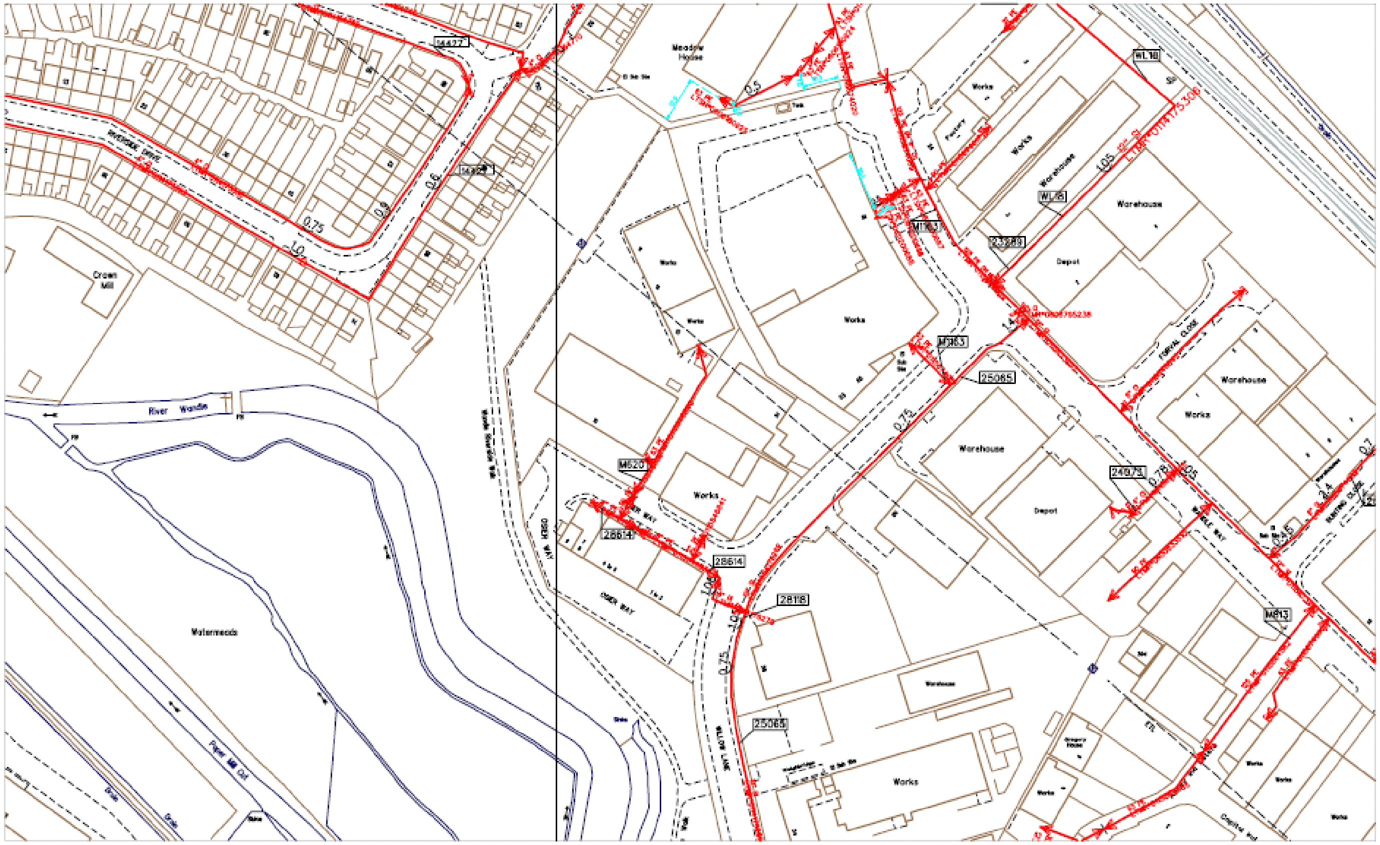

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Plant Owner = Transco or the relevant Gas Distribution Network MAPS Viewer V4.10.1

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Water Maps – Source: Thames Water Company

Thames Water

ADS Water Map Key

If you have any queries about the symbols on this key call the relevant number below:

Asset Location Team: 0118 923 6664

Commercial Drainage & Water Team: 0118 923 6652

Water Pipes

Distribution Main: The most common pipe shown on water maps. With few exceptions, domestic connections are only made to distribution mains.

Trunk Main: A Main carrying water from a source of supply to a treatment plant or reservoir, or from one treatment plant or reservoir to another. Also a main transferring water in bulk to smaller water mains used for supplying individual customers.

Supply Main: A supply main indicates that the water main is used as a supply for a single property or group of properties.

Fire Main: Where a pipe is used as a fire supply, the word FIRE will be displayed along the pipe.

Metered Pipe: A metered main indicates that the pipe in question supplies water for a single property or group of properties and that quantity of water passing through the pipe is metered even though there may be no meter symbol shown.

Transmission Tunnel: A very large diameter water pipe. Most tunnels are buried very deep underground.

Raw Water Main: A main that carries untreated water rather than water that is safe to drink. These mains are usually found near reservoirs where their purpose is to link reservoirs or to feed untreated water from a reservoir into a water treatment works.

Other Water Company Main: Occasionally other water company water pipes may overlap the border of our fresh water coverage area. These mains are denoted in purple and in most cases have owner of the pipe along them.

Other (Specified on the plan)

Proposed Main: A main that is is still in the planning stages or in the process of being laid. More details of the proposed main and its reference number are included near the main.

Private Main: Indicates that the water main in question is not owned by Thames Water. These mains normally have text associated with them indicating the diameter and owner of the pipe.

02920324 12/2003
9403

Hydrants

Single Hydrant

Double Hydrant

The abbreviations below indicate the use of the hydrant symbols above.

FH Fire Hydrant
WO Washout
RWH Raw Water Hydrant
P Private Hydrant

Meters

Meter

The abbreviations below indicate the use of the meter symbol above. Meter symbols without an abbreviation should be taken as revenue meters.

ZM Zonal
DM District
WM Waste

Valves

Open General Purpose Valve

The abbreviations below indicate the use of the valve symbol above.

BF Butterfly
BP Bypass
EV Emptying
WW Waste Water

Closed General Purpose Valve

The abbreviations below indicate the use of the valve symbol above.

DB District Boundary
SS Stand Shut
ZV Zonal Pressure Valve
ZZ Other (specified on plan)

Air Valve

The abbreviations below indicate the use of the valve symbol above.

AV Air Valve
AC Air Cock (manual air valve)
AAV Automatic Air Valve

The abbreviations below indicate the use of the valve symbol above.

PS Pressure Sustaining
PC Pressure Controlling

Pressure Reducing

Reflux

Stopcock

End items

Symbol indicating what happens at the end of a water main.

Blank Flange

Capped End

Emptying Pit

Undefined End

Manifold

Supply Assets

The abbreviations below indicate the use of the supply asset symbol above.

BS Booster Station
PS Pumping Station
SI Inspection Shaft
SP Pumping Shaft
SR Service Reservoir
TO Tower
TW Tower Works
XX Other (specified on plan)

Other Symbols

Protection Test Point

Protection Point / Anode

Pressure Transducer

Data Logger

Telemetry Pit

Other (specified on plan)

Depth of Water Pipes (Normal Cover)

PIPE DIAMETER	DEPTH BELOW GROUND
Up to 300mm (12")	900mm (3')
300mm - 600mm (12" - 24")	1100mm (3' 8")
600mm and bigger (24" plus)	1200mm (4')

For enquiries about the depth of transmission tunnels, please ring the number at the top of this key.

RWE GROUP

Thames Water

ADE/233629

HEWITT ADRIAN
4th April 2005

LONDON BOROUGH OF MERTON
PRINCIPAL ENVIRONMENT OFFICER
ENVIRO & REGENERATION DEPT
MERTON CIVIC CENTRE LONDON ROAD
MORDEN
SURREY SM4 5DX

merton Environmental Services DIVISION | AS | SD | PDM | RNR | PP | SM | Received 06 APR 2005

Dear Sirs,

>TQ2767NE & TQ2768SE

In response to your enquiry dated 4th April 2005 concerning the above property, I am able to comment as follows:-

Please find enclosed a map showing the approximate position of our mains and associated apparatus. Standard cover for most water mains and associated apparatus is approx: 0.75m for Domestic & Fire Supplies, 0.9m for Distribution Mains, 1.2m for Large Trunk Mains. If you require further information please telephone 0845 9200 800.

The replies contained in this letter are given following inspection of the public service records available to this Company. No responsibility can be accepted for any error or omission in the replies.

Yours faithfully,

M. Kennedy

Margaret Kennedy - (0118) 9251622
Asset Location Services.

RWE Group

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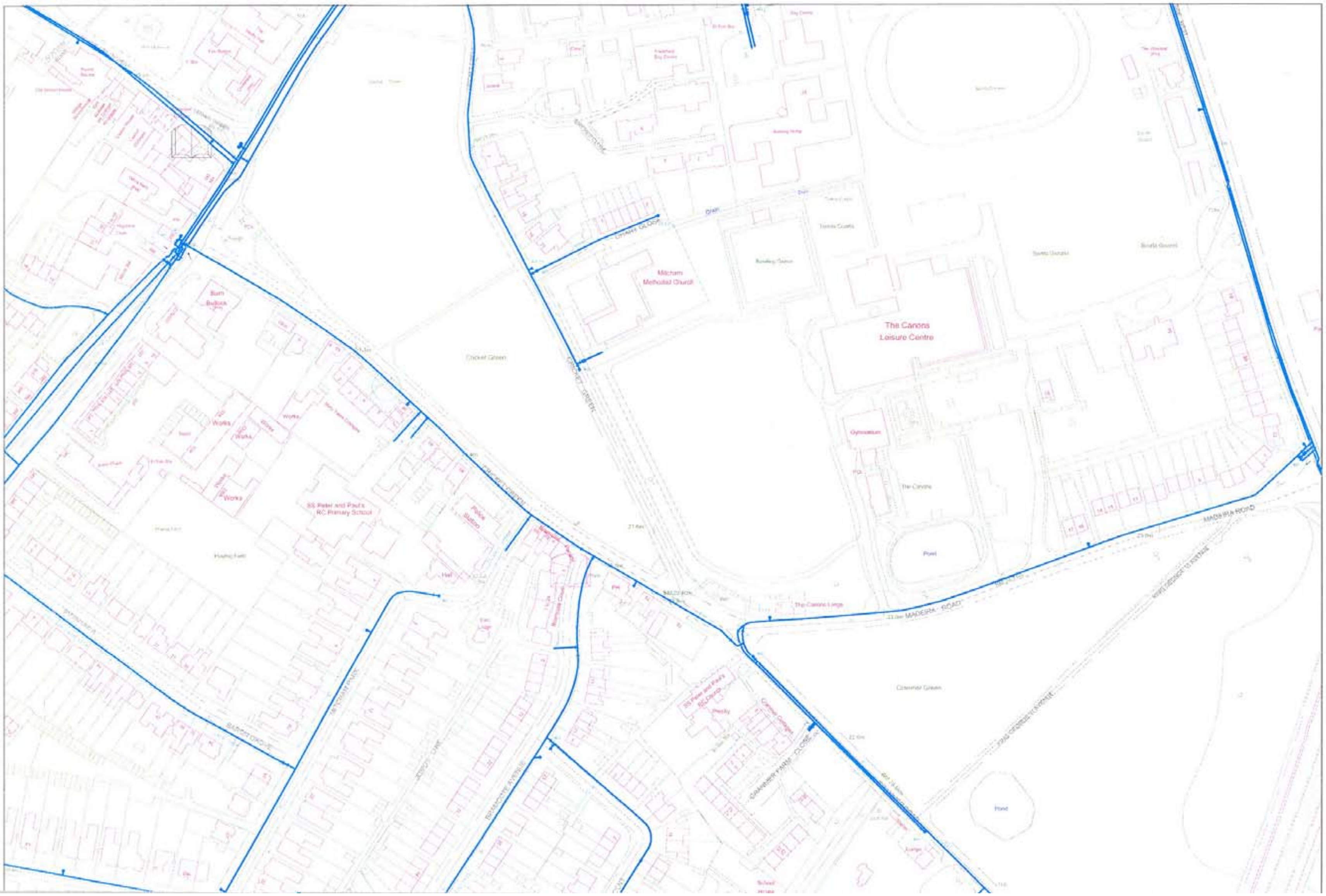
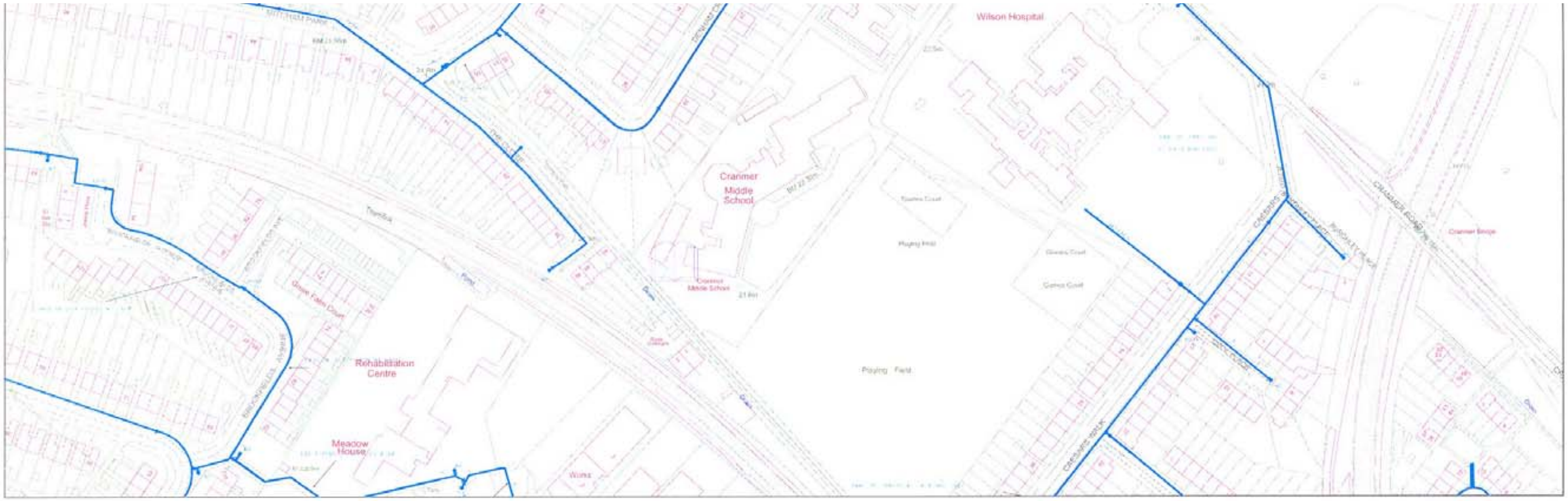
ALS WATER





The position of the apparatus shown on this plan is given without obligation and warranty, and the accuracy cannot be guaranteed. Service pipes are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Thames Water for any error or omission. The actual position of mains and services must be verified and established on site before any works are undertaken.

100 metre intervals

EAGLE hardcopy facility - Normal Map.
The plot is centred on (527750 , 168250), which is in TQ2768SE. Printed on 4 April 2005 at 11:19:38 by MKENNEDY.

Comments:

Page 1 of 1

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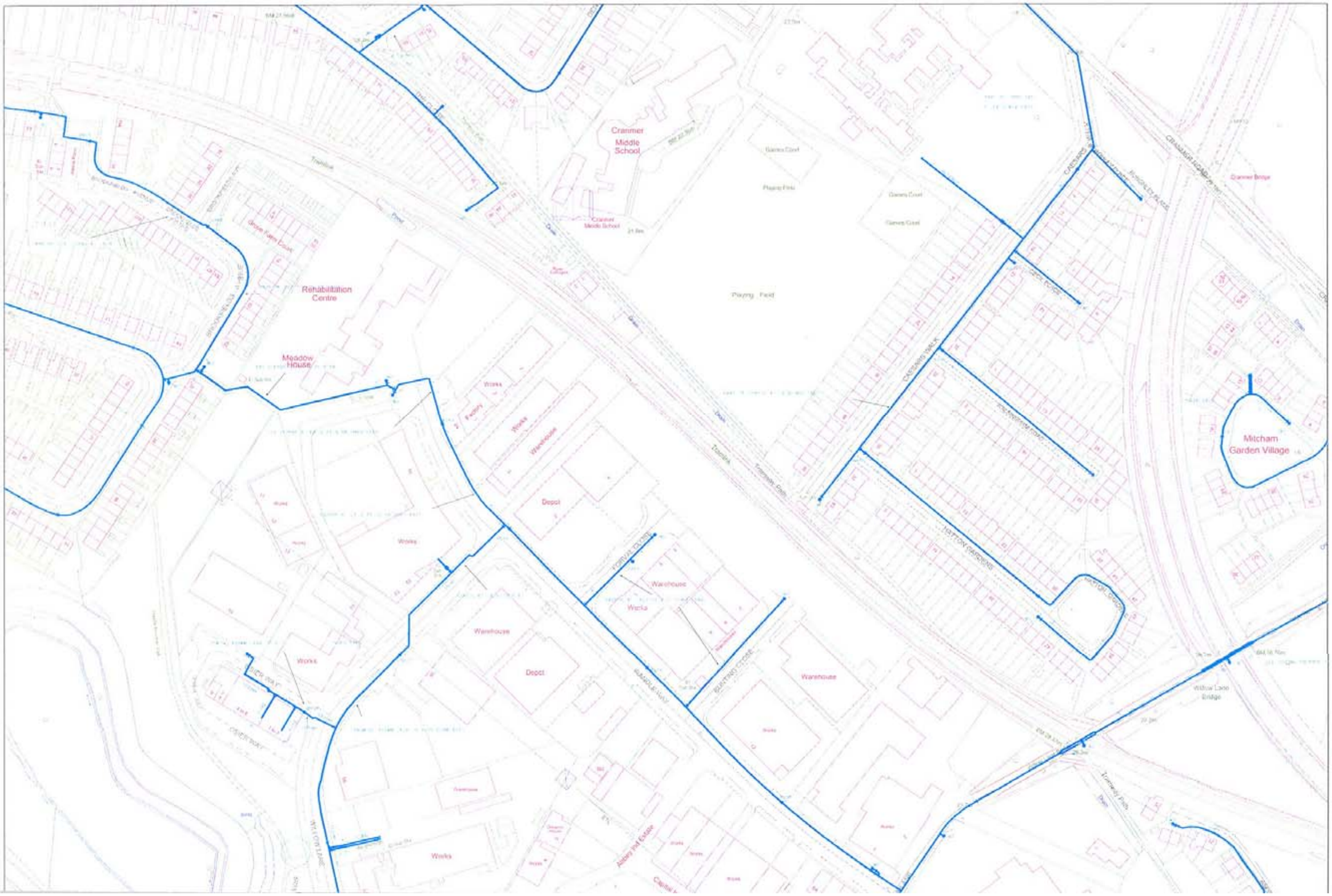
ALS WATER



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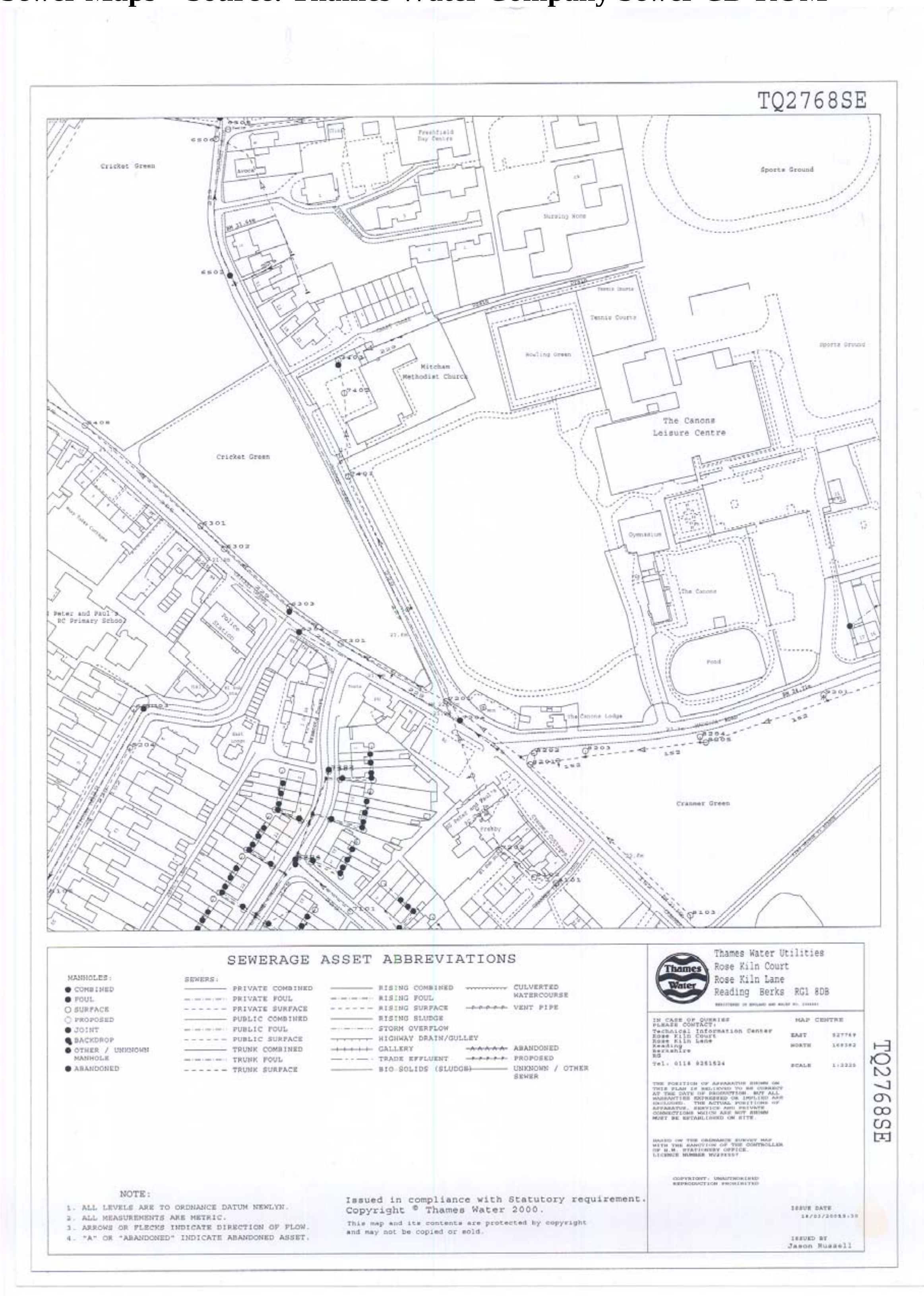
100 metre intervals

EAGLE hardcopy facility - Normal Map.
The plot is centred on (527750 , 167750), which is in TQ2767NE. Printed on 4 April 2005 at 11:20:23 by MKENNEDY.

Comments:

Page 1 of 1

Sewer Maps – Source: Thames Water Company Sewer CD-ROM



TQ2767NE

SEWERAGE ASSET ABBREVIATIONS

MANHOLES:
- COMBINED
- FOUL
- SURFACE
- PROPOSED
- JOINT
- BACKDROP
- OTHER / UNKNOWN MANHOLE
- ABANDONED

SEWERS:
- PRIVATE COMBINED
- PRIVATE FOUL
- PRIVATE SURFACE
- PUBLIC COMBINED
- PUBLIC FOUL
- PUBLIC SURFACE
- TRUNK COMBINED
- TRUNK FOUL
- TRUNK SURFACE
- RISING COMBINED
- RISING FOUL
- RISING SURFACE
- RISING SLUDGE
- STORM OVERFLOW
- HIGHWAY DRAIN/GULLEY
- GALLERY
- TRADE EFFLUENT
- BIO-SOLIDS (SLUDGE)
- CULVERTED WATERCOURSE
- VENT PIPE
- ABANDONED
- PROPOSED
- UNKNOWN / OTHER SEWER

NOTE:
1. ALL LEVELS ARE TO ORDNANCE DATUM NEWLYN.
2. ALL MEASUREMENTS ARE METRIC.
3. ARROWS OR FLECKS INDICATE DIRECTION OF FLOW.
4. "A" OR "ABANDONED" INDICATE ABANDONED ASSET.

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Thames Water Utilities
Rose Kiln Court
Rose Kiln Lane
Reading Berks RG1 8DB

IN CASE OF QUERIES PLEASE CONTACT:
Technical Information Center
Rose Kiln Court
Rose Kiln Lane
Reading
Berkshire
RG
Tel: 0118 9251524

MAP CENTRE
EAST 527448
NORTH 167635
SCALE 1:2224

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ISSUE DATE
18/03/2008

ISSUED BY
Jason Russell

TQ2767NE

TQ2767NE

SEWERAGE ASSET ABBREVIATIONS

MANHOLES:
- ● COMBINED
- ● FOUL
- ○ SURFACE
- ○ PROPOSED
- ● JOINT
- ● BACKDROP
- ● OTHER / UNKNOWN MANHOLE
- ● ABANDONED

SEWERS:
- PRIVATE COMBINED
- PRIVATE FOUL
- PRIVATE SURFACE
- PUBLIC COMBINED
- PUBLIC FOUL
- PUBLIC SURFACE
- TRUNK COMBINED
- TRUNK FOUL
- TRUNK SURFACE
- RISING COMBINED
- RISING FOUL
- RISING SURFACE
- RISING SLUDGE
- STORM OVERFLOW
- HIGHWAY DRAIN/GULLEY
- GALLERY
- TRADE EFFLUENT
- BIO-SOLIDS (SLUDGE)
- CULVERTED WATERCOURSE
- VENT PIPE
- ABANDONED
- PROPOSED
- UNKNOWN / OTHER SEWER

NOTE:
1. ALL LEVELS ARE TO ORDNANCE DATUM NEWLYN.
2. ALL MEASUREMENTS ARE METRIC.
3. ARROWS OR FLECKS INDICATE DIRECTION OF FLOW.
4. "A" OR "ABANDONED" INDICATE ABANDONED ASSET.

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Rose Kiln Court
Rose Kiln Lane
Reading
Berkshire
RG
Tel: 0118 9251524

MAP CENTRE
EAST 527646
NORTH 167947
SCALE 1:2224

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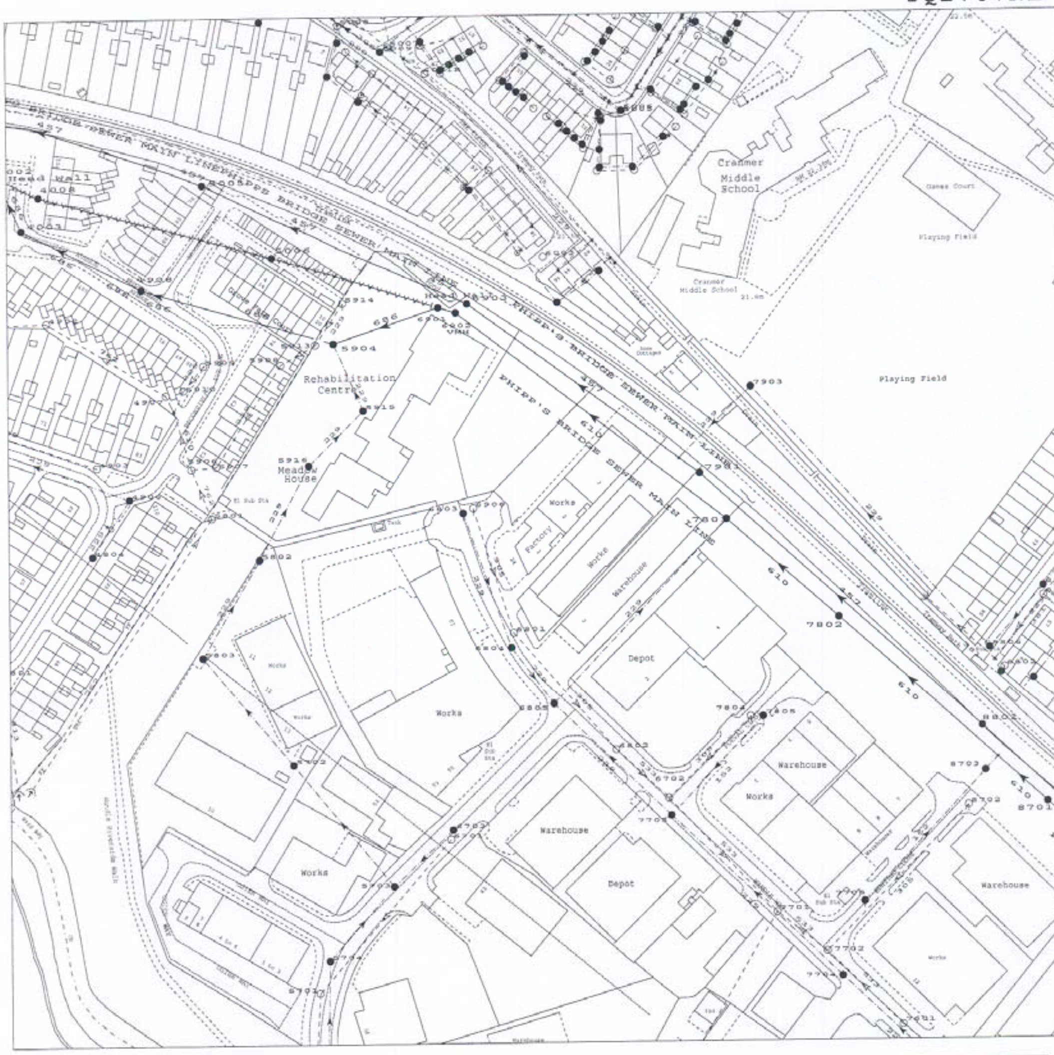

SEWERAGE ASSET ABBREVIATIONS

MANHOLES:
- COMBINED
- FOUL
- SURFACE
- PROPOSED
- JOINT
- BACKDROP
- OTHER / UNKNOWN MANHOLE
- ABANDONED

SEWERS:
- PRIVATE COMBINED
- PRIVATE FOUL
- PRIVATE SURFACE
- PUBLIC COMBINED
- PUBLIC FOUL
- PUBLIC SURFACE
- TRUNK COMBINED
- TRUNK FOUL
- TRUNK SURFACE
- RISING COMBINED
- RISING FOUL
- RISING SURFACE
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- ABANDONED
- PROPOSED
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MAP CENTRE
EAST 527647
NORTH 167892
SCALE 1:2228

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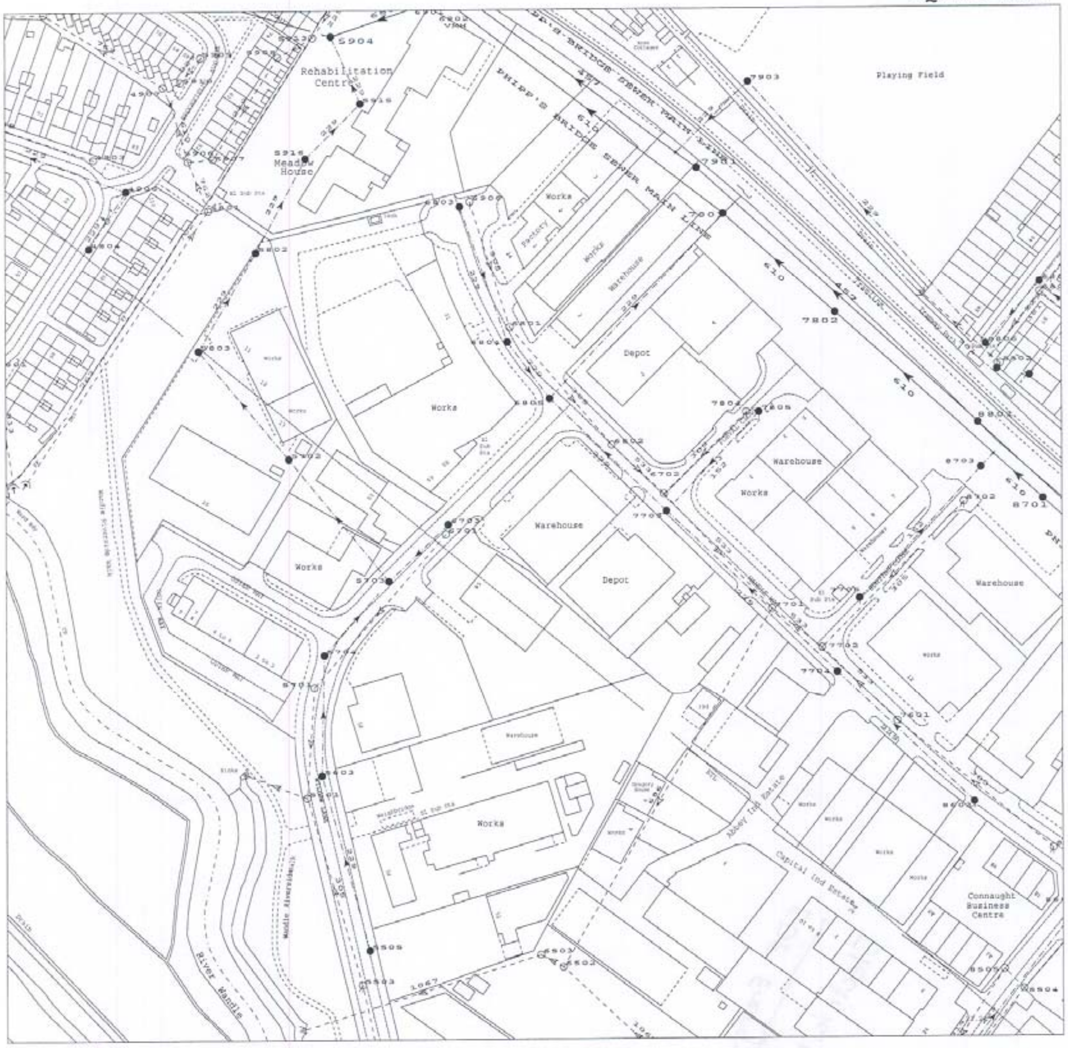

SEWERAGE ASSET ABBREVIATIONS

MANHOLES:
- COMBINED
- FOUL
- SURFACE
- PROPOSED
- JOINT
- BACKDROP
- OTHER / UNKNOWN MANHOLE
- ABANDONED

SEWERS:
- PRIVATE COMBINED
- PRIVATE FOUL
- PRIVATE SURFACE
- PUBLIC COMBINED
- PUBLIC FOUL
- PUBLIC SURFACE
- TRUNK COMBINED
- TRUNK FOUL
- TRUNK SURFACE
- RISING COMBINED
- RISING FOUL
- RISING SURFACE
- RISING SLUDGE
- STORM OVERFLOW
- HIGHWAY DRAIN/GULLEY
- GALLERY
- TRADE EFFLUENT
- BIO-SOLIDS (SLUDGE)
- CULVERTED WATERCOURSE
- VENT PIPE
- ABANDONED
- PROPOSED
- UNKNOWN / OTHER SEWER

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MAP CENTRE	
EAST	527447
NORTH	167770
SCALE	1:2226

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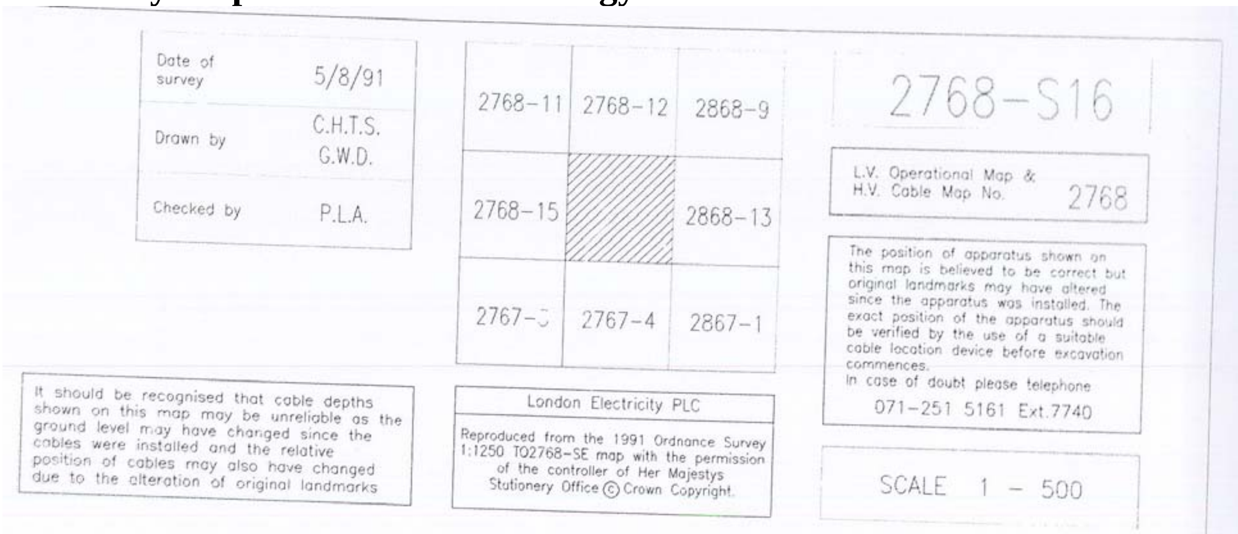
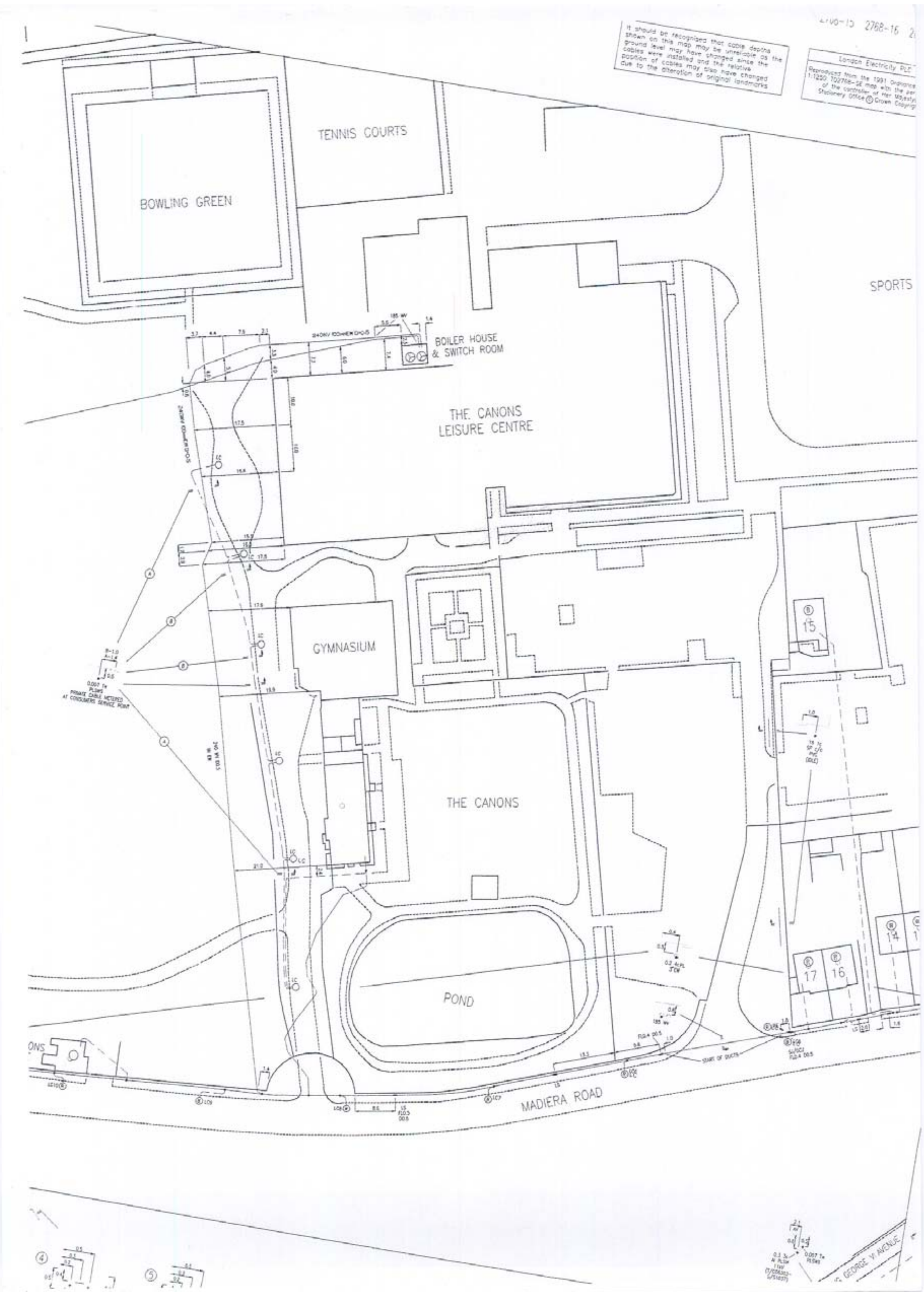
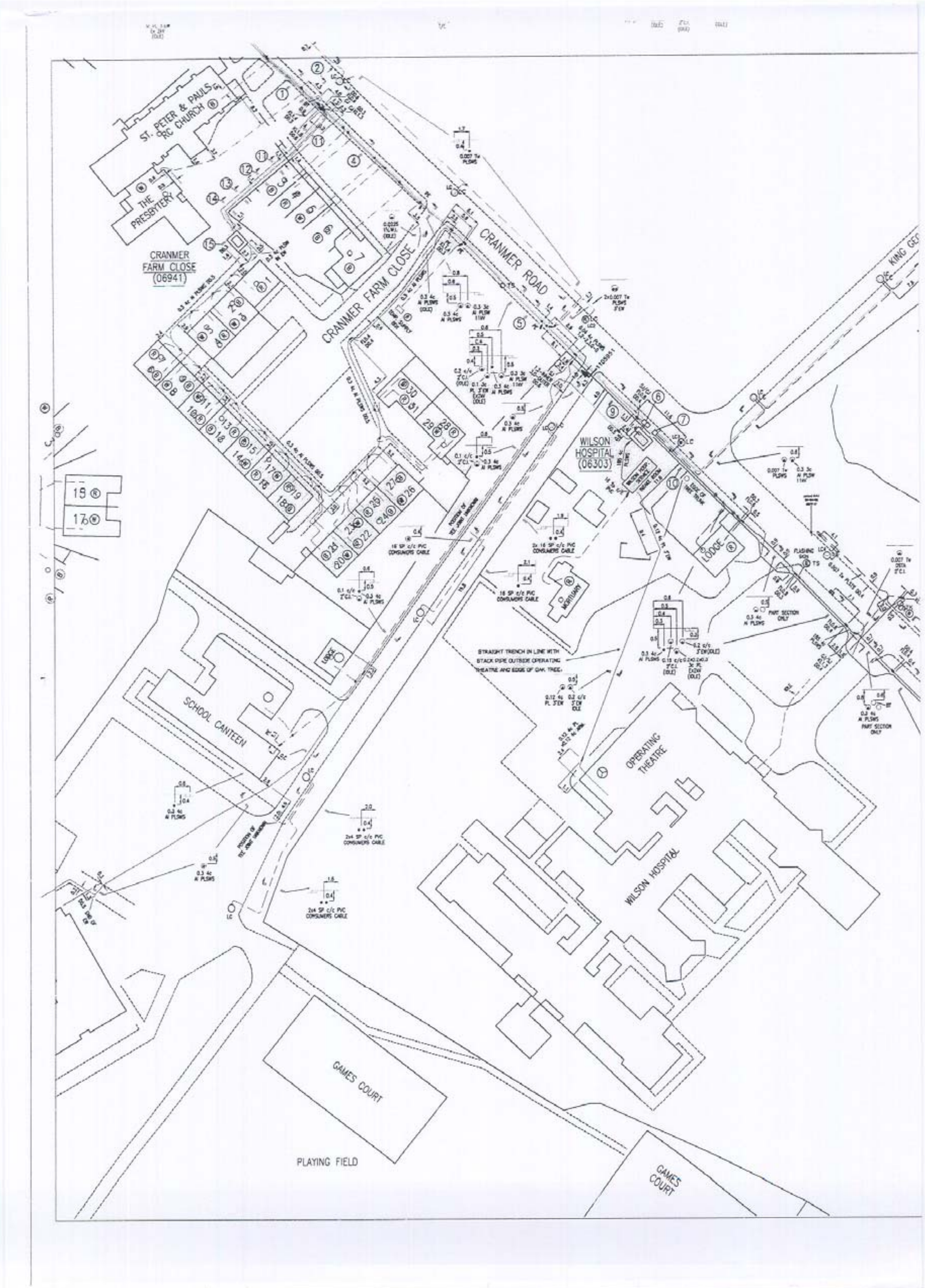
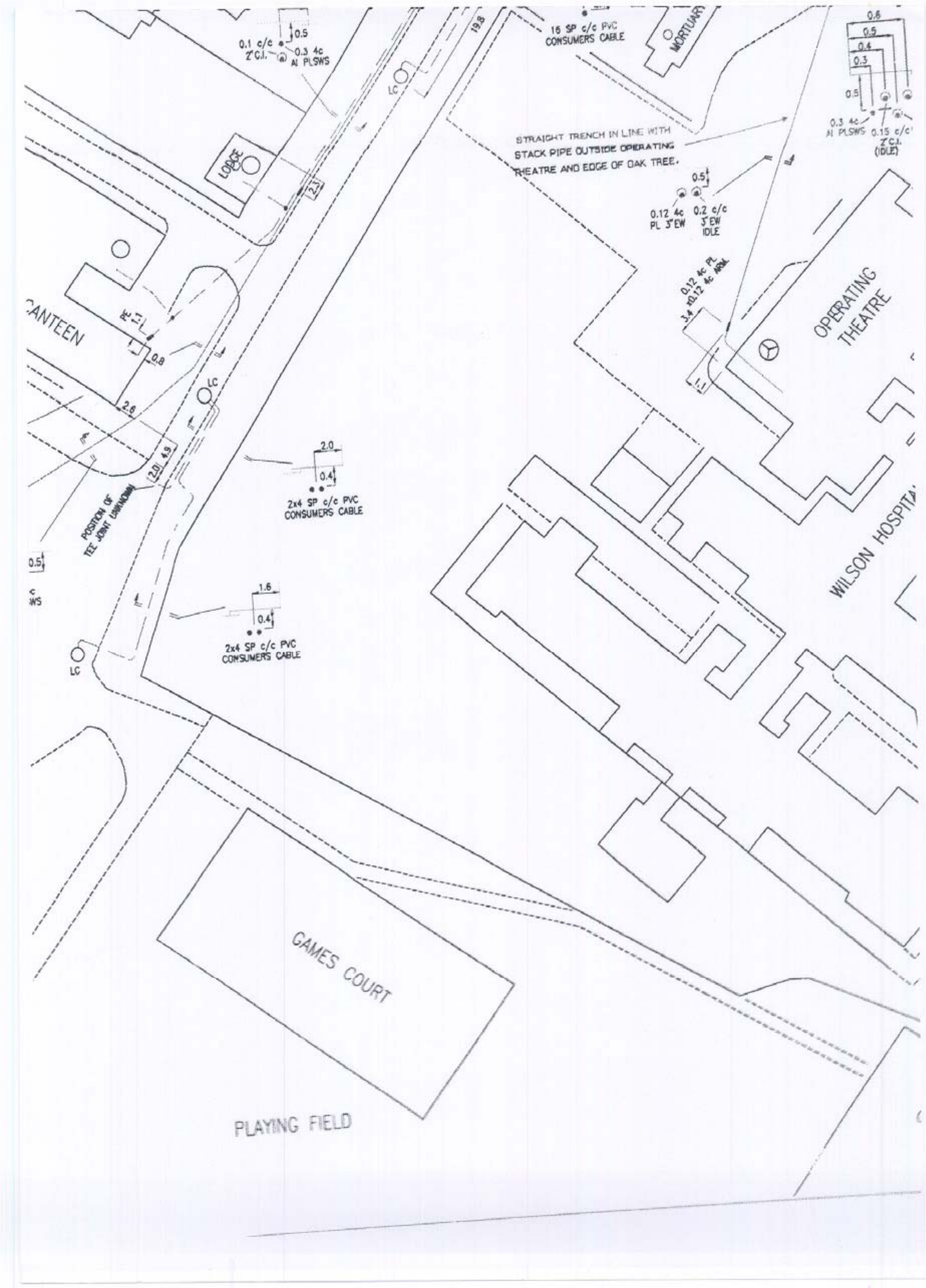
Electricity Maps – Source: EDF Energy Microfilm



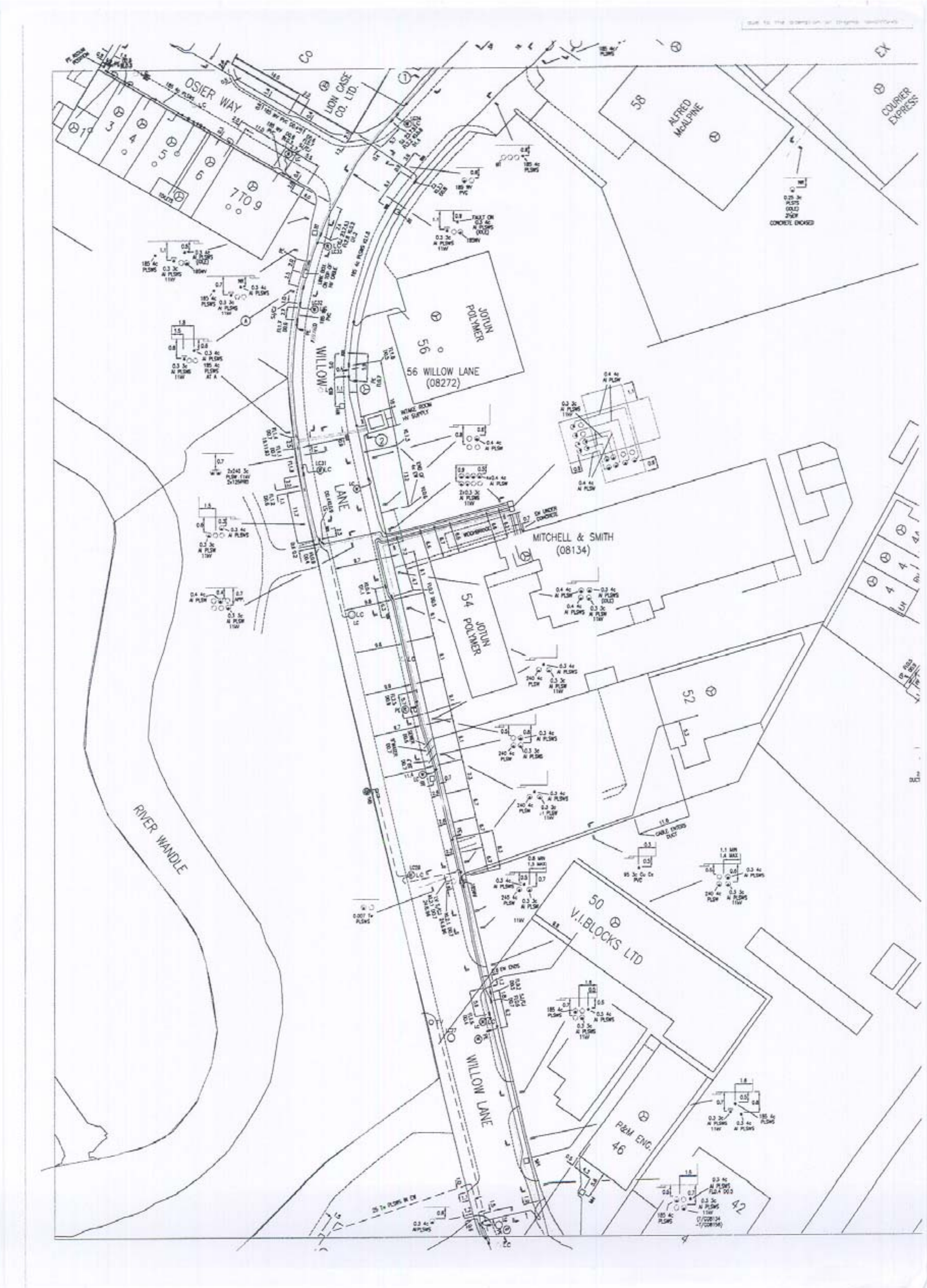


2768-16
It should be recognised that cable depths shown on this map may be unreliable as the ground level may have changed since the cables were installed and the relative position of cables may also have changed due to the alteration of original landmarks
London Electricity PLC
TENNIS COURTS
BOWLING GREEN
SPORTS
BOILER HOUSE
& SWITCH ROOM
THE CANONS
LEISURE CENTRE
GYMNASIUM
THE CANONS
15
14
17
16
POND
START OF DUCTS
MADIERA ROAD
GEORGE V AVENUE

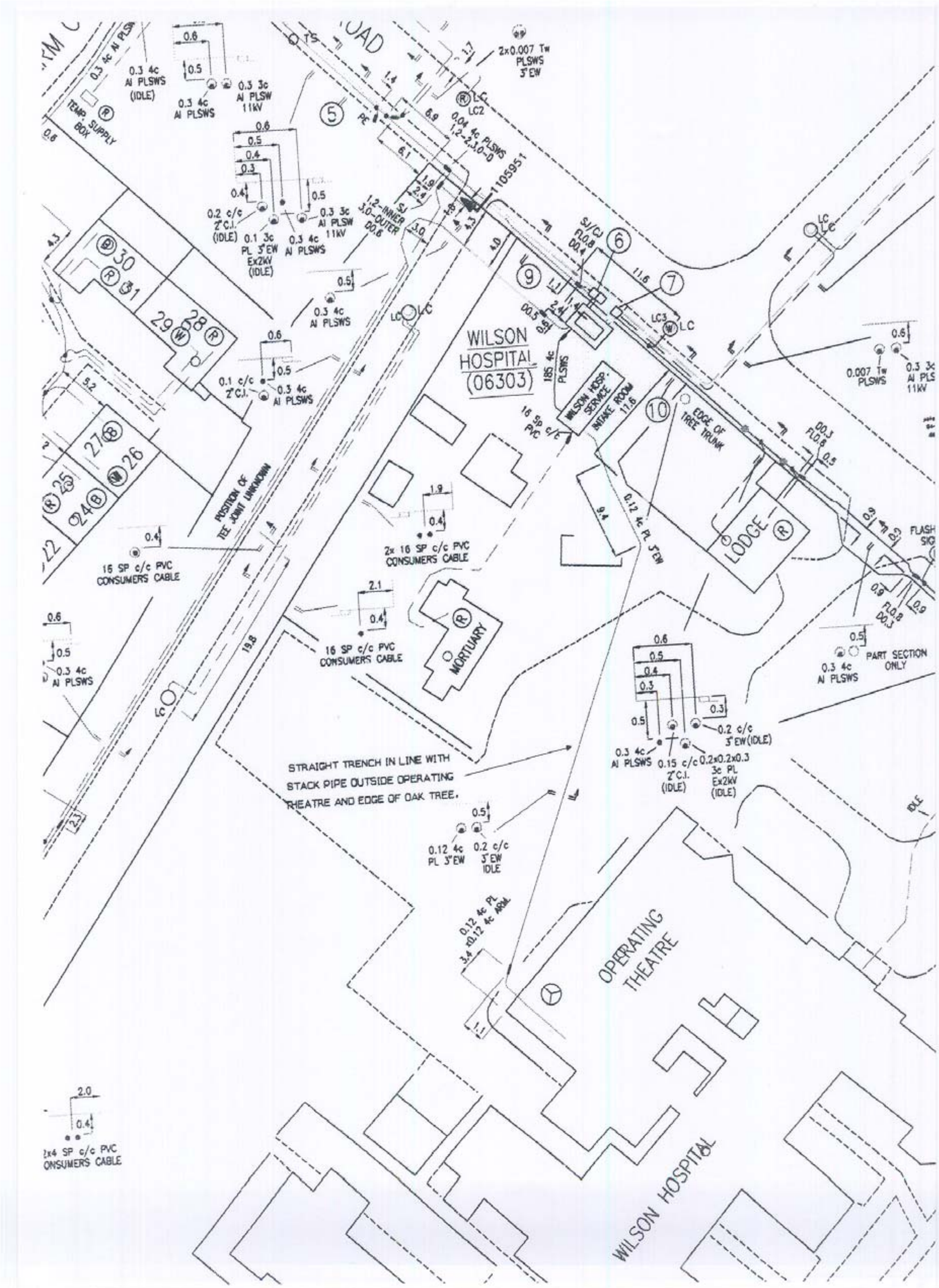

ST. PETER & PAULS RC CHURCH
THE PRESBYTERY
CRANMER FARM CLOSE (06941)
CRANMER FARM CLOSE
CRANMER ROAD
WILSON HOSPITAL (06303)
LODGE
STRAIGHT TRENCH IN LINE WITH STACK PIPE OUTSIDE OPERATING THEATRE AND EDGE OF OAK TREE.
SCHOOL CANTEEN
OPERATING THEATRE
WILSON HOSPITAL
GAMES COURT
PLAYING FIELD
GAMES COURT

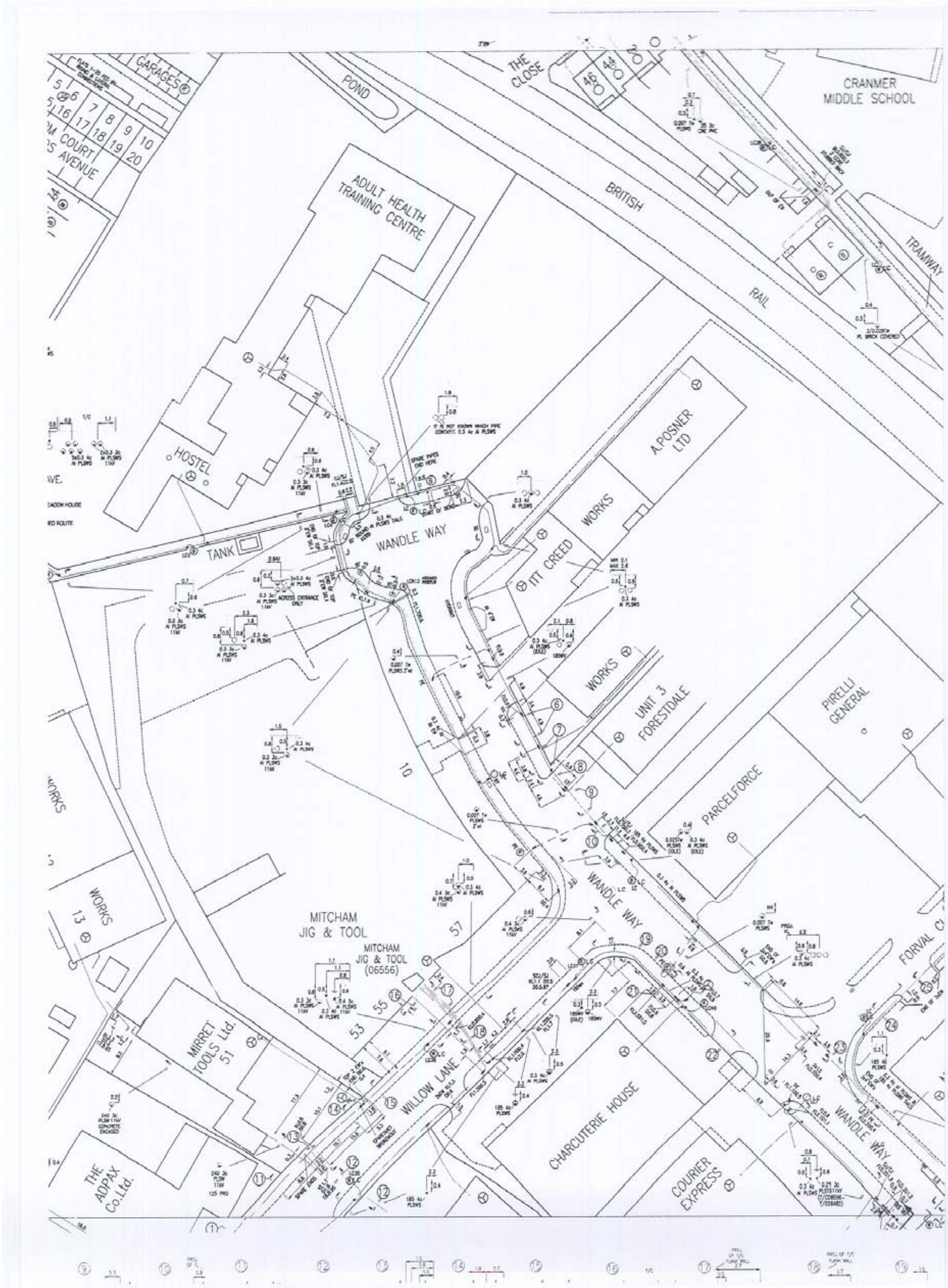


0.1 c/c
2"C.I.
0.5
0.3 4c
Al PLSWS
LC
19.8
16 SP c/c PVC
CONSUMERS CABLE
MORTUARY
0.6
0.5
0.4
0.3
0.3 4c
Al PLSWS
0.15 c/c
2"C.I.
(IDLE)
LODGE
2.1
STRAIGHT TRENCH IN LINE WITH
STACK PIPE OUTSIDE OPERATING
THEATRE AND EDGE OF OAK TREE.
0.5
0.12 4c
PL 3"EW
0.2 c/c
3"EW
IDLE
CANTEEN
PE
1.1
0.8
LC
2.6
OPERATING
THEATRE
1.1
2.0
0.4
2x4 SP c/c PVC
CONSUMERS CABLE
POSITION OF
TEE JOINT UNKNOWN
4.9
2.01
0.5
WILSON HOSPITAL
1.6
0.4
2x4 SP c/c PVC
CONSUMERS CABLE
LC
GAMES COURT
PLAYING FIELD



OSIER WAY
LION CASE CO. LTD.
58
ALFRED McALPINE
COURIER EXPRESS
7 TO 9
JOTUN POLYMER
56
56 WILLOW LANE
(08272)
WILLOW
LANE
MITCHELL & SMITH
(08134)
54
JOTUN POLYMER
52
RIVER WANDLE
50
V.I.BLOCKS LTD
WILLOW LANE
P&M ENG.
46
42


WILSON HOSPITAL (06303)
WILSON HOSP. SERVICE INTAKE ROOM
MORTUARY
LODGE
OPERATING THEATRE
WILSON HOSPITAL
STRAIGHT TRENCH IN LINE WITH STACK PIPE OUTSIDE OPERATING THEATRE AND EDGE OF OAK TREE.
EDGE OF TREE TRUNK
POSITION OF TEE JOINT UNKNOWN
TEMP SUPPLY BOX
16 SP c/c PVC CONSUMERS CABLE
2x 16 SP c/c PVC CONSUMERS CABLE
PART SECTION ONLY



GARAGES
COURT
AVENUE
ADULT HEALTH TRAINING CENTRE
POND
THE CLOSE
BRITISH
RAIL
TRAMWAY
CRANMER MIDDLE SCHOOL
HOSTEL
TANK
WANDLE WAY
ITT CREED
WORKS
A.POSNER LTD
WORKS
UNIT 3 FORESTDALE
PIRELLI GENERAL
PARCELFORCE
MITCHAM JIG & TOOL
MITCHAM JIG & TOOL (06556)
WORKS 13
MIRRET TOOLS Ltd. 51
WILLOW LANE
CHARCUTERIE HOUSE
COURIER EXPRESS
THE ADPAX Co.Ltd.
FORVAL

Appendix J: Insurance Policy

RISKS AND EXPOSURES	TYPE OF POLICY
1. Assets Temporary and permanent works (including buildings, machinery, plant) in the course of construction, erection or installation and while commissioning/testing.	CONTRACTORS' ALL RISKS
Loss or damage to buildings (including weatherproofing of roofs and/or external walls) due to an inherent defect in the aforesaid.	SEE OPERATIONAL PHASE (LATENT AND INHERENT DEFECTS)
Hired plant, equipment, temporary buildings which are the responsibility/risk of the contractor(s).	CONTRACTORS' ALL RISKS
2. Income Loss of future anticipated revenue, increased cost of construction and other financial losses caused by loss or damage to the works in the course of construction, erection or installation, but prior to completion.	ADVANCED PROFITS
Loss of future anticipated revenue caused by loss or damage to buildings (including weatherproofing of roofs and/or external walls) due to an inherent defect in the aforesaid.	SEE OPERATIONAL PHASE (LATENT AND INHERENT DEFECTS)
3. Liabilities Ensure professional advisers carry legal liability arising out of error or omission in the professional advice or designs undertaken by advisers to the project.	PROFESSIONAL INDEMNITY
Legal liability to pay compensation for death, injury, illness or disease, other than to employees, or property damage.	PUBLIC LIABILITY
Legal liability to pay compensation to employees for death, injury, illness or disease.	EMPLOYER'S LIABILITY

RISKS AND EXPOSURES	TYPE OF POLICY
1. Assets Buildings owned or for which you are responsible, including landlord's fixtures and fittings and tenants' improvements, external walls, fences, gates, landscaping, car parks, outbuildings, yards, machinery bases and underground services.	PROPERTY
Contents of the buildings, and machinery, plant and equipment, trade and office furniture, fixtures and fittings.	PROPERTY
Loss or damage to buildings (including weatherproofing of roofs and/or external walls) due to an inherent defect in the aforesaid.	LATENT AND INHERENT DEFECTS
Stock and materials in trade, work completed and in progress, customers and other goods in trust.	PROPERTY
Terrorism/subsidence.	OPTIONAL PROPERTY COVER
Leakage of sprinklers.	PROPERTY OR SPRINKLER LEAKAGE
Steam boiler and pressure plant explosion.	ENGINEERING
Accidental damage to or breakdown of computers including peripherals used in the production process or office. Also reinstatement of data, increased cost of working following breakdown or accidental damage.	COMPUTER
Machinery, plant and equipment hired in.	PROPERTY OR ENGINEERING
Breakdown of machinery and plant.	ENGINEERING BREAKDOWN
Property while in transit within the UK.	PROPERTY IN TRANSIT OR PROPERTY
Vehicles and plant and machinery, including those hired in, where Road Traffic Act cover is necessary.	MOTOR
Money at your own premises and in transit.	LOSS OF MONEY
2. Income Loss of gross revenue and additional cost of working following loss or damage to your property.	BUSINESS INTERRUPTION
Loss of gross revenue and additional cost of working resulting from breakdown/failure of machinery/plant.	ENGINEERING BUSINESS INTERRUPTION
Loss of future anticipated revenue caused by loss or damage to buildings (including weatherproofing of roofs and/or external walls) due to an inherent defect in the aforesaid.	LATENT AND INHERENT DEFECTS

RISKS AND EXPOSURES	TYPE OF POLICY
Loss of gross revenue and additional cost of working following loss or damage at suppliers' or customers' premises and failure of public utilities.	BUSINESS INTERRUPTION AND ENGINEERING BUSINESS INTERRUPTION EXTENSIONS
Reinstatement of data, increased cost of working etc. following computer breakdown or accidental damage.	COMPUTER BUSINESS INTERRUPTION
Unrecoverable outstanding business following loss of or damage to business records.	BOOK DEBTS AND COMPUTER BOOK DEBTS
Loss due to insolvency or failure to pay accounts due to default of customers to whom goods or services have been delivered or work done on credit terms.	CREDIT
3. Liabilities Legal liability to pay compensation for death, injury, illness or disease, other than to employees, or property damage arising from the business activities, the products/services provided or the premises occupied.	PUBLIC/PRODUCTS LIABILITY
Legal liability to pay compensation for death, injury, illness or disease to employees arising from the business activities.	EMPLOYERS' LIABILITY
Legal liability to pay compensation arising from pollution (other than sudden and accidental) – first and third party.	ENVIRONMENTAL IMPAIRMENT
Liability of directors and officers.	DIRECTORS' AND OFFICERS' LIABILITY
Legal liability to pay compensation arising out of libel or slander.	PUBLIC LIABILITY OR PROFESSIONAL INDEMNITY
Legal expenses of the company in defending or mounting an action.	COMMERCIAL LEGAL EXPENSES
4. Statutory Inspection Inspection of machinery, plant and equipment where periodic inspection is required by legislation or is advisable as good risk-management practice.	ENGINEERING INSPECTION
5. Some other considerations Death, injury and disablement benefits for key and/or all directors/employees following accident.	GROUP PERSONAL ACCIDENT COVER
Theft by employees (staff honesty).	FIDELITY GUARANTEE
Personal accident, medical and emergency expenses and travel assistance for employees travelling abroad.	BUSINESS TRAVEL

Source: GPG234

Appendix K: GeoReport Level Summaries

Retrieved April 14, 2005 from http://www.bgs.ac.uk/georeports/

Geological assessment — basic

This report is aimed at users carrying out preliminary site assessments or at people who have a general interest in the rocks around their property.

The report describes the rock types that might be encountered at the surface or at 'rockhead' beneath a site (meaning the rocks lying directly beneath the soil layer). It also briefly considers mining and quarrying hazard, and contains a listing of the key geoscience data sets held in the National Geoscience Data Centre for the area around the site (same as included in the separate Geoscience data list report). The report **does not**, however, consider natural geological hazards (in particular natural subsidence and radon), the concealed (buried) geology, or hydrogeology at the site (these are described in the standard or detailed geological assessment reports, available separately).

Geoscience data list	£ 23.75
Geology map extracts	£ 23.75
Natural Ground Stability	£ 50
Water borehole prognosis	£ 198
Geological assessment basic	£ 155
Geological assessment standard	£ 235
Geological assessment detailed	£ 376

Geological assessment — standard

This report is aimed at users carrying out preliminary site assessments, who require a brief indication of the geology and any related geological hazards around the site.

In addition to the features included in the basic geological assessment, the standard report also considers natural ground stability and includes a sketch cross-section of the site (showing how the various rock layers relate to each other). Colour geological maps extracts, taken from the BGS 1:50 000 scale digital geological map of Great Britain (as included in the separate geology map extracts report), are also provided.

Geological assessment — detailed (Report Recommended)

This report is aimed at users carrying out preliminary site assessments, who require a comprehensive assessment of the geology, hydrogeology and any geological hazards around the site.

In addition to the features included in the basic and standard geological assessments, the detailed report also considers radon hazard (in terms of the level of radon protection required in new dwellings) and the detailed hydrogeology of the site.

Appendix L: Recommendations Summary Table

Topic	Recommendation
CHP Specifications	
Load Assessments	• Perform detailed load assessment • Consider Domestic Hot Water and District Cooling applications
CHP Plant Identification	• Identify most effective CHP plant type to match load
Distribution System Assessment	• Determine distribution system specifications to deliver heat and power
Construction	
Trenching Technology	• 900 mm x 900 mm trench, preferred method for open ground
Trenchless Technology	• Assess in case by case basis particularly for railway crossing and road and infrastructure crossings
Safe Digging	• Use HSG47 and comply with CDM regulations
Route Considerations	
Utility Map Surveys	• Use locating devices to map subsurface utilities
Crossing Tramline	• Assess all details for avoiding tramline disruption • Negotiate with Tramlink
Marketing Route	• Look into bringing buildings along route into the heat and power network as a way of gaining their support
Best Practices	• Continue pursuing best practice information from other successful CHP networks such as the Borough of Woking
Environmental Impact	• Complete an EIA • Assessment for contamination of sites (Willow Lane and Wilson Hospital) • Develop reinstatement plan for vegetation
Noise	• Obtain and conform with BSI 5228
Archaeology	• Obtain site assessment from English Heritage
Geology	• Obtain GeoReport from British Geological Survey
City Knowledge	• Develop system for adding new reports and assessment data into GIS for future reference

Appendix M: Timeline for Project (D Term 2005)

Task	March 14	March 21	March 28	April 4	April 11	April 18	April 25
Archival Research							
Schedule Interviews							
Interviews							
On-site Investigations							
Organize Data							
Analyze Data							
Recommendations/Conclusions							
Final Report	I, B, M	(I, B, M), R	M, R, A	All	Full draft	Final draft	Final

Weekly meeting with Advisors
Monday 6:00pm at IES

Weekly meeting with Sponsor and Advisors
Wednesday 2:00pm at Merton Civic Center

Note:
Introduction = I
Background = B
Methodology = M
Results = R
Analysis = A
Conclusions and Recommendations = C

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