

BAE SYSTEMS Environmental

# Preliminary Risk Assessment For Land Contamination

Bishopton

Redrow Group & BAE Systems Property Investments Ltd

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# Preliminary Risk Assessment For Land Contamination

## Bishopton

## Redrow Group & BAE Systems Property Investments Ltd

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INVESTORS IN PEOPLE

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## EXECUTIVE SUMMARY

### Background

The former Royal Ordnance site in Bishopton is located to the south-west of Bishopton village in Renfrewshire, Scotland, approximately 15 km west of Glasgow City Centre. The Site occupies an area of approximately 1,005 hectares, centred on National Grid Reference NS 433 691.

BAE Systems Environmental was appointed as Remediation Consultant to undertake preliminary site investigations and develop an outline remediation strategy in relation to redevelopment of the Site.

This document presents the findings of the first stage of the investigations - the Preliminary Risk Assessment for Land Contamination (PRALC), or 'desk study'.

The history and environmental setting was determined by desk-based research, interviews with factory employees and visual inspection of the Site. The initial research carried out in 2002 was updated and reinterpreted for this issue of the report.

### History

Georgetown, a WWI munitions filling factory, occupies the southern part of the Site, now predominantly wooded. The Royal Ordnance factory was built in WWII over much of the remainder of the Site for the manufacture of military gun and rocket propellant, and tetryl. Propellant production involved the manufacture of nitroglycerine, nitrocellulose and nitric and sulphuric acid.

The factory subsequently diversified into a number of related activities including: manufacture of RDX, picrite, ball powder, lead salts and ammonium perchlorate; breakdown of surplus ammunition; filling of munitions with white phosphorus; and environmental testing of ordnance. The factory ceased manufacturing in 2002.

### Geology, hydrogeology and hydrology

In the central and southern part of the Site bedrock is formed by Carboniferous sandstones, limestone and coal measures. Higher ground to the north is underlain by volcanic rocks also of Carboniferous age. Glacial till directly overlies bedrock and outcrops primarily on higher ground. Soft glaciomarine silts and clays underlie the flat-lying central and southern areas, and there are substantial outcrops of peat within the Site boundary.

Groundwater has been encountered at shallow depths in previous investigations (1-2m bgl). Shallow groundwater flow is anticipated to be towards nearest surface watercourses. Groundwater within Volcanic formations is likely to be negligible. Groundwater may however be present within sedimentary formations.

The majority of the Site is in the surface water catchment of Dargavel Burn which flows through the centre of the Site from north-west to south-east.

## **Potential contamination sources**

The PRALC has identified a number of potential contamination sources largely resulting from the industrial use of the Site. These relate mainly to previous manufacturing operations, raw materials storage, product storage and handling, waste storage and handling, and wastewater management. The key contaminants anticipated to be associated with such sources has also been assessed and include heavy metals, explosives, asbestos, oils and solvents. The possibility of explosives devices and fragments (propellant) being present has also been identified. These sources have been recorded, along with potential pathways and receptors in the new development, to produce an initial Conceptual Site Model (CSM).

## **Preliminary risk assessment**

The preliminary risk assessment has identified the potential for land contamination to exist at the Site and that there is a potential for this contamination to cause harm to human health, property and the water environment. As land contamination is a material planning consideration, then recommendations have been provided to investigate whether these sources exist, and if so, if they are at concentrations that could cause harm or pollution (based on the proposed redevelopment landuses). Further information is also required in order to confirm pathways as existing and to further characterise them, particularly with regard to the water environment.

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## **1. INTRODUCTION**

### **1.1. Instruction**

BAE Systems Property Investments Ltd. and Redrow Group entered into a legal agreement in relation to the redevelopment of the former Royal Ordnance site in Bishopton.

Under the agreement, on 15 June 2004 BAE Systems Property Investments Ltd. appointed BAE Systems Environmental (a trade name of BAE Systems Properties Ltd.) to act as Remediation Consultants for the project.

The scope of this commission was to undertake preliminary site investigations and develop an outline remediation strategy.

### **1.2. Background**

The former Royal Ordnance factory in Bishopton ceased production in 2002 and proposals were prepared by BAE Systems (the owners) and Redrow (development partner in the project) to bring the Site back into beneficial use. It was proposed to regenerate and remediate the Site using redevelopment as the enabler.

The regeneration plan for the Site includes mixed-use development including residential, commercial, employment, community and recreational open space end uses.

In view of the Site's 80 year industrial history, it was considered that remediation would be required in order to make the Site suitable for its proposed next use(s). In addition, land contamination is required to be assessed and appropriately addressed as a material planning consideration.

It is therefore necessary to present a remediation strategy to support the application for outline planning for the redevelopment. In order to gain sufficient information to develop the strategy, it is necessary to conduct preliminary investigations.

### **1.3. Scope and Objectives**

A phased approach to the investigation of land contamination was considered appropriate and agreed with Renfrewshire Council Environmental Services and SEPA.

The first phase of the assessment is the Preliminary Risk Assessment, the purpose of which is to develop an initial conceptual site model (CSM) and establish whether there are any potential pollutant linkages at the Site. This report presents the findings of the Preliminary Risk Assessment.

The Preliminary Risk Assessment was commissioned originally by Royal Ordnance (now BAE Systems Land Systems) in 2002, when the initial research was carried out. The assessment has since been updated to include newly acquired information and made to comply with recent guidance and good practice.

The Site's history and environmental setting was determined by documentary research, interviews with factory employees and visual inspection of the Site. The

types of documents consulted included: British Geological Survey information, regulatory authority data, factory plans and publications, historical maps and photographs, previous site investigations, and other documents from local and national archives. References are provided in Appendix 7.

Interviews were undertaken with a number of factory employees in 2002, and in subsequent years further information has been provided to BAE Systems Environmental by factory employees and others.

Visual inspection of the Site was conducted between 28th February and 11th April 2002 over a period of 16 days. Relevant observations made since 2002 have also been included in the report.

The scope of the assessment is described in more detail at the beginning of the appropriate section of this report (sections 3.1, 6.1 and 7.1).

This document contains summaries of information relevant to the Preliminary Risk Assessment and does not comprise a comprehensive record of the substantial volume of information collected.

#### **1.4. Report Layout**

Section 2 describes the Site. Sections 3 and 4 details the geology, hydrogeology and hydrology, Section 5 describes the Site surroundings, and Section 6 gives an outline of the historical development.

Based on an assessment of the activities carried out at the Site, potential contamination sources are given in Section 7.

Section 8 presents the initial conceptual site model based upon all the information gathered through our researches.

#### **1.5. Reporting Conditions**

A preliminary risk assessment can only indicate the potential for contamination to be present on the Site. It aims to highlight potential pollutant linkages in line with current industry guidance.

The report refers to the conditions present at the Site at the time of the study.

It should be noted that BAE Systems Environmental has relied on the accuracy of information contained in external documents and provided by third parties, and is in no circumstances responsible for the accuracy of such information or data supplied.

This report has been specifically prepared for the purposes stated in Section 1.3 and, therefore, should not be used for any other purpose without prior consultation with BAE Systems Environmental.

This assessment considers the risk posed to receptors that are introduced to the Site as part of the proposed development. Previous investigations (referenced in Appendix 7) suggest that land contamination at the Site poses no significant risk to human health in its current use.

## 1.6. Limitations

Like many industrial sites, there is the potential for unrecorded and/or unauthorised activities that have not been discovered by this study.

Responses from regulatory authorities have been assumed to be complete and accurate.

There are a number of gaps in the historical record, in particular for the period shortly after WWII.

The recollections of factory employees have been used to determine the recent history of the Site, but these have been confirmed by documentary evidence, where possible.

BAE Systems Environmental has made best endeavours to establish issues of potential concern relating to land contamination. A large volume of information exists relating to the Site, and this has been used to produce what it believes to be a comprehensive assessment.

## **2. THE SITE**

### **2.1. Site Location**

The Site is located to the south-west of Bishopton village in Renfrewshire, Scotland, approximately 15 km west of Glasgow City Centre, centred on NGR NS 433 691. The term 'Site' refers to land owned by BAE Systems at Bishopton, as shown in Figure 1.

### **2.2. Site Description**

#### **2.2.1. Site Setting**

The Site is roughly rectangular in shape and occupies an area of 1,005 hectares (ha). The Site is bounded to the east by the Glasgow to Greenock railway, to the south by the B790, to the west by Turningshaw Road and Reilly Road and to the north by an unnamed road between the A8 and Formakin Mill.

The land surrounding the Site is predominantly agricultural, being a mix between arable, pasture and woodland. Bishopton village is adjacent to the north-east boundary.

The centre and south of the Site is generally flat lying at between 5 and 15 metres above Ordnance Datum (m.AOD). The land rises steeply in the far north and north-west of the Site to elevations of around 60 m.AOD.

The Site and its immediate surroundings are shown on the Site Plan presented in Figure 2.

#### **2.2.2. Georgetown and RO Bishopton**

Some 779 ha of the Site is fenced off and contains the former Royal Ordnance factory. The 226 ha area of land between the factory fence and the Site boundary is predominantly tenanted arable or pasture land except for Barochan Moss, a large area of afforested peat.

Georgetown, a First World War (WWI) munitions filling factory, occupies approximately 195 ha in the southern part of the Site. The vast majority of buildings associated with the Georgetown factory were demolished shortly after the Second World War (WWII) and the area is now predominantly wooded.

The Royal Ordnance factory was built around WWII over much of the remainder of the Site and also occupies the northern part of Georgetown. The major function of the factory was the production of military gun and rocket propellant, and was in use until production ceased in 2002.

For the most part the factory comprises explosives process buildings and magazines, spread out between areas of grass and patches of woodland. Areas of larger, more closely spaced buildings are associated with nitrocellulose (NC), acids and picrite production, and the administration and maintenance departments.

The majority of explosives buildings are protected by 'traverses', usually comprising mounds of soil adjacent to the building. In some areas the traverses have been created by utilising existing topography

Few areas within the factory fence have not been utilised for production or other purposes. A notable exception is the densely wooded area between the Environmental Test Facility (ETF) and the picrite lagoons.

Parts of the factory have not been used for up to 60 years. These 'legacy' areas include numerous derelict buildings that remain in place or have been demolished to slab level. Legacy buildings are also scattered within production sections that have been operational in recent years.

Royal Ordnance Factory (ROF) Bishopton was originally built as three largely independent factories commonly known as Factories I, II and III. Each factory contained a number of production areas or 'sections', that are used to identify discrete units. These sections are commonly abbreviated, for example NG II is Factory II Nitroglycerine Section, NC I is Factory I Nitrocellulose Section.

A Factory Plan identifying the locations of the principal production sections and other features referred to in this report is provided in Figure 3. Further details of the various factory activities is provided in Section 6.5.

### **3. GEOLOGY AND HYDROGEOLOGY**

#### **3.1. Sources of Information**

British Geological Survey (BGS) publications relating to the geology and hydrogeology of Bishopton have been examined and are listed in the References in Appendix 7. Extracts of the Solid and Drift Geological Maps and a generalised geological cross section of the Site based on the published geological maps are provided in Figures 4 and 5. Extracts of the Hydrogeological Map and Groundwater Vulnerability Map are presented in Figures 6 and 7.

Geological information is also provided by a number of site investigations that have been carried out at the Site, as referenced in Appendix 7. Boreholes and trial pits have been excavated for geotechnical purposes, to install groundwater monitoring points, and as part of site investigations for potential contamination. They are summarised in the following table.

#### **3.2. Made Ground**

Made ground is known or suspected to be present in significant thicknesses at a number locations within the Site. Outside the Site boundary, substantial areas of made ground are associated with Reilly Quarry and Southbarr landfill sites (see Sections 3.5 and 7.6).

The principal areas of made ground are listed below and, to avoid repetition, are discussed in detail in other sections of this report.

- Boghall dump and the nearby vegetation tip (see Section 7.4.2)
- Boiler ash disposal areas (Section 7.4.3)
- Picrite lagoons (Sections 7.4.4)
- Sulphur dump (Section 7.4.5)
- Miscellaneous areas of buried waste (see Section 7.4.8)
- Areas of historical mineral extraction (see sections 3.5 and 7.4.9)

Thinner layers of reworked natural material and construction fill are likely to be present associated with buildings, roads, railways and areas of hardstanding. Buildings in parts of the factory appear to have been constructed on raised ground either to provide a level surface or to raise their floors above often waterlogged ground. The latter is particularly apparent in the northern part of the Gun Propellant Section of Factory III.

Mounds surrounding most process buildings and magazines (traverses) can be considered made ground and probably comprise reworked natural soils.

Made ground will also be encountered adjacent to the slabs of some former buildings where the remains of demolished walls and roofs have often been left nearby.

The land between the factory fence and the Site boundary has remained agricultural and, therefore, made ground is not expected to be present in these areas. Notable exceptions to this are:

- the car park outside the main gate;
- former buildings and structures associated with the dwelling at Wester Rossland in the north-east of the Site;
- land near Ingliston Drive at the location of the former military camp;
- part of the former Georgetown factory to the west of the rail magazines; and,
- the strip of land in the far south-west of Georgetown where staff quarters and other buildings were located.

### **3.3. Superficial Deposits**

The combined thickness of superficial deposits varies considerably across the Site. Site investigations indicate that superficial deposits vary in thickness between 0 and 10 m around the northern perimeter of the Site. Towards the centre of the Site the thickness of superficial deposits is in excess of 15 m, and in the south the depth to bedrock may be greater than 40 m in places.

Although the general picture is one of thickening superficial deposits towards the centre of the Site and to the south, it can be seen that the concealed bedrock surface is very uneven. Buried steep sided ridge and valley features exist in the centre of the Site.

It should be noted that boulders and cobbles in the glacial till may have obstructed drilling and, if incorrectly identified, may have lead to underestimates of total superficial deposit thickness.

The geological maps indicate the Site to be underlain by superficial deposits comprising glacial till, glaciomarine and glaciofluvial strata, recent intertidal deposits, and peat. Each lithology is discussed in turn in the following sections.

#### **3.3.1. Wilderness Till Formation**

Glacial till of the Wilderness Till Formation forms a mantle of irregular thickness over the entire Site, except where bedrock is at the surface. Over the majority of the Site the glacial till is overlain by younger superficial deposits, predominantly the Linwood Formation and Paisley Formation. The Wilderness Till Formation is present at the surface of the Site in areas of high ground such as: Gladstone Hill; the high wooded ground to the east of the Picrite Section; Barochan Hill; Factory II NG; and, the slight promontory in Factory I Gun Propellant

In the regional area the deposits generally consist of infrequent boulder, cobble and gravel sized rock fragments in a matrix of sandy clay. Colour varies between brown, reddish brown and grey depending on the parent strata. Minor features noted in nearby BGS boreholes include bands and pockets of medium sand and laminated clay bands.

At the Site the glacial till has been described as stiff and very stiff, brown, sandy clay with much fine to coarse sub-angular gravel of sandstone, limestone, mudstone, coal, basalt and dolerite. The presence of cobbles and boulders within the glacial till often inhibited drilling.

Atterberg limit tests indicate the soil to be an inorganic clay of low plasticity. Undrained shear strengths calculated from laboratory samples and in-situ tests ranged between 100 and 400 kilopascals (kPa) indicating a range of firm to very stiff soils. The soils were found in the laboratory to be of low to very low compressibility.

The thickness of the Wilderness Till Formation is usually around 5 to 10 m, but varies considerable and is likely to be strongly controlled by surface topography and fluctuations in the underlying bedrock surface.

### **3.3.2. Glaciomarine and Glaciofluvial Deposits**

Quaternary strata overlying the glacial till are predominantly comprised of silts and clays of the Linwood and Paisley formations. Sand and gravels of the Killearn and Broomhouse formations form isolated outcrops.

#### **Linwood Formation and Paisley Formation**

Silts and clays of the glaciomarine Linwood Formation are present in varying thicknesses beneath the flat-lying parts of the Site. These are underlain by deposits of the Paisley Formation that are of a similar origin and lithology.

The Paisley Formation is likely to be present beneath much of the Linwood Formation. The two formations are not easy to distinguish between and have not been differentiated in site investigation boreholes.

The Linwood and Paisley formations are a sequence of silts and clays with rare gravel, black sulphide bands, shells and vegetative matter. Where observed in exploratory holes at the Site the deposits have been described as very soft and soft, dark grey or grey/brown sandy silts and clays, occasionally laminated, with a little gravel.

Geotechnical testing has been carried out as part of several site investigations at the Site. A detailed evaluation of their geotechnical properties was made for the preliminary geotechnical investigation (BAE Systems, 2003).

The silts and clays were found to be very soft and highly compressible. Drilling equipment often sank under its own weight and conventional undisturbed sampling was not possible. Hand shear vane tests indicate shear strengths in the order of 10 to 20 kPa. Several samples possessed moisture contents in excess of their liquid limit.

The geotechnical characteristics of these deposits were found not to vary significantly with depth, although a slightly stiffer crust was present within 1 to 2 m of the ground surface.

The thickness variation of the Linwood and Paisley formations follows a similar pattern to combined superficial deposits thickness, although these formations are generally absent where bedrock is within 10 m of the surface.

In Georgetown the soft silts and clays were found to be up to 28 m thick where the base of these deposits was proved. These strata thin towards the picrite lagoons where subsequent investigations indicated around 5 to 15 m thickness.

### **Killearn Formation and Broomhouse Formation**

Glaciofluvial sand and gravels of the Killearn Formation are shown on the Geological Map to form 4 No. small isolated outcrops overlying the Linwood Formation. These are located at Factory II Nitroglycerine (NG) Hill, the centre of Factory I, north of Factory I NC/Acids Section and on the promontory between Reilly Quarry and the main burning ground.

The western part of Factory II NG Hill is shown on the Geological Map to be formed by sand and gravel of the Broomhouse Formation. This Formation is older than the surrounding Linwood and Paisley Formations and, if the deposits have been correctly attributed to the Broomhouse Formation, they must extend some distance laterally and vertically underground (forming a relatively steep sided mound shape), and directly overlie the Wilderness Till Formation.

Neither formation has been observed in exploratory holes at the Site and their thicknesses are not known.

### **3.3.3. Recent Deposits**

#### **Erskine Formation**

Published data indicates the thin strip of land between the B790 and the River Gryfe is formed by marine intertidal deposits of the Erskine Formation. These strata have not been observed in site investigations at the Site but are described in the literature as soft to firm, brownish grey, very silty clay with sand and silt laminae, and contain sulphide bands. The thickness of the Erskine Formation is not known.

#### **Clippens Peat Formation**

Extensive accumulations of peat are present in two areas of the Site. The first, Barochan Moss, is a wooded area in the west, within the Site boundary but outside the factory fence. The second forms a wide strip of land parallel with the south-eastern boundary of the Site covering the north-eastern part of Georgetown, the picrite lagoons and most of the surrounding woodland to the west.

Observations of the peat have been made during site investigations. The peat generally comprised very soft dark brown or orange/brown spongy fibrous peat with recognisable plant remains (branches, twigs, roots) and a distinct sulphurous odour.

Typical thicknesses ranged from 0.5 to 1.5 m with the base of the peat generally occurring at between 1.5 and 3.0 m.bgl.

Boreholes drilled around the factory perimeter road (BAE Systems, 2002) indicate that the peat of Barochan Moss extends inside the factory fence and attains thicknesses of up to 4 m.

Undisturbed samples of peat are difficult to obtain and in-situ tests often fail. It can be assumed that the peat is of low strength and highly compressible.

### 3.4. Bedrock

Previous site investigations carried out at the factory generally did not encounter bedrock. The methods used were designed to investigate the made ground and superficial deposits, and where bedrock was encountered it was generally only proven at the base of boreholes.

Bedrock beneath the Site has been inferred from published geological maps and memoirs which generally rely on information from a relatively small number of deep boreholes and rock outcrops in the vicinity.

Geological maps indicate the Site to be underlain by sedimentary and volcanic rocks of Carboniferous age. Structurally, the strata dip between 5 and 7° to the east and are intruded by igneous dykes, also of Upper Carboniferous age.

The Upper Carboniferous strata are displaced by a number of predominantly east-west trending faults. The Blythwood Fault runs through the centre of the Site and has a downthrow to the south of approximately 70 m. The Northbrae Fault throws up rocks of the Clyde Plateau Volcanic Formation at the location of Reilly Quarry and the promontory between the Quarry and the main burning grounds. Numerous north-west to south-east trending faults displace the volcanic rocks to the north-west of the Site.

Each geological unit is discussed in the following sections.

#### 3.4.1. Clyde Plateau Volcanic Formation

The oldest rocks beneath the Site are olivine-basalt lavas of the Clyde Plateau Volcanic Formation. These rocks generally form high ground in the area and are present beneath the western part of Factory III, the high ground north-west of Factory I, and the promontory to the west of the main burning grounds. There are scattered surface outcrops in these areas.

Individual lava flows are reported to be generally between 1 and 10 m thick in the vicinity of the Site. An outcrop of the Clyde Plateau Volcanic Formation in Reilly Quarry shows that the rocks are crystalline and massive except for the upper margins of the flows which are vesicular (i.e. contain largely unconnected ellipsoidal cavities). Jointing is reported to be poor and those apparent in Reilly Quarry are likely to have been a result of blasting during quarrying activities.

#### 3.4.2. Lawmuir Formation

Bedrock underlying the remainder of Factories I and III, the northern part of Factory II, and Barochan Moss, are from the older Lawmuir Formation, comprising a thickness of between 20 and 150 m of interbedded sandstones and mudstones with coal and limestone horizons.

There are a number of marine mudstones and limestones with associated coal seams within the upper part of the Formation. The Hollybush Limestone outcrops in the far west of the Site, with the Lady Anne Coal, which is up to 0.66 m in thickness, lying some 12 m above this stratum. The Balckbyre Limestone, Hurllet Coal and Alum Shale lie close to the top of the Lawmuir Formation. The Hurllet Coal attains a thickness of up to 1.5 m and has been mined to the east of Bridge of Weir and near Howwood.

### **3.4.3. Lower Limestone Formation**

The Lower Limestone Formation largely consists of dark grey mudstones with sequences of sandstones, limestones and coals, the mudstones often containing thin ironstone bands. These strata underlie the southern part of Factory II and Georgetown.

The Formation is given its name by seven limestone bands, although only two of these are more than 1 m thick. The Hurlet Limestone marks the base of the Formation, varying in thickness between 1.7 and 12.7 m, and outcrops at depth in the south-west of the Site. The Blackhall Limestone varies in thickness between 0.45 and 1.9 m and outcrops in the central southern part of the Site. The Main Hosie and Top Hosie Limestones outcrop towards the east of the Site, the latter marking the top of the Formation.

Two thin (less than 0.35 m) and discontinuous coal seams occur below the Blackhall Limestone, and the Lillie's Shale Coal occurs beneath the Top Hosie Limestone. The latter seam is understood to have been worked in the past. Ironstones are abundant around the Blackhall Limestone.

### **3.4.4. Limestone Coal Formation**

The Limestone Coal Formation outcrops beneath superficial deposits near to the south-eastern tip of Georgetown and predominantly comprises mudstones with sandstones, ironstones and coal seams.

### **3.4.5. Upper Carboniferous Igneous Intrusions**

The sediments are intruded by two Upper Carboniferous sub-vertical quartz-dolerite dykes running approximately east-west, around 20 to 30 m wide at the surface. An exposure of this dyke is present in Reilly Quarry and shows no open joint system. The southern-most igneous intrusion runs in a line from Reilly Quarry, beneath the main boilerhouse and Picrite Section, to Barrangary. The second dyke runs in a line between Boghall Tip and the main Administration building (No. 18/001).

## **3.5. Mineral Extraction**

### **3.5.1. Superficial Deposits**

Clays and sands have been worked in many small-scale excavations in the region. Some of the larger clay pits in the local area are those associated with Dargavel (formerly Gladstone) Brick Works which operated until the early 20<sup>th</sup> Century (see Appendix 1). The main excavations later became Dargavel Ponds A, B and C to the south of the Administration Building.

Clay excavations were opened in the southern part of Southbarr prior to construction of the landfill site (see Section 0). Historical maps indicate that railway sidings associated with this pit extended into the Georgetown area up to the early 20<sup>th</sup> Century (see Appendix 1).

A brickfield (an area of shallow clay workings) covering an approximate area of 0.25 ha was in existence in the mid 19<sup>th</sup> Century (see Appendix 1), 100 m north-west of the former dwelling known as East Glenshinnoch. This is now in the area of building No. 28/183 that housed a gun propellant screw extruder.

Historical maps indicate that sand was worked from a natural mound, later the site of Factory II Nitroglycerine Section to the south-east of Dargavel House around the same time as the brick works. Two small sand pits, each less than 20 m in diameter, are marked at the approximate locations of building No. 24/205B (Dynamite Preparation House) and building No. 24/218B (Mixed Acid Storage Tanks).

### **3.5.2. Upper Carboniferous Igneous Rocks**

Historically, rocks of the Clyde Plateau Volcanic Formation were extracted from small quarries scattered to the north and west of the Site including pits at Barbeg Hill, Formakin Mill and Gatehead.

Only Reilly Quarry was subsequently worked to any great extent. Initially, rocks from the quartz-dolerite dyke were quarried then the excavation was extended into the surrounding olivine-basalt lavas. Excavation proceeded to the south-west from the northern access road. The rock was used as aggregate during the construction of the Erskine Bridge and its approach roads, and the void subsequently filled with waste (see Section 7.6.1).

### **3.5.3. Coal**

The Limestone Coal Formation is the principal local source of coal and has been extracted in numerous workings in the Paisley area. The nearest large-scale colliery is indicated on a map dated 1898 located near Walkinshaw, 1.2 km south-east of the Site. The colliery is marked as being disused by the early 20<sup>th</sup> Century.

A Coal Authority Report was commissioned during the Georgetown Desk Study (RO ESG, Apr. 1996).

The report indicates that, at the time, the Coal Authority did not possess any records of past or present underground mining that could affect the Georgetown area, and also stated that there were no plans to conduct any underground mining in the vicinity in the future. The Coal Authority stated that there are no records of any mine entries beneath Georgetown and there are no records of any land subsidence due to mining in the vicinity. The report stated that Georgetown does not lie within 200 m of any current opencast sites, and it is not proposed to mine coal by opencast methods in the future within 800 m of Georgetown.

Although the report is specific to southern part of the Site, the strata underlying the northern areas are considered even less likely to have been worked than those in the vicinity of Georgetown. The situation with regard to plans for future coal mining in the vicinity of the Site is unlikely to have changed since the report was commissioned in 1996.

## **3.6. Hydrogeology**

### **3.6.1. Groundwater Observations**

During the Georgetown investigation (RO ESG, Oct. 1996) groundwater was generally encountered as shallow seepages within made ground, peat or the upper horizons of the Linwood Formation at depths between 1.0 and 4.5 m.bgl. Deeper groundwater was struck in the upper part of the glacial till in borehole GT3 at 24.1

m.bgl. A groundwater strike at the top of the Lower Limestone Formation in borehole GT14 at 21.9 m.bgl rose rapidly to within 1.4 m of ground surface.

The area surrounding the picrite lagoons has been subject to a number of groundwater investigations which generally conclude that groundwater flows at shallow depth radially away from the lagoons.

Boreholes drilled in the Picrite Section were often dry (RO ESG, Jan. 1996). In one borehole groundwater was struck at 10.8 m.bgl in glacial till, rising to 8.6 m.bgl on completion of the borehole.

Groundwater was encountered in around half the monitoring wells installed along the perimeter of the factory (BAE Systems, 2002). Shallow strikes were generally recorded at the base of made ground or peat where it overlay the Linwood Formation or glacial till. Water was found on encountering bedrock in two boreholes. The majority of groundwater strikes were reported within the Linwood Formation or glacial till but, during drilling, groundwater level rises (within 20 minutes) were generally small.

Observations made in the nearby Reilly Quarry indicate that the Clyde Plateau Volcanic Formation has negligible permeability. It is understood that no seepages were evident in the quarry sides and there was no evidence of an open joint system.

### **3.6.2. Groundwater Movement**

Groundwater flow is likely to be dominantly local and shallow. The majority of rainfall infiltrating into the ground probably flows relatively short distances to nearby watercourses in perched groundwater bodies in the made ground, peat and the Linwood Formation. Due to the general low permeability of the superficial deposits, and the fact that groundwater in the bedrock appears to be confined, the proportion of water able to migrate to deeper strata may be limited.

Sporadic strikes made within the Linwood Formation and Wilderness Till Formation indicate bodies of perched groundwater, some partially confined by overlying material. The strikes also suggest the possibility of preferential pathways in the clay deposits.

### **3.6.3. Groundwater Use**

The Hydrogeological Map of Scotland (BGS, 1988) indicates that the Clyde Plateau Volcanic Formation falls into the category of 'impermeable rocks generally without groundwater except at shallow depth'. The superficial deposits are categorised 'aquifers of limited or local potential' and the Carboniferous sedimentary rocks as 'highly productive aquifers (not extensive)' in which 'flow is dominantly in fissures and other discontinuities'.

An extract of the Hydrogeological Map is presented as Figure 6.

The Groundwater Vulnerability Map of Scotland (BGS, 1995) classifies the Clyde Plateau Volcanic Formation as 'weekly permeable' and the Carboniferous sedimentary rocks as 'moderately permeable'.

An extract of the Groundwater Vulnerability Map is presented as Figure 7.

Historically, groundwater has been used widely in the vicinity of the Site, particularly to the north and west. Wells were associated with numerous farms and other dwellings in the area, including at least 6 No. within the Site boundary before the development of the factory. These local supplies are likely to have been reliant on low yields from the superficial deposits and/or the upper horizons of bedrock. Higher yields may have been possible where wells intercepted fractured bedrock or coarse grained superficial deposits such as those found beneath Factory II Nitroglycerine Section.

Many of these wells would have become disused with the construction of reservoirs and improvements to the water supply network, and only a handful appear to be in existence today. A system of abstraction licences is not operated in Scotland so the continued use of these wells is not known. The wells indicated on historical maps to be within the Site boundary are no longer used.

Further afield, groundwater from the Carboniferous Lower Limestone Formation, Limestone Coal Formation and Upper Limestone Formation has been abstracted in the central Glasgow area. Yields were as high as 10 litres per second (l/s) where wells intercepted mine workings in the Limestone Coal Formation. Groundwater in these strata is understood to have been of poor quality containing high concentrations of iron, sulphate and dissolved methane. Gradual pollution of supplies led to their abandonment in the late 1980s.

#### **3.6.4. Groundwater Quality**

Samples of groundwater have been analysed as part of the investigations of Georgetown, the picrite lagoons, the burning grounds and as part of a routine monitoring programme from 2002.

The principal issues of concern have been associated with the picrite lagoons, discussed in Section 7.4.4. A number of samples have had high metals concentrations, but this is thought to be linked to the suspended solids content of the samples.

## **4. HYDROLOGY**

### **4.1. Rainfall**

Long term average rainfall charts for Glasgow Airport (years unknown) indicate total rainfall to be an estimated 991 mm/year, potential evaporation 587 mm/year, and effective rainfall 509 mm/year.

### **4.2. Drainage Characteristics**

#### **4.2.1. Surface Water Flow**

Dargavel Burn flows from north-west to south-east parallel with the long axis of factory. Along the Burn's course it is joined by numerous ditches, drainage pipes, former process water drains and small streams, some of which emanate from outside the factory boundary.

Dargavel Burn rises from a spring near Barscube Hill and flows for approximately 2 km before entering the Site at Nethermill. It runs for approximately 6 km inside the Site boundary before leaving at the southern tip of Georgetown.

Along its course, Dargavel Burn is joined by a number of tributaries including Craigton Burn which rises in Erskine. Upstream of its confluence with Dargavel Burn, Craigton Burn receives Cordite Burn which takes surface water and, formerly, process effluents from most of Factory I. The Picrite Drain starts near the picrite lagoons and enters Dargavel Burn in Factory II.

Under a legal agreement between BAE Systems and Tarmac, treated surface water from Reilley Quarry is discharged into Dargavel Burn within the Site boundary. The discharge enters the Site near the former Northbrae gate and joins Dargavel Burn upstream of the main burning grounds.

Dargavel Burn enters the River Gryfe at the southernmost tip of Georgetown which, in turn, enters Black Cart Water 0.8 km to the south-west. Black Cart Water joins White Cart Water 4.5 km east of Georgetown flowing north for 1 km before entering the Clyde Estuary. The Clyde Estuary is 1.2 km from the Site boundary at its closest point.

The lowest reaches of Dargavel Burn are affected by the tide, the Normal Tidal Limit being located at the crossing of the B790.

All land inside the Site boundary lies within the surface water catchment of Dargavel Burn, with the possible exception of land to the east of the picrite lagoons which may contribute to flow in ditches around Southbarr Landfill Site. Water in these ditches flows into Lin Burn then to the River Gryfe 0.3 km downstream of the entry of Dargavel Burn.

Certain areas of the factory flood regularly, notably the eastern part of Georgetown.

Dargavel Burn is partly diverted at an intake east of Boghall Tip to the three Dargavel Ponds. Overflow is returned to Dargavel Burn via Craigton Burn which flows between the ponds. When the factory was at its height of production, water in Dargavel Ponds was used extensively for process cooling water and fire-fighting.

The River Gryfe was used as a source of water for the Georgetown factory and was piped to the RO factory up until the 1970s.

The general surface water drainage pattern within the Site boundary can be seen on the Factory Plan presented in Figure 3.

#### **4.2.2. Surface Water Flow Measurements**

The nearest gauging station on the River Gryfe is at Craigend, approximately 4 km upstream of the Dargavel Burn entry. There are no significant confluences on the Gryfe between these two points. The long term (35 year) mean flow at this point is 3.8 cubic metres per second (m<sup>3</sup>/s), with a 95th percentile low flow of 0.24 m<sup>3</sup>/s.

The flow in Dargavel Burn is not routinely monitored. In July 1982, an exceptionally dry summer month when virtually all the water in the Burn was diverted to Dargavel Ponds, Crouch and Hogg (1983) measured flows as low as 5 l/s. The average and wet weather flows in Dargavel Burn are not known.

In the past the flows in individual ditches and process drains were strongly linked to the volumes of process effluent. In dry months up to 70% of the flow leaving the factory in Dargavel Burn was a process effluent.

### **4.3. Surface Water Quality**

#### **4.3.1. Dargavel Burn and Tributaries**

During and immediately after WWII, Dargavel Burn was treated as an industrial drain into which factory effluents were discharged with limited treatment. A study in 1943 showed that the effect of acid effluent was to reduce pH in the Gryfe at times to 1.8 and in Black Cart Water to 2.3. The pH in Dargavel Burn ranged between 1.4 and 2.5 and would not have supported significant aquatic life at this time. Of more concern at that time was the loss of an estimated 20 tonnes of sulphuric acid each day into Dargavel Burn and the implications for factory productivity.

Developments in acid recovery processes and a scaling down in production led to the improvements shown by a survey in 1958. Samples of Dargavel Burn were taken upstream and downstream of the factory and were found to differ in pH on average by less than half a unit (ranging between 6 and 7), although this is rather improbable given that there was little if any treatment of acidic effluent at this time.

In the early 1980s, at a time when production had increased and environmental protection legislation was being implemented, great concern was expressed by Clyde Rivers Purification Board (CRPB). It considered that the 'grossly polluted' and 'practically sterile' Dargavel Burn was having a detrimental effect on the River Gryfe, into which salmon had returned.

As a result of CRPB's concern, a study on effluent disposal was commissioned (Crouch and Hogg, 1983) which included chemical analysis, toxicity testing and documentary research into potential effluent treatment strategies. The study identified the most serious pollution problems to be as follows:

- Very low pH effluent from the nitrocellulose and acids sections.
- Effluent containing toxic concentrations of nitroglycerine from Factory I.

- 'Red water' (TNT derived effluent) from the Ammunition Breakdown Section.
- Effluent with high solid content (NC and latex) from the Combustible Charge Container (CCC) Section.
- High concentrations of lead in Dargavel Burn and the River Gryfe probably originating from nitrocellulose, nitroglycerine and lead salts sections.
- Ammonia rich effluent from the picrite lagoons and low pH effluent from the Picrite Section.

In 1983 the factory was still a Crown Establishment and the RO Board were not obliged to act on Crouch and Hogg's recommendations. Two years later RO was privatised and became subject to the full rigors of rapidly developing environmental legislation. As a result, many of Crouch and Hogg's proposed effluent treatment strategies were subsequently put into practice, including sodium hydroxide neutralisation plants in the nitrocellulose and picrite sections.

In 1986, discharge consents were issued by CRPB for the sewage treatment works, NG II (temporary), Cordite Burn (covering NC I, Acids and NG I), Picrite Drain, White Phosphorus Section/boiler house and CCC Section. Specific conditions attached to the consents were varied over the years to reflect changes in process characteristics. A further discharge consent was issued later for the Lance Missile decommissioning project.

From the late 1980s until the mid to late 1990s factory production sections experienced difficulty in complying with the new discharge consents. Breaches of limits for pH, nitrite, nitroglycerine, sulphate and suspended solids were commonplace, particularly at the Cordite Burn, Picrite Drain and the sewage treatment works consent points.

For example, prior to installation of the effluent treatment plant, the NG limit was continually exceeded at the Cordite Burn consent point, and often at the sewage treatment works. Concentrations were normally in the range 1 to 10 mg/l compared with a consent condition of 0.7 mg/l. A value of > 1000 mg/l was reported on 20th March 1990.

During this period there are a number of recorded incidents relating to the Integrated Pollution Control authorised processes - nitrocellulose, nitroglycerine, picrite and, to a lesser extent, the boilerhouse. Most relate to uncontrolled discharges to controlled waters due to leakages and plant breakdown.

In the late 1990s and early 2000s the frequency of consent breaches reduced significantly due to improvements in effluent treatment and the scaling down of manufacture. In 2000 the Scottish Environmental Protection Agency (SEPA) relaxed various discharge conditions to reflect this. With the exception of the sewage works discharge, all consents relating to the Site have now been cancelled and monitoring by SEPA has ceased.

In June 1999 a benthic macroinvertebrate study carried out by SEPA concluded that the factory as a whole no longer had a significant effect on Dargavel Burn. Biological Monitoring Working Party (BWMP) scores indicated excellent (A1) biological quality upstream of the factory and good (A2) biological quality

downstream at the River Gryfe. The survey also highlighted that the quality of Craighton Burn was significantly affected by the inflow of Cordite Burn.

Selected analytical data for Dargavel Burn at its confluence with the Gryfe between January 2000 and May 2002 (14 No. samples) are summarised in the following table.

Parameter	Units	Min	Mean	Max
Alkalinity as CaCO <sub>3</sub>	mg/l	49	74	95
BOD	mg/l	1.0	1.7	2.4
Chloride	mg/l	16	29	62
Conductivity	µS/cm	193	379	869
Total hardness as CaCO <sub>3</sub>	mg/l	84	99	114
Ammoniacal N	mg/l	0.04	0.08	0.15
Nitrite N	mg/l	0.01	0.16	0.59
Nitrate N	mg/l	1.3	6.1	27.3
Dissolved O <sub>2</sub>	mg/l	8.4	10.4	12.4
Suspended solids	mg/l	4	12	44
pH	units	6.6	7.5	8.0

**Table 1 – SEPA data for Dargavel Burn downstream of the Site**

At present, for classification purposes SEPA regularly monitor the chemical quality of Dargavel Burn upstream of the Site at Formakin. Based on the latest published data (2004) the Burn is classified as A2 (good).

#### 4.3.2. River Gryfe

Since the construction of the Gryfe Valley Sewer and the closure of a number of sewage works along its length, the River Gryfe has become a relatively clean river with no major polluting discharges. The River is now an important habitat for salmonid fish and sea trout.

Based on the latest published data, the Gryfe is classified as A2 (good) upstream and downstream of the Dargavel Burn confluence.

## 5. SITE SURROUNDINGS

### 5.1. General

The surrounding land is predominantly agricultural, a mixture of arable, pasture and managed woodland. The nearest population centres are Bishopton (adjacent to the north-east boundary) and Houston (1.5 km to the south-west). The Site is bound to the east by the Glasgow to Greenock railway.

Glasgow Airport is situated to the south-east approximately 1.5 km from the Site boundary. Inchinnan Business Park is located 1.2 km to the east and contains various light industrial and commercial premises.

Further details regarding Reilly Quarry and Southbarr landfill sites, and areas of designated land are provided later in this section.

The Site surroundings are shown on the Site Location Plan and Site Plan presented as Figures 1 and 2.

### 5.2. Ecological/Archaeological Designations

There are no statutory designations within the Site. The following areas of land in the vicinity of the Site have been identified as having local or national designations on account of their ecological value. Formakin, Black Cart Water and the Inner Clyde are Sites of Special Scientific Interest (SSSIs). The remaining areas are designated Sites of Importance for Nature Conservation (SINCs) in the local plan (2004), some of which are within the Site.

Location	Designation	Description	Distance from Site
Formakin	SSSI	Lowland grassland	0.5 km
Black Cart Water	SSSI	Icelandic whooper swans	0.7 km
Inner Clyde	SSSI	Wintering wildfowl	1.2 km
Barrangary Woods	SINC	Woodland	0.1 km
Linwood Moss	SINC	Peat deposits	1.0 km
Woodland surrounding the picrite lagoons	SINC	Woodland	on Site
Barochan Moss	SINC	Woodland and mire	on Site
ROF Bishopton	SINC	Woodland, scrub and grassland	on Site
Land west of Formakin	SINC	Not known	0.5 km
Castlehill plantation and Whitemoss dam	SINC	Not Known	0.5km
Land around Reilly Quarry	SINC	Not known	on Site
Crosslee Strip	SINC	Riverside habitat with fossil exposure	2.0 km

**Table 2 – Ecological designations**

The Roman Fort at Barochan Hill adjacent to the western boundary of the Site is a Scheduled Ancient Monument. Formakin Estate is also a Historical Landscape.

## 5.3. Waste Disposal Sites

### 5.3.1. Reilly Quarry Landfill Site

Waste Management Licences for the disposal of waste in Reilly Quarry (see also Section 3.5.2) were issued to WH Malcolm in 1991, 1996 and 1999. In 2002 the site covered an approximate area of 8 ha and the quarry floor was at approximately 20.7 m.AOD.

The permitted wastes have not changed significantly since the first licence was issued and principally comprise soil, brick, crushed concrete and rubble. In 2002 the following wastes were permitted for disposal in admixture with soil or rubble, not to exceed 5% of total waste input: plasterboard, asphalt, bitumen, coated roadstone, wood, sawdust, paper, cardboard, ceramic, glass, bonded asbestos, plastic, metal and shredded tyres. Polychlorinated biphenyls (PCBs) and polychlorinated triphenyls (PCTs) were permitted at concentrations less than 50 milligrams per kilogram (mg/kg).

Between 1998 and 2000 waste input rates were 150,000 to 200,000 tonnes/year. In 2000, an additional 100,000 tonnes of waste was recycled at the site.

The site has been divided into 4 No. phases, each designed as a containment cell with a 1 m thick,  $1.0E-09$  metres per second (m/s) permeability, reworked clay basal and side-wall liner, and an engineered cap. Landfill gas management is passive. Leachate is actively abstracted and treated in settlement/aeration lagoons located in the northern part of the site. Chemical treatment is available and its use is dependent on the results of leachate analysis. Surface water from the base of the quarry is discharged through the Site to Dargavel Burn (see Section 4.2.1).

Methane is not normally reported in perimeter gas monitoring wells; carbon dioxide concentrations generally vary between 1 and 8%.

Historically, SEPA inspection reports indicate that mud on the access road, steep sided flanks, and not covering asbestos waste are the principal concerns with regard to compliance with the Waste Management Licence.

Quarrying and landfilling is continuing at the site. The final restoration plan is for woodland and amenity uses.

### 5.3.2. Southbarr Landfill Site

Waste disposal at the former mineral extraction site at Southbarr (see also Section 3.5.1) began in the early 1980s and is now closed and restored. The Waste Management Licence held by WH Malcolm is still current.

Permitted waste types did not change significantly over the lifetime of the landfill and included exactly those permitted for Reilly Quarry Landfill, with the same conditions attached. The design of the landfill cells are not known but it is understood that the older phases to the south of the site did not incorporate a basal liner. Leachate is collected and directed to treatment lagoons prior to discharge into surface watercourses. Landfill gas management is passive.

In total, there have been seven phases of tipping resulting in over 500,000 tonnes of waste deposited at the site. Tipping phase Nos. 1 to 4 (in the area previously

used for tipping) operated until March 1999, receiving approximately 1,500 tonnes per day of non-hazardous industrial waste. During this time peat extraction was reported to have been carried out, with stripped areas being infilled with waste. However, alternative anecdotal information suggests that not all of the peat was removed before filling.

Amongst issues such as debris on the access roads and the burning of cables, SEPA have also been concerned with outbreaks of leachate in the south-eastern part of the site. In the past, strong hydrogen sulphide-like odours have been detected in the factory at the boundary of the landfill site.

An environmental report for 2000 indicated that methane was not usually detected above 0.1% in perimeter monitoring boreholes. Carbon dioxide concentrations were generally less than 1.5% but with isolated readings of up to 5.3%. Manganese, iron and ammonia were viewed to be the prevalent species in leachate with maximum concentrations of 4.39, 34.7 and 12.0 mg/l respectively. The report identified upstream and downstream differences in iron concentration thought to be caused by the outbreak of leachate into the southern ditch.

Leachate described as having a 'hydrogen sulphide' odour was noted from phase No. 5 on 22<sup>nd</sup> January 1990. Foul smelling leachate was noted in the ditch on 9<sup>th</sup> May 1991 and 5<sup>th</sup> June 1992. Phase No. 5 was closed in July 2002.

On 13<sup>th</sup> September 1990 an application was lodged for phase Nos. 6 and 7 and additional tipping in phase Nos. 1, 2, 3 and 5. The application included a request for the tipped area to increase in height from 6 to 14 m. The area it was planned to extend into was described as 5.73 ha of scrub woodland, 4.95 ha of agricultural field and 1.89 ha of another agricultural field. As part of the application 5 No. boreholes were drilled for the purpose of recovery of soil samples. Made ground was not encountered. Soft clay and silt was found to a depth of 19.3 m underlain by a silty sand to at least 19.9 m depth. The groundwater level was recorded as 3.35 m below ground level

The landfill closed and was restored to productive agricultural use in 2003.

## **6. HISTORICAL DEVELOPMENT**

### **6.1. General**

The history of the Site and surrounding area has been examined in order to establish the nature and location of potentially contaminative operations that have been conducted in the past and to identify hazardous materials used during such operations.

Sources of information include, but are no limited to, the following:

- Ordnance Survey maps and Royal Ordnance factory plans.
- Royal Ordnance records such as building ledgers, yearbooks and process method manuals.
- Local and national libraries.
- Aerial photographs dated from 1939 to 2001.
- Historical photographs.
- Interviews with factory employees.
- Regulatory authority information.

A selection of the historical material consulted, such as maps and aerial photographs, are provided as appendices.

The industrial history of the Site can be divided broadly into two eras. The first is the construction of the Scottish Filling Factory (more commonly referred to as Georgetown) soon after the outbreak of WWI; the second is Royal Ordnance Factory (ROF) Bishopton, which was laid out in the early part of WWII.

### **6.2. Pre-Georgetown History**

A map dated 1863 (given in Appendix 1) shows that the Site was in an agricultural setting centred on Dargavel House, a B listed building that remains at the Site. Scattered farmhouses include Fulwoodmoss, West Fulwood, Hareshaw, Blackburn, North and South Crooks, Mosshall, East and West Glenshinnoch, Nether Mill, Easter Newton and Boghall. Some of these names were preserved as railway stations, roads and other features in the RO factory.

At this time, Bishopton village was a handful of houses situated at the crossing of the A8 and the Glasgow to Greenock railway, but was already served by a railway station to the south-east. The railway station was located next to a hamlet called Rosslan that was gradually absorbed by the expanding Bishopton village in the 1960s and 70s. The main administration building was the location of Gladstone House, with emerging excavations of the brick works to the south (see Sections 3.5.1 and 7.4.9).

The northern part of the Site was divided into numerous fields of between 1 and 5 ha in size. Field boundaries appear to have been formed by hedges, ditches, watercourses, paths and roads.

The two areas of peat, Barochan Moss and the north-eastern part of Georgetown, were not split into fields, probably indicating unsuitable ground for agriculture. Dargavel Burn, Craigton Burn and a number of smaller watercourses are shown to follow their present courses. Their 'straightness' in some places indicates that the courses were altered to improve field drainage, prior to development of the Georgetown and WWII factories.

In the late 19<sup>th</sup> Century, non-agricultural industry in the area included sawmills at Wester Fullwood (400 m south of the Armoured Fighting Vehicle (AFV) Depot) and Barochan House (300 m south of Barochan Hill), Formakin Corn Mill (100 m north of the Site), and a smithy in Bishopton village. In addition, numerous small quarries and pits were operated during this time (see Section 3.5). A 'mineral railway' and sidings likely associated with mineral extraction at Southbarr, appeared in north-east part of Georgetown in the late 19<sup>th</sup> Century.

Overall, very little development or change is shown inside the Site boundary until the construction of Georgetown and, later, the Royal Ordnance factory.

At least six buildings survived construction of the factories: Dargavel House (building No. 18/023); Ingliston House (25/127); Gladstone Cottage (20/009); Bolerno (20/008), Ditch (now 37/007A – Bishopton Works Department (BWD) Store) and a small building in Factory II NG Section used as plumber's workshop (37/046). The remains of dwellings at West Glenshinnoch, Wester Rosslund, Easter Newton and Boghall are still visible.

### **6.3. Site Surroundings from 1914**

Apart from the expansion of the village of Bishopton, there have been few significant developments within 500 m of the Site boundary since the construction of Georgetown in WWI.

Of the numerous small-scale mineral extraction sites in the local area, only Reilly Quarry and Southbarr expanded. Both were subsequently infilled with waste (see Section 7.6).

A small military camp was situated outside the factory fence in the north of the Site. Plans of the camp show approximately 25 No. rectangular buildings which appear to have been for accommodation or administrative use. The camp was present during WWII but was probably dismantled soon after. Part of the former Military Camp has now been built-over with housing.

The most rapid expansion to Bishopton village occurred between the 1950s and 1980s. A sewage works was constructed at the crossing of Craigton Burn by the railway line (30 m east of the Site) in the early 20<sup>th</sup> Century but was moved further north-east in the 1980s (to 150 m east of the Site). The M8 was constructed in the 1970s.

## 6.4. Georgetown

The principal source of information relating to operations at Georgetown is the comprehensive Official History of the Scottish Filling Factory (Ministry of Munitions of War, 1919). The Georgetown Desk Study for Potential Contamination (RO ESG, Apr. 1996) provides a summary of the history of the Georgetown factory. The relevant section is provided in Appendix 2 and should be referred to for further information.

Georgetown was originally conceived as a single factory but as demand for munitions increased during the First World War (WWI) a second factory was constructed to the west of Dargavel Burn. The original factory was known as No. 1 (Cartridge) Factory and the later facility became known as the No. 2 (Shell Filling) Factory. The two factories are easily visible in the bottom right of Plate 3.1 an aerial photograph dated October 1939. A plan showing the former layout of the factories is given in Appendix 2.

Production began at No. 1 Factory in 1916 for the filling and assembly of cartridges for Quick Firing (QF) and Breach Loading (BL) ammunition including those for 60 pounder (pdr.), 9.2" and 4.5" rounds. Later that year filling of 18 pdr. high explosive (HE) shells began. Operations included the filling and assembly of components such as primers, gaines, igniters and fuzes. Cordite, TNT and black powder were used in large quantities at the factory.

No. 2 Factory was designed for the filling of shells with Amatol, a mixture of TNT and ammonium nitrate, and subsequent assembly with fuzes, gaines and primers. Filled shells included 4.5", 8", 9.2" and 12" Howitzer, 60 pdr. shrapnel, 105 mm, 13 and 18 pdr., anti-aircraft, 3" anti-aircraft, and trench mortar bombs.

The factories were gradually wound down during 1918 and closed in November of that year, shortly after Armistice. Plans for the afteruse of the Factories included the establishment of a permanent Garden City but the scheme never came to fruition. The majority of buildings were demolished between the two World Wars and the area afforested.

(The Armoured Fighting Vehicle (AFV) Depot is a separately fenced-off part of the former Georgetown No. 2 Factory which was used in WWII as a staging post for American AFVs shipped in from Greenock (see Plates 3.2 and 3.3)).

## 6.5. RO Bishopton

### 6.5.1. Origins and Design of RO Bishopton

The purchase of land at Bishopton for the construction of a propellant factory was approved in 1937 after it was realised that the existing factories were vulnerable and would not meet demand if war broke out. The Bishopton site was favoured primarily for its proximity to abundant sources of labour and good quality water, but also because the Site's topography and climate were suitable for the manufacture of nitroglycerine.

Royal Ordnance Factory (ROF) Bishopton, designated ROF No. 32, was conceived as three self-sufficient factories, each of which would be able to continue to function in the event of an accident or enemy attack. Construction of ROF Bishopton began at the outbreak of WWII; many of the processes were closely modelled on those at

Royal Gunpowder Factory (RGPF) Waltham Abbey and Royal Naval Cordite Factory (RNCF) Holton Heath.

Unlike many of the ROFs where roads and buildings were set out in a regimented fashion, ROF Bishopton was laid out on an existing network of country roads, field boundaries and ditches. The courses of Dargavel Burn and Craighton Burn were not altered significantly, although smaller drains and streams were either realigned or piped underground to make way for buildings. Some existing ditches were converted to process effluent drains.

A Luftwaffe aerial reconnaissance photograph taken on 2<sup>nd</sup> October 1939 (Plate 3.1, Appendix 3) shows the north-easternmost factory to be almost complete and the southernmost factory under construction. These two factories were subsequently known as Factories I and II, respectively. Meanwhile, Factory III, the last to be constructed, is shown in the photograph to be pasture land. Factory I was in production by March 1940.

Each of the three factories had its own coal fired boilerhouse, nitroglycerine, nitrocellulose and acids sections. The NG sections were sited on existing promontories; NG I and III on rising ground to the north, and NG II on the natural mound to the south of Dargavel House. Mixing houses were sited near the base of the 'NG Hills' where NG was mixed with NC to form 'paste'. The paste was transferred after drying and breaking to sections of the factory where the propellant was extruded, cast or otherwise formed. Factory I was designed to have facilities for gun and rocket propellant, Factory II for rocket propellant, and Factory III for gun propellant.

It is reported that the factory was completed at a cost of £17M and included:

- 36 km of roads;
- 27 km of broad gauge railway;
- 121 km of narrow gauge railway;
- 40 km of steam mains; and,
- 27 No. substations.

The factory employed a total of 20,000 people during WWII.

### **6.5.2. General History of RO Bishopton**

After WWII, ROF Bishopton was retained as the principal producer of conventional military propellants eventually at the expense of ROF Wrexham, ROF Ranskill and Royal Naval Propellant Factory (RNPF) Caerwent that were built around the same time.

Post-war production was characterised by peaks and troughs. The factory almost closed after WWII but orders increased for the Korean War in the early 1950s. A drastic curtailment in activity was experienced in 1957 and production remained at a relatively low level until business picked-up in the 1970s as a result of the Cold War and large orders from the Shah of Iran. The late 1980s and 1990s saw the closure

of many production lines and the winding down of others during a period of considerable rationalisation. All production ceased in early 2002.

The factory had to continually respond to the changing requirements for munitions and, particularly in the late 1950s and 60s, sought to diversify to remain viable. Since large numbers of buildings were laid dormant after the WWII, plant for new production lines was easily accommodated. This has resulted in certain areas of the factory having had two or more uses during their history.

For example, when the factory was constructed the manufacture of high explosives was conducted in two tetryl sections, Tetryl A and B. During WWII minor changes to plant allowed the installation of Research Department composition 'X' (RDX) manufacturing facilities in both areas. Subsequently, RDX A became the location of the Picrite Section and RDX B was converted to Ammunition Breakdown.

Some of the buildings in the original Tetryl/RDX B Acids Section were used later as storage for the adjacent main burning grounds. It was often the case that redundant buildings and tanks were used as storage for nearby production sections.

The following sections summarise the historical development of the main production sections and include a brief outline of the processes involved. The location of each production section is shown on the Factory Plan in Figure 3.

### 6.5.3. Nitrocellulose

NC is a basic ingredient of all conventional gun propellants and most solid rocket propellants. NC was manufactured at Bishopton throughout the factory's operational lifetime.

NC is formed by the treatment of cellulose with a mixture of nitric and sulphuric acids. Two basic processes have been used for the manufacture of NC at RO Bishopton: 'mechanical' and 'displacement'. Originally NC was made by the 'displacement' process where cellulose is submerged in mixed acids and covered with water for the duration of nitration. At the end of the reaction the acid was tapped from the base of the tank, the water displacing the acid in the cellulose mass. The 'mechanical' nitration process involves the stirring of an acid and cellulose mixture.

Cellulose nitrated by either method was then stabilised by boiling in water to remove residual acid and passed through various centrifuge, washing, and pulping stages. These were designed to alter the fibrous structure of the NC, clean it and make the resulting slurry mildly alkaline. Process effluent, primarily comprising waste acid and suspended NC was directed to settling lagoons via particulate traps. Plate 4.1 in Appendix 4, dated 1944, shows the settling lagoons in Factory II that were later used for CCC effluent. Nitrocellulose was periodically excavated from the settling ponds and burnt at burning ground No. 16/007A.

Depending on the type of propellant, the source of cellulose for nitration was either cotton or wood-based paper. Nitrated cotton, or 'guncotton', was primarily used as the basic ingredient for gun propellants, although the semi-solvent gun propellants contained NC based on paper. NC for rocket propellants was based on paper.

Each of the three factories at Bishopton was equipped with NC manufacturing plants. The nitrocellulose section within Factory III ('NC III') was concerned with the

manufacture of guncotton. NC from Factory II was traditionally used in the adjacent Rocket Propellant Section. NC from both sources was manufactured in NC I.

In addition to being a necessary constituent for conventional propellants, guncotton was also formed into small blocks for military demolition purposes. Demolition guncotton was manufactured in Factory I until a few years after WWII. The manufacturing process involved moulding, pressing and drilling using acetone as a solvent, followed by dipping in phenol.

Nitrocellulose for double and triple based propellants was piped or bagged for transportation to each factory's mixing houses to be combined with nitroglycerine.

Nitrocellulose manufacture in Factories II and III discontinued shortly after WWII. Some of the buildings associated with NC manufacture in Factory III were demolished in the 1950s and 1960s and the area was subsequently put to a number of uses including ammunition storage and breakdown. NC II was mothballed and later partly converted to the production of combustible charge containers (CCCs) and for the filling of ordnance in the White Phosphorus Section.

After WWII, nitrocellulose production continued in Factory I. Initially, the original guncotton displacement plant situated in building Nos. 30/103, 105A and 106A was operated adjacent to a wood cellulose nitration plant (Nos. 30/503, 505 and 506) for the manufacture of semi-solvent propellants. The mechanical nitration plant, located adjacent to the guncotton section, was installed in the late 1950s with US funding. The new plant was soon dormant but was resurrected in the early 1980s for guncotton manufacture until the factory closure in 2002. Manufacture of nitrocellulose based on wood was phased out in the late 1990s.

Over the years many of the buildings made redundant by the closure of NC production lines were subsequently used for NC slurry storage and general storage.

In the 1990s an effluent treatment plant (building No. 25/165) was installed on Cordite Burn for the neutralisation of acid by dosing with sodium hydroxide.

In later years the nitrocellulose process was regulated by Integrated Pollution Control (IPC) (under The Environmental Protection (Prescribed Processes and Substances) Regulations 1991) which placed restrictions on emissions to the environment and requirements for regular monitoring.

Factory I NC Section is shown on Plate 3.4 in Appendix 3, an aerial photograph dated 1988.

#### **6.5.4. Nitroglycerine**

Four methods for the production of nitroglycerine have been operated at the factory, each entailing the controlled nitration of glycerine using a mixture of nitric and sulphuric acids; these are the Batch, Schmid, Biazzi, and Nillssen and Brunnberg (NAB) Injector processes.

An important consideration for the design of plant is the quantity of NG present in the process stream at any point in time. With each process improvement came a reduction in unit explosion risk. Quantities of NG in excess of 1,000 kg were handled during the Batch process whilst only approximately 100 kg was at risk

during the Biazzi process. Introduction of the NAB Injector process brought the quantity down to approximately 10 kg.

In all processes, nitration formed an emulsion of NG and waste acid. The NG was separated from the acid by several washing stages using water and sodium carbonate solution to neutralise the acid. A high proportion of waste nitration acid was re-concentrated in the acids sections and re-used for nitration.

NG was transported by gravity from the nitration houses at the top of the hills via elevated lead-lined gullies (later lined inside with plastic pipe), through the washing houses to the mixing houses where NG was combined with NC slurry to form a paste.

At each factory, effluent from the wash houses and mixing houses was directed via NG traps and save-alls to a circular clay-lined wash water pond. Periodically, an explosive charge would be detonated in the pond with the aim of removing any build-up of NG. Overflows from the ponds drained to surrounding ground.

An aerial photograph of NG II Hill dated 1988 (Plate 3.5, Appendix 3), shows the main NG production buildings in the centre of the photograph. Wash water ponds can be seen in the middle-left and top-right of the picture.

NG manufacture by the Batch process was carried out on nine hills during WWII, although parts of Factory III were never fully commissioned before becoming inactive shortly after the end of the WWII. Many of the buildings in Factory III were demolished in the 1960s.

Production of NG was scaled down after the War, and Schmid and Biazzi plants were introduced into Factories I and II to replace the more dangerous and cruder Batch process. For ten years until the mid 1950s NG was produced by the Schmid and Biazzi processes at various times in Hills A, B and C in Factory II and Hills A and B in Factory I. In the late 1950s all production was from the semi-automatic Schmid plant in Factory I Hill C whilst plans were drawn up for the installation of a remotely controlled Biazzi plant in Factory II Hill A. Factory I Hill A and Factory II Hill B were on stand-by.

An explosion in June 1960 destroyed the nitration and washing houses in Factory I Hill C. The Biazzi plant in Factory II Hill A was rushed into production and all paste production transferred to Factory II. Meanwhile, an automatic Biazzi plant was installed in Factory I.

In 1963 (and in the early 1980s) pilot studies were carried out to investigate the viability of manufacturing diethyleneglycol dinitrate (DEGDN) in Factory I and dynamite in both factories. Production of DEGDN never came to fruition but dynamite plants were installed in Factory I Hill A and Factory II Hill B, and were in production until the late 1980s.

In 1972 an explosion forced the temporary closure of the NG manufacturing plant in Factory I Hill B. Factory II was re-commissioned whilst Factory I was rebuilt and improvements made to paste mixing process. NG was manufactured in both factories intermittently throughout the 1970s and 1980s.

The NAB Injector system was installed in Factory I Hill B in 1987. Reduced demand and the need to install effluent treatment facilities for NG production led to the closure of Factory II in the late 1980s.

In later years nitroglycerine manufacture was regulated by Integrated Pollution Control (IPC) (under The Environmental Protection (Prescribed Processes and Substances) Regulations 1991) which placed restrictions on emissions to the environment and requirements for regular monitoring.

#### **6.5.5. Acids**

The manufacture of nitrocellulose, nitroglycerine, picrite, tetryl and RDX requires large quantities of nitric and/or sulphuric acid (mixed acid). Each of the three factories incorporated production sections where acids were manufactured, stored, and recovered after being used in the factory. An additional acids section was located adjacent to Tetryl/RDX B.

Sulphuric acid was manufactured in Factory II (near the Cathedral, building No. 34/270) until the late 1950s by the Contact Process. Elemental sulphur was burnt to produce sulphur dioxide which formed sulphur trioxide when mixed with dry air and a catalyst (normally vanadium pentoxide). The sulphur trioxide was then absorbed to form sulphuric acid. As well as being used at the factory, sulphuric acid was exported during the 'sulphur crisis' of the 1950s.

Nitric acid was manufactured intermittently for factory use and export until the mid 1980s. The Pressure Oxidation Process (POP) used anhydrous ammonia as a feedstock to form the acid. Ammonia was oxidised at high temperature and pressure over a platinum-rhodium catalyst, then further oxidised to nitrogen dioxide and hydrated to form nitric acid.

Compared to nitric acid, sulphuric acid takes a lesser part in nitration, its function being to absorb water produced during the reaction. After the closure of the manufacturing plant, sulphuric acid was recovered from the spent acids and stocks were topped-up by imports when necessary.

In 1964 an inhibited red fuming nitric acid (IRFNA) unit was transferred from ROF Pembrey to Factory I Acids Section and small quantities were manufactured for export, particularly to Rocket Propulsion Department (RPD) Westcott.

Factory I Acids Section is shown in the lower part of Plate 3.4 in Appendix 3.

#### **6.5.6. Gun Propellant**

Throughout the factory's operation, gun propellants have been the primary end product. Countless types of propellants have been manufactured during the factory's history, for many gun systems. Gun propellant was manufactured in Factories I and III.

Double and triple-based gun propellants were the most commonly produced. Double-based propellants contain NC and NG. Triple-based or 'flashless' propellants contain NC, NG and picrite.

The majority of gun propellants were 'solvent' propellants, as opposed to 'solventless' (mainly for rocket propellant) and 'semi-solvent'.

The manufacture of solvent propellant began at the base of the NG Hills. NG/NC paste from the mixing house was dried in trucks in the drying stoves and then broken into pieces in the paste breaking buildings. Carbamite (a stabiliser), picrite (for triple-based) and acetone (a solvent) along with other additives as required, were added with paste in the incorporators. Rotating blades in the incorporators mixed the various constituents into a dough which was then transferred to a press house.

Dough in the press cylinder was extruded into a spaghetti-like cord, normally between 0.2 and 5 mm diameter. The lengths were then cut to the required size – around 600 to 900 mm for stick propellants and 10 to 15 mm for granules – dependent on the type of gun propellant being produced. The propellant was dried over a period of a week or more to remove residual solvent and then blended and ‘lotted’ before packing and storage in magazines.

Very small diameter granules were required for certain small arms propellants and were produced in the screw presses.

The semi-solvent process was much the same, although dibutyl phthalate (a plasticizer) was added at the incorporator stage. The semi-solvent dough from the incorporator was pressed into ‘rough cord’, dried, and taken to a rolling mill in the Semi-solvent Section where it was rolled into sheets and cut into squares. The squares were pressed into a ‘charge’ before final extrusion by broadly the same methods as for solvent propellants. Drying, blending and lotting was carried out within buildings on the solvent propellant production line.

A high energy propellant containing RDX was manufactured by the semi-solvent process in addition to triple base propellants used by the Royal Navy. RDX was added in the paste mixing houses.

#### **6.5.7. Rocket propellant**

Solid rocket propellants were manufactured throughout the lifetime of Royal Ordnance Bishopton in Factories I and II. The Propellant Section in Factory II was designed solely for this purpose.

The process for the production of most conventional solid rocket propellants was similar to extruded gun propellants. The main difference was that the dried paste was gelatinised using heated rollers before extrusion into the required shape. Rocket propellants made by this technique were termed Extruded Double Base (EDB). The gelatinised sheets were extruded into cylindrical ‘grains’ of up to around 0.4 m diameter. The distinctive shape of the press houses in Factory II are shown in the lower part of Plate 3.5. Appendix 4.

Cast Double Base (CDB) propellants were manufactured between the 1960s and 1980s in Factory I. NC powder was poured into a cast followed by NG which was transferred by tank mixed with triacetin (which acted as a stabiliser) from the NG Section.

In addition to NC and NG, rocket propellants contained a number of substances added at either the paste mixing or in an incorporator stage. Details of these substances are given in Section 7.2.4. The extruded propellant ‘motors’ were often X-rayed, ‘inhibited’ by the addition of a sheathing (usually cellulose acetate) which adhered to the propellant, and then assembled into rocket motor hardware.

### 6.5.8. Tetryl and RDX

The factory was built to include two tetryl manufacturing plants; Tetryl A and B. Both plants were closed before the end of WWII and replaced with RDX manufacturing facilities. RDX A plant was in production for a few years before being removed and replaced by the Picrite Section in the early 1950s. RDX B is thought to have had a trial production run of only 6 weeks in 1945. Many of the buildings in RDX B were later used for ammunition breakdown.

Tetryl, predominantly used as a booster charge in high explosive ordnance, was manufactured at Bishopton by the nitration of dimethylaniline using sulphuric and nitric acids. The resultant mixture was washed to remove acid and the tetryl recrystallised in acetone.

RDX is a high explosive which saw extensive use in WWII particularly in a mixture with 40% TNT. RDX manufacture at Bishopton involved the nitration of hexamine by nitric acid then recrystallisation in a cyclohexanone solution.

RDX was mixed with TNT in RDX A (in buildings later used for storage of picrite) before packing and dispatch.

A decommissioning programme for both plants was implemented in the late 1950s (RO, 1957).

### 6.5.9. Picrite

Picrite, or nitroguanidine, is an energetic material that acts as a flash reducer when added to gun propellants. Propellants containing picrite (as well as NC and NG) are termed triple based propellants and commonly contain 55% picrite.

At Bishopton the first stage in the manufacturing process was the fusion of ammonium nitrate and dicyandiamide at high temperature to form guanidine nitrate flake. Dehydration of guanidine nitrate by reaction with sulphuric acid produces picrite. The picrite was separated from much of the waste acid, cooled, filtered, recrystallised and dried.

Waste sulphuric acid was neutralised by limestone (later by lime) and piped as a slurry to the picrite lagoons.

After 1993 waste acid was transported off-site for neutralisation and disposal due to concerns expressed by CRPB over the environmental impact of the lagoons (see Section 7.4.4).

The picrite plant superseded tetryl and RDX manufacture in the north-east of factory II. The first fusion plant (Picrite A) was in production in 1953 but soon became dormant through lack of orders.

A modified process ('Picrite B') was introduced into the Picrite Section in 1957 near the sulphuric acid manufacturing plant. The plant was installed into a new building, 'The Cathedral' (building No. 34/270), although the process was not a success and was soon left on stand-by. Plate 4.2 in Appendix 4 shows the Cathedral in 1958 shortly after construction. During the installation and testing of the Cathedral process, staff were withdrawn from Picrite A and the plant shut down.

Picrite A was rehabilitated in 1965 and the process ran until the factory's closure. The Cathedral was used for tank space and materials storage.

For around ten years from 1973 to the early 1980s, attempts were made to manufacture picrite from urea and silica gel that were more readily available than dicyandiamide.

In later years the manufacture of picrite was regulated by Integrated Pollution Control (IPC) (under The Environmental Protection (Prescribed Processes and Substances) Regulations 1991) which placed restrictions on emissions to the environment and requirements for regular monitoring.

#### **6.5.10. Ammunition Breakdown**

In 1959 items of plant were acquired from ROF Irvine and installed into modified and re-commissioned buildings in the redundant Tetryl/RDX B Section. By the end of the year approximately 27,000 tonnes of ordnance was being stored at the factory, primarily in the AFV Depot (see Plate 4.3 in Appendix 4) and on the slabs of former propellant buildings in Factory III.

In the 1960s and 70s tens of millions of devices were broken down in the Ammunition Breakdown Section. These included high explosive (HE) bombs, HE and pyrotechnic shells, incendiary bombs, mortars, large calibre tank and artillery ammunition, small arms ammunition, grenades, torpedoes, cartridges, fuzes, caps and primers.

Mechanical disassembly of devices was carried out primarily in the central area of the Section. Buildings in this area were dedicated to unpacking, de-cartridging, nosepiece removal, removal of primers and fuzes, and the preparation of devices for firing, burning, further breakdown or packing for off-site disposal.

RDX/TNT and Torpex were boiled out of HE ordnance in two buildings in the former tetryl acids section (building Nos. 43/408 and 43/304A) known colloquially as the 'Big Steamie' and the 'Little Steamie'. In the larger of the two buildings the red water effluent was directed to an external settling tank that was periodically emptied of sediment and the contents burned. After boiling-out, some shells were treated with white spirit to dissolve the bituminous lining.

In the early 1960s several hundred thousand incendiary bombs were broken down in the redundant Factory III NC Section. After inspection and de-clustering in building No. 25/301, barium nitrate was recovered from individual cluster bombs in 25/302 by a process involving heating, recrystallisation and centrifuging.

High explosive fillings were burnt on the main burning ground as well as burning grounds C and H (see also Section 7.4.1). Primers and fuzes were fired in building Nos. 43/322 and 43/307B. The explosive residues on shells and other metallic items were sent to burning grounds dedicated to scrap metal proving such as C, H and J.

After boiling-out, some ammunition (mainly 1,000 lb bombs and anti-submarine projectiles) were filled with lightweight concrete for use as training rounds.

## Lance Missile

The Lance Missile employed unsymmetrical dimethyl hydrazine (UDMH) and inhibited red fuming nitric acid (IRFNA) as a liquid propellant. Over time the interior of the missile body was prone to corrosion and required periodic refurbishment.

Between 1990 and 1993 Lance Missiles were refurbished in the redundant Factory III NC Section. The missiles were delivered to the factory without warheads. Refurbishment involved purging IRFNA from the missile body, flushing out the residual corrosive layer, re-naturing the IRFNA in tanks and re-filling the missile. A number of missiles to be used for training were filled with trichloroethene and mineral oil.

The recovery and re-use of IRFNA became difficult because of the presence of hydrogen fluoride, and the project was discontinued.

In 1995 work began on the demilitarisation of Lance Missile in the same area of the factory in which refurbishment had been carried out. The main process buildings were Nos. 80/004 – IRFNA Detank, and 80/005 – UDMH Detank. Acid effluent liquors were neutralised by sodium hydroxide in tanks placed in former ponds nearby (No. 80/006).

### 6.5.11. Ball Powder

Ball powder is a propellant for small arms ammunition and was manufactured at Bishopton by the Olin process. NC was mixed with ethyl acetate to produce a lacquer which formed globules when immersed in water. NG could be added at this stage to produce a double-based propellant. On heating, the solvent evaporated leaving balls of NC which were then passed through coating, rolling, de-coating, glazing and several drying stages. Diphenylamine was used as a stabiliser and added at the glazing stage (in the 'sweetie barrels').

The Ball Powder Section was constructed in the late 1950s with the aid of the USA Facilities Assistance Programme. (The propellant was not used extensively by UK Services due to storage and stability difficulties.)

Experimental work and production trials were carried out between 1957 and 1960 and the long awaited first order for 100 tonnes was received in 1960 and completed in 1961. Only small scale production was carried out in the following years and the plant was dormant by the late 1960s.

### 6.5.12. White Phosphorus

White phosphorus burns in contact with air giving off dense white fumes and is used in a wide range of ordnance to produce screening smoke.

The white phosphorus filling plant was transferred from ROF Pembrey in 1964 and installed into building No. 50/201, a nitration house in the then empty Factory II Nitrocellulose Section. Mortars, shells and grenades were filled there until the late 1990s.

Phosphorus was brought into the factory in drums, melted using hot water and poured into the devices. Components such as fuzes and exploder pellets were

brought into the factory and complete items of ordnance were assembled, painted and stencil marked in building No. 50/202 and adjacent buildings.

#### **6.5.13. Ammonium Perchlorate**

Ammonium perchlorate in crystalline form is used as an oxidising agent in explosives and propellants. The majority of ammonium perchlorate manufactured at Bishopton was transferred to RO Bridgwater for use as an additive in the manufacture of plastic rocket propellant. Latterly, ammonium perchlorate was supplied to RO Summerfield and RO Bridgwater for use in the manufacture of rubbery propellants.

The manufacturing processes, located in Factory I, involved the controlled electrolysis of a sodium chlorate liquor using platinum electrodes. The resultant sodium perchlorate was reacted with ammonium chloride to precipitate out ammonium perchlorate which was subsequently recrystallised.

The plant was acquired from Laporte in 1959 and placed in the demolition guncotton Blending and Moulding House which was gutted and decontaminated prior to installation. The plant was not fully utilised until 1965 when the first significant orders were received from RO Bridgwater. Production continued until the mid 1980s.

#### **6.5.14. Combustible Charge Containers (CCCs)**

Combustible Charge Containers (CCCs), also known as Combustible Cartridge Cases, are rigid cylinders of NC, paper, latex and other additives which, on firing, are designed to combust with the main propellant charge.

CCC production trials began as early as 1962 and a small-scale manufacturing plant was in continuous use until the conversion of the Pulping and Blending House in Factory II NC in the late 1960s and early 1970s.

Water wet NC was delivered in bags to building No. 60/206 from Factory I. The NC was pulped with paper and blended with carbamate, aluminium sulphate (and in some cases talc) and latex. The mixture was diluted and transferred to cylinder forming machines. Lacquering utilised a number of solvents including butyl acetate and isopropyl alcohol.

Effluent from the CCC process passed through a save-all and filter before discharging into the settling lagoons formerly used for during the manufacture of paper NC (see Plate 4.1).

CCC production continued until the factory's closure.

#### **6.5.15. Lead Salts Manufacture**

Certain lead and copper salts act as 'platonisers' when added at between 1 and 5% to rocket propellants. Platonisers minimise the effect of pressure fluctuation on burning rate.

Lead salts manufacture started in 1979 for export primarily to Imperial Chemical Industries (ICI). Salts included lead citrate, salicylate and acetophalate. Development work was carried out at building No. 29/141 in the vacant Ball Powder

Section prior to the part conversion of building No. 25/102A (NC I) for small-scale manufacture.

The salts produced in the Lead Salts Section were not used as additives to propellants at Bishopton.

The plant operated until the mid 1980s and was transferred to RO Bridgwater in 2001.

#### **6.5.16. Burning Grounds**

Burning grounds were the primary route for the disposal of waste explosives and materials potentially contaminated with explosives. Fourteen burning grounds are known to have been used for this purpose during the factory's history (see Section 7.4.1). In recent years only the main burning grounds (C, F, G, H, K and L) have been used, including an oil-fired incinerator sited on burning ground No. 16/007C.

In addition to process waste and surplus materials from production sections, large quantities of explosives were burnt on the main burning grounds arising from ammunition breakdown activities. In particular, RDX, RDX/TNT and Torpex were disposed of in large quantities. Waste solvents have been disposed of at the burning grounds.

At burning ground No. 16/007E, the Georgetown hearth, lead was melted into crude ingots and refined in the Works Department (No. 31/005) for re-use in the factory. A decontamination oven was also located here for shells from Ammunition Breakdown that could not be proved with a flame torch, such as those with paint linings.

The Blueprint Review of Disposals (RO, 1994) provides background information on the use of burning grounds and should be referred to for more details concerning their operation.

#### **6.5.17. Environmental Test Facility (ETF)**

The ETF occupies approximately 10 No. buildings in the former Factory II Rocket Propellant Section. The facility was introduced in 1985 primarily for the environmental testing of large bombs and torpedoes.

With the rest of the factory now closed, the ETF is the only remaining active section (see also Section 7.3.4).

#### **6.5.18. Ancillary Activities**

A wide variety of ancillary activities were necessary for the operation of the factory, such as power supply (coal, gas and oil-fired power stations), steam supply, air raid protection, laboratory work, waste disposal, administration, laundry, engineering, maintenance (Bishopton Works Department (BWD)) and transportation (broad and narrow gauge railways).

The history of these activities is not necessarily relevant to this report, but where these activities are judged to have resulted in potential contamination sources, they are discussed further in Section 7.

### **6.5.19. German Air-dropped Unexploded Ordnance**

Although there is evidence of reconnaissance being carried out by Germany in the early years of WWII, the new factory escaped the heaviest bombing in the region that occurred in November 1940 and between March and May 1941.

A number of minor isolated air raids affected villages and towns surrounding the Site, including Renfrew, Kilmalcolm and Houston, and ICI's factory at Ardeer was badly damaged during bombing in July 1940.

The Site was affected by one such raid on 2<sup>nd</sup> October 1940. Six bombs were reported, all unexploded and subsequently dealt with by bomb disposal squads. Three 250 kg high explosive (HE) bombs were recovered from craters of between 2.5 and 5.5 m depth. One unexploded HE fell on a building and caused minor damage. Two 250 kg unexploded incendiary bombs also fell on open ground and failed to ignite. The exact locations of the bombs was not recorded.

The nearest other raid involved the dropping of 2 No. HEs on Halton (or Hatton) Farm to the north-west of Bishopton village.

## **7. POTENTIAL CONTAMINATION SOURCES**

### **7.1. Introduction**

Based on a review of historical data and existing information, this report has identified a number of activities that are known or believed to have occurred on the Site. The following section identifies potential contamination sources associated with the historical use of the Site and aims to identify the likely nature and location of potential contaminants.

Visual inspection of the Site was conducted between 28th February and 11th April 2002 over a period of 16 days. A selection of photographs taken during the survey are presented in Appendix 6. Relevant observations made since 2002 have also been included in the report.

The walkover survey was conducted to establish the current environmental setting of the Site and allow visual inspection and assessment. This included the collection of visual evidence of any contamination present on the Site or surrounding area.

This section should be read in conjunction with the two drawings in Appendix 5. The drawings show the locations of discreet potential contamination sources including bulk chemical storage, significant areas of made ground and other features of particular note. For reference, the Factory Plan in Figure 3 shows the factory divided into production areas.

### **7.2. Production Sections**

The principal substances used in each production area are identified in the following sub-sections. Where possible, the likely accumulation areas of potential contaminants are detailed, such as drains and soil surrounding areas of bulk storage.

Certain substances such as greases, oils and solvents, are likely to have been used in all parts of the factory for tasks such as maintenance and cleaning. These are not mentioned in the following paragraphs except where they are thought to have been stored or used in large quantities.

#### **7.2.1. Nitrocellulose**

The manufacture of NC involved the use of large quantities of mixed acid and produced large volumes of acidic effluent containing NC. Other substances were not used in significant quantities.

Nitrocellulose is likely to have accumulated in the drainage system between process buildings and lagoons and in interceptor systems. In Factory I, at the time of the survey, accumulations of NC were visible along the sides of open process drains and attached to the surrounding grass (see Plate 6.1, Appendix 6). The acid tiled process drains were generally in good condition but it is inevitable that, in places, the drains have been denuded around joints allowing NC and acid to escape into the soil.

The settling lagoons associated with each factory have been emptied and the contents composted, but it is possible that the bases of the lagoons were leaky and

that NC has accumulated in the underlying soil. Periodically, NC was excavated from the lagoons and stockpiled on adjacent ground before being transferred to the burning grounds for disposal. In Factory I the area to the east of the lagoons was used. NC contamination is possible in these areas and in the vicinity of each lagoon.

The manufacture of demolition guncotton involved the use of phenol and acetone.

### **7.2.2. Nitroglycerine**

The primary raw materials for NG manufacture were mixed acid and glycerine.

The principal locations of potential NG contamination are likely to be associated with the wash water drainage system and drainage from the mixing houses and sheeting tables. NG may have accumulated in process drains and surrounding soil where drains were damaged.

The handling of nitroglycerine was tightly controlled and spillages of NG emulsion were rare. A notable spillage occurred in 1970s when a split pipeline led to the loss of NG emulsion from the gantry between building Nos. 24/107B and 24/116B. Alcoholic caustic soda ('NG Killer') was used to treat the ground. In 2001, a small quantity of NG was spilt near No. 24/116A, a paste mixing house.

There are reports of a spillage in Factory III in the 1950s. A batch (approximately 1 tonne) of NG was lost due to a gap in guttering, although the exact location of the incident is not known. A factory plan shows that the contaminated soil was excavated and spread over an area of approximately 0.75 ha in Georgetown.

Caustic soda and sulphuric acid are stored in tanks at the effluent treatment plant.

Lead was used for pipework transmitting NG. Lead salts and RDX were added at the paste mixing stage for some propellant types.

The wash water ponds were intrusively investigated in 2002. NG and NC were found in the sediment of ponds in Factory I and III, and RDX was detected in one pond in Factory I.

### **7.2.3. Acids**

The manufacture, storage and transmission of sulphuric and nitric acid presents a number of potential contamination sources.

Nitric acid and sulphuric acid were stored in large quantities in the acids sections and elsewhere in production sections. Acids were generally stored in ASTs of around 50,000 to 100,000 litres capacity. In the majority of cases the tanks were located on hardstanding finished with acid resistant tiles, protected by shallow bunds and high concrete walls. Numerous concrete bunds and former tank supports show signs of acid attack (see Plate 6.2, Appendix 6).

It is likely that significant quantities of these acids have escaped from tank farms and pipelines. This may have resulted in soils and surface/groundwater with low pH and high concentrations of sulphate and nitrate.

In most circumstances, acids promote the mobility of trace metals such as chromium, lead, copper and zinc. Leaking acids may have dissolved metals from stainless steel pipelines and other structures before entering soil or surface/groundwater. Steel is an alloy of iron, chromium, carbon and manganese but also contains small quantities of metals such as nickel, molybdenum and vanadium.

Anhydrous ammonia was used in large quantities in each of the three factories for the manufacture of nitric acid. Sulphur was the primary raw material for the manufacture of sulphuric acid in Factory II (see also Section 6.5.5).

For a short period of time, 'producer gas' was manufactured from coke in Factory I Acids Section. Associated potential contaminants include coke, tars and hydrocarbons such as polycyclic aromatic hydrocarbons (PAHs). Coke was also extensively used in acid scrubbers to reduce air emissions.

IRFNA was manufactured for a short period of time in Factory I and involved the use of hydrogen fluoride.

Acid pipework was generally stainless steel in construction, although many pipes were lead lined. In particular, lead was used as a lining for weak sulphuric acid vats. Asbestos, including crocidolite (blue asbestos) was used extensively in the acids sections, particularly to seal pipe joints. For a time, small quantities of asbestos grease were prepared in a small building, no longer present, in front of Ingliston House (building No. 25/127).

#### **7.2.4. Gun and Rocket Propellant**

The principal raw materials associated with these sections are NG and NC. These may exist together in many forms such as dried paste, reworked or waste material from the presses and associated buildings, or finished propellants. Such substances are most likely to be found around the entrances of production buildings and alongside narrow gauge railway lines. Granules and fragments of stick propellant are visible at the surface in many parts of Factory I Gun Propellant Section.

Picrite was a major constituent of triple based propellants made at the factory. The most likely location of picrite contamination associated with the Gun Propellant Section is around building No. 28/168 – Picrite Sieving, but picrite could be found in other parts of the Section after being incorporated into dough.

Other substances added at the incorporator stage included cryolite (a naturally occurring mineral composed of sodium, aluminium and fluoride) and carbamite (diethyl diphenylurea).

Acetone was extensively used in large quantities particularly for the manufacture of solvent gun propellant, and was stored in a number of tank farms around the factory. In most cases the solvent was transferred to day tanks near process buildings by road, narrow gauge railway, or piped.

Other solvents used in significant quantities included cellulose acetate, dibutyl phthalate, industrial methylated spirits, di-ethyl ether and ethyl acetate. Shallow bunded concrete drum storage areas were located in the propellant sections but solvents were also kept haphazardly on natural ground near process buildings.

Where required in larger quantities, solvents such as ethyl acetate and methylated spirits were stored in tanks such as those near building No. 28/103.

RDX was added to semi-solvent propellant but, since the semi-solvent production line utilised buildings in the solvent gun propellant section, RDX has potentially been used in many areas of the section.

Lead and copper salts such as stannate, resorcyate, salicylate and acetate were normally added to rocket propellant at the incorporator stage. Building No. 28/234E, near the CCC lagoons, was used as a storage building for metal salts. It is understood that lead salts were also stored in the Romney Huts in Georgetown (see Section 7.4.8).

The presses were hydraulic and required large quantities of oil to function. Spillages and leakages inside the buildings basements were very common. Oils may have escaped from inside the buildings in the drainage system or by other routes. Contamination by these substances may also be found in drum storage areas.

Potassium perchlorate contamination is a possibility in the vicinity of building No. 28/163. The chemical was brought into the factory in coarse form then dried, sieved and milled for use as an additive.

X-rays were used for quality control purposes in the rocket propellant sections. Units were located building Nos. 28/312D, 40/202, 42/201 and 70/001 (ETF). The X-ray units utilised small closed sources of radioactive material (including cobalt-60 and caesium-137) but the likelihood of radioactive contamination associated with these activities is very low. This is due to the strict rules and regulations for the storage and use of such materials.

### **7.2.5. Tetryl and RDX**

The manufacture of tetryl requires the use of nitric and sulphuric acids, dimethylaniline and acetone. RDX manufacture involves hexamine, nitric acid and cyclohexane. TNT was brought into the factory and mixed with RDX prior to dispatch in buildings that were later used for the storage of picrite.

These sections were decommissioned in the late 1950s (RO, 1957) during which several tonnes of RDX, tetryl and RDX/TNT were recovered and burnt. Most of the explosive material was recovered from within process buildings but a significant amount was found in external drains.

Clearly there is a potential for these materials to have accumulated in the soil, particularly in and around underground drains and interceptor systems. In the environment, tetryl can biodegrade into picric acid which itself is a toxic explosive with significant solubility in water.

### **7.2.6. Picrite**

The primary materials involved in the manufacture of picrite are dicyandiamide (DCD), ammonium nitrate, guanidine nitrate and sulphuric acid.

Outside process buildings, these substances may be found in and around drains, and in the soil as a result of storage and localised spillage.

Spent acid was stored in large quantities in at least three storage ponds, Nos. 34/274A (covered), 34/274 and 34/216. At the time of the survey, leakage was evident from the latter two ponds (see Plate 6.3, Appendix 6).

Because of concerns surrounding acid leakage, Raeburn Drilling carried out a ground investigation in 1998 in the vicinity of building No. 34/208 (Cooling and Neutralisation). The report concluded that contamination by sulphuric acid was locally intense but relatively confined both laterally and vertically by low permeability soils.

An investigation carried out by RO ESG in January 1996 in the vicinity of building Nos. 22/105 and 34/219 revealed only slightly elevated concentrations of sulphates, metals, and PAHs and slightly alkaline pH.

### **7.2.7. Ammunition Breakdown**

A wide variety of ordnance has been broken down at the factory; there is both an explosive risk and contamination risk from devices and substances arising from these activities.

Potentially dangerous substances include RDX, TNT, NC, NG, barium nitrate, white phosphorus, and many other explosives potentially contained in primers, fuzes and igniters.

There is the potential for any of the above substances to be found in and around buildings used by the Ammunition Breakdown Section but several areas present a higher risk. There is a greater risk of RDX and TNT contamination around the buildings used for steaming-out (Nos. 43/408 and 43/304A), in particularly the 'Big Steamie' where a large tank outside (now removed) was used for settling-out of sediment from 'red water' effluent. Barium is most likely to be found in the vicinity of building Nos. 25/301 and 25/302 where barium nitrate was recovered from incendiary devices.

White spirit was used to dissolve the liners of some devices, although the exact location of storage/use is not known.

There is the potential, albeit low, for discreet devices such as fuzes and igniters to be found, particularly in the central area of the Section where devices were dismantled and prepared for firing or burning.

Ammunition was stored in large quantities at designated locations around the factory. Hardstanding in the AFV Depot was used (see Plate 6.3, Appendix 6) as were building slabs in the Factory III Gun Propellant Section. There is a possibility of discreet items of ordnance being present in these areas, particularly on any soft ground adjacent to hardstanding that has been used for this purpose.

There is no evidence to suggest that chemical weapons were dismantled at the factory.

### **Lance Decommissioning**

A Waste Management Licence was acquired and subsequently surrendered for the storage and transfer of scrap metal in building No. 80/011A. At the time of licence

surrender concern was expressed by SEPA that asbestos may be present in the soil as a result of asbestos containing materials in certain missile components.

Asbestos air monitoring was carried out and results found to be significantly less than Occupational Exposure Limits. In addition, RO ESG (1998) were commissioned to analyse shallow soil samples from within the licensed area. A number of samples were found to contain elevated levels of cadmium, copper, nickel, zinc and pH. Six samples contained chrysotile, although since the missile components contained both chrysotile and amosite, the asbestos was not thought to derive from the Lance decommissioning activities.

Prior to licence surrender the area was covered with 1 m soil to prevent any exposure to asbestos discovered during the ground investigation.

Potential contaminants arising from the Lance decommissioning project in the former III NC Section include UDMH, asbestos, acids, metals, trichloroethene and oil.

#### **7.2.8. Ball Powder**

Potential contaminants associated with the manufacture of ball powder include NG, NC, ethyl acetate and diphenylamine. Ethyl acetate was stored in two concrete above-ground storage tanks (ASTs) (building Nos. 29/103A and B) and prepared with diphenylamine in the adjacent building.

An underground storage tank (UST) containing dibutyl phthalate and/or isopropyl alcohol is located adjacent to the 'sweetie barrel' building (No. 29/114) in the Gun Propellant Section.

#### **7.2.9. White Phosphorus**

White Phosphorus is the principal potential contaminant associated with this section. The most likely area of potential contamination is the open ground at the rear of the main process building where, at the time of the walkover survey, many hundreds of phosphorus drums and empty ammunition cases were stockpiled (see Plate 6.4, Appendix 6). This area was also used for the storage of white phosphorus prior to filling. Phosphorus may also have accumulated in and around drains around the process building.

There is a potential for devices to be present in this area since whole mortars, grenades and shells were assembled as part of the process. Many boxes, drums and open piles of components were stored in the area of open ground but were likely not to contain explosive materials. Components include mortar bodies, mortar tails and grenades.

The empty drums, ammunitions cases and components have since been removed from this area.

Completed devices were spray painted and stencilled so there is the potential for paints and thinners to be present in this area.

### **7.2.10. Ammonium Perchlorate**

Potential contaminants in the area around building Nos. 41/106 and 41/107 include ammonium perchlorate, sodium perchlorate and ammonium chloride.

### **7.2.11. Combustible Charge Containers**

Potential contaminants associated with the manufacture of CCCs include NC, carbamate, aluminium sulphate, butyl acetate and isopropyl alcohol.

Drummed solvents and oils were stored in a shallow bunded area next to building No. 60/204 and in other locations around the main building. Drum storage in undesignated locations within this production section was noted in Aspinwall's Environmental Report (1990).

The effluent treatment lagoons have been emptied and residues composted but it is likely that solids have accumulated in the soil around and beneath the lagoons.

Applications were made for registrations under the Radioactive Substances Act 1993 relating to the assembly of CCCs into cases that contained depleted uranium (DU) components. At least 2 No. applications were submitted – the first in September 1996 was superseded by a second in February 1998 – but the activity was not subsequently carried out at the factory. The second application was granted on 1 April 1998 and cancelled by SEPA on the same day.

### **7.2.12. Lead Salts Manufacture**

Contamination associated with lead salts manufacture is possible in the vicinity of building No. 29/141 - the development building in Ball Powder Section, and No. 25/102A – the main production area in Factory I NC Section. These substances were manufactured in small quantities and the likelihood of finding widespread contamination is low. There is still the potential for accumulations in drains and in the ground outside the buildings as a result of spillages.

## **7.3. Ancillary Activities**

### **7.3.1. Steam and Power**

Each factory had its own coal fired power station such as the one in Factory III shown in the background on Plate 6.4, Appendix 6. As production levels decreased, the new boiler in Factory II became the main steam supply in the factory and was subsequently converted to being oil fired.

In later years the Main Boilerhouse in Factory II was regulated by Integrated Pollution Control (IPC) (under The Environmental Protection (Prescribed Processes and Substances) Regulations 1991) which placed restrictions on emissions to the environment and requirements for regular monitoring.

The main waste product from the burning of coal is boiler ash, and the disposal of this waste is discussed in Section 7.4.3.

Evidence of bulk coal storage can be seen in two areas of the factory. At the time of the survey, vegetation appeared stressed in these areas. Coal storage for

Factory II boiler included an underground conveyor trench of approximately 6 m depth.

Dependent on the source, coal can contain PAHs and have high sulphur concentrations. These substances can leach into the underlying ground and the often acid nature of the leachate can increase the mobility of trace metals. Coal can also represent a combustion hazard.

A wide variety of chemicals are likely to have been used as additives to the water-feed and for boiler cleaning. Such chemicals include acids, alkalis and small quantities of chemicals containing hydrazine, sodium hydroxide and phosphates.

Two oil tanks, each approximately 250,000 litres in capacity, were constructed when the Factory II boiler was converted. The tanks were bunded and show no sign of leakage except for minor spills around the filling point.

Asbestos is likely to have been used extensively in the power stations for insulation and plant components.

There are somewhere in the region of 30 No. substations located at the factory. Outside each substation are two below-ground oil sumps with circular metal covers. In 2000, all the electrical equipment was tested for the presence of PCBs and were found in only one location, a circuit breaker inside building No. 9/202D. This suggests that PCBs have not been used widely in recent years, but the possibility that PCB containing oils having been used at some time in the past cannot be discounted.

The factory was served by a network of above-ground lagged steam pipes. Generally, these have been removed from redundant areas of the factory. The steam pipes were traditionally lined with asbestos and a rolling programme of removal and replacement was initiated in the 1970s. The ground beneath these pipes may be contaminated locally with asbestos.

A similar network of steam pipes may have served Georgetown and it is likely that some of the asbestos contamination found during the ground investigation (RO ESG, Oct. 1996) was a result of the installation, degradation and eventual removal of these materials. Much of the asbestos observed in samples is considered likely to be associated with cement-bonded sheeting, fragments of which are evident at the surface in many locations.

Similarly widespread contamination may be found in 'legacy' areas of the RO factory e.g. Factory III NG and NC sections where steam mains have been removed.

### **7.3.2. Transport**

Narrow and standard gauge railway trucks and road vehicles were used extensively in the factory for transportation. Associated potential contamination sources (not including spilt loads) include underground fuel tanks, battery charging stations, and maintenance workshops.

Underground fuel tanks are located opposite Nethermill Crescent (building No. 37/056), on Dargavel Road (Nos. 37/006A and 37/018), in the Stores Yard (No. 37/006B) and near the Laundry (No. 28/145) (see Plate 6.5, Appendix 6).

At least 5 No. battery charging stations were located around the factory. A handful of these appear to have been converted to general workshops. In addition to substances used for general maintenance works, potential contaminants include battery acids and metals such as cadmium and nickel.

Narrow gauge railway trucks were used to transport raw materials (e.g. acetone and acid), intermediaries (e.g. paste and dough), waste and finished propellant. Spillages of these materials are likely to have occurred in individual production sections. Areas of the factory where trucks have been repaired or washed also present potential contamination sources of these substances.

### **7.3.3. General Materials Storage**

A number of open areas in the factory were used for general storage. Whilst it is clear what types of materials have been stored in recent years, the range of materials stored historically cannot easily be determined. The range in potential contaminants in these areas is therefore wide, and will reflect the range in types of substances used in the factory during its history.

The Stores Yard on Dargavel Road has primarily been used for factory vehicle parking and general storage of non-explosive materials. At the time of the walkover survey, the yard was home to a number of redundant vehicles, gas cylinders and approximately 60 No. drums on pallets. Chemicals contained in the drums included diethyl ether, ethyl acetate and industrial methylated spirits. A vehicle inspection bay and petrol UST are also located in this area.

In latter years the Romney Huts in Georgetown were used primarily for storage of paper, packaging, ammunition boxes, mortar cases and construction materials. In the past, this area was used for the storage of sections of drainage pipes and associated components. It is understood that lead salts and other unspecified substances have been stored in this location.

The area to the south of the Ammunition Breakdown Section, formerly the location of broad gauge rail unloading platforms for the Tetryl/RDX sections, was subsequently used for storage by the Ammunition Breakdown Section and for the main burning grounds. At the time of the walkover, stored materials included numerous unidentifiable containers, drums of ethyl acetate, and mounds of demolition material. It was probably used for ordnance storage at some point in the past (see Section 7.2.7).

Aerial photographs and historical factory plans indicate that an area between broad gauge railways to the west of the sewage works was used for stockpiling predominantly earthenware pipes and pipe components.

### **7.3.4. Environmental Test Facility**

The ETF is an active section of the Site that is primarily engaged in the environmental testing (including vibration and climatic) of explosive devices and components under controlled conditions.

Activities have generally been confined to buildings in the fenced-off area within the former Factory II Rocket Propellant Section, although firing has been carried out at the 'chicken gun' (immediately to the south of the ETF) and in one of the Romney

Huts. Road magazine building No. 70/100 is used for climatic testing and a number of other magazines have been used for storage.

The ETF intend to reuse the former Rocket Propellant Section burning ground (building No. 16/007B) located in the wooded area near the Picrite Lagoons.

A number of devices with depleted uranium (DU) components have been tested, but the nature of the material and the testing carried out is such that release of radioactive material into the environment is not plausible. The registrations under the Radioactive Substances Act 1993 relating to this activity have been cancelled.

The ETF are currently registered for the keeping and use of cobalt-60 as a source in radiography equipment.

### **7.3.5. Laundry**

The main laundry situated to the west of Dargavel Ponds cleaned work-wear from all sections of the factory. There is no evidence that dry-cleaning processes have been carried out at the laundry.

There is a potential for various substances used in the factory to have accumulated in drains and immediately adjacent to the Laundry.

### **7.3.6. Composting of NC and CCC Waste**

A number of hardstanding areas have been used to locate windrows for NC and CCC waste composting. These projects were carried out between 1999 and 2004, managed by BAE Systems Environmental.

Windrows have been located in the AFV Depot and in the former Factory III NC Section as shown in Appendix 5. The windrows comprise a mixture of chicken manure, coffee beans and either NC or CCC waste.

Leachate and run-off from the windrows is likely to contain high proportions of organic matter, nitrogen compounds and phosphorous.

### **7.3.7. AFV Depot**

The Armoured Fighting Vehicle (AFV) Depot was used during WWII for the storage of military vehicles. A structure near the southern boundary is probably the location of a fuel tank, as indicated on a historical map of the area. Vehicle maintenance was carried out in two workshops.

Substances associated with these activities are likely to have included hydrocarbons such as fuels, oils and solvents. The scale of the activities and the relatively short period of operation limit the potential for pollution to be present.

The hardstanding in the AFV Depot has been subsequently used for ammunition storage prior to breakdown (see Section 7.2.7) and as a base for composting windrows (see Section 7.3.6).

The AFV Depot was investigated during the Georgetown site investigation (Area 3) as discussed in Section 7.5.

### 7.3.8. Laboratories

The main laboratories (building Nos. 18/004 and 18/008) are situated adjacent to the Administration Building with small chemical stores located nearby to the west. Relatively small quantities of potentially a large range of chemicals and substances have been stored inside buildings and within cages on hardstanding in this area.

Many other laboratories were located around the factory including building No. 25/127 behind Ingliston House. Individual production sections had dedicated laboratories for routine testing and other tasks.

Considering the scale of activities and the quantities of substances used, it is unlikely that laboratories around the Site constitute a significant contamination source.

### 7.3.9. Made Ground Associated with Construction

Made ground is likely to exist throughout the Site associated with buildings, roads, rail lines and underground services. Minor constituents of made ground observed in previous site investigations have included ash, clinker, concrete and 'blaes' (burnt shale).

Potential contaminants are likely to include metals and PAHs.

### 7.3.10. Other Activities

It is likely that many other activities have been carried out on a small scale within the factory boundary, particular for research and development and for pilot-scale projects. The following are known examples:

- Building Nos. 26/142 and 26/143 located to the south of road magazine (building No. 35/004E) were used in the 1970s to investigate NG detonation in transmission pipelines. Later trials involving ammonium perchlorate may have been carried out in this location.
- Building No. 24/310C, a former NG process building in Factory III has been used for rocket propellant trials, rocket motor disposal and paste detonation trials for RO Summerfield.
- Dyes, pigments and solvents were used for the production of a chemical agent tracking system (for crime detection) in building No. 60/202.
- From the early 1950s NC with a low nitrogen content for use in LP records was produced in the Factory I Nitrocellulose Section and processed in a building near building No. 28/123A.
- In the 1950s, the factory received a small order for the grinding of sodium chlorate, used by the Navy in 'oxygen candles'. The exact location of this activity is unknown.
- Pesticides and herbicides could have been used on the landscaped grounds surrounding the administration building and laboratory.

- In 1949 the factory was engaged in re-dyeing RAF equipment, probably utilising the large vats in the NC sections.
- In recent years building No. 50/205 in the former White Phosphorus Section was used by Exchem for the storage of ammonium nitrate based industrial explosives.
- On occasion, the Site was used for secure overnight storage of military hardware (possibly including nuclear weapons) in transit between Ministry of Defence sites.

## 7.4. Waste Disposal

### 7.4.1. Burning Grounds

The primary route for the disposal of explosives and explosives contaminated materials was by burning. It was customary for each burning ground to be dedicated to certain types of materials. This was generally adhered to throughout the factory's history but it is possible that materials were disposed of other than those listed in the following table.

Building No.	Location	Known activities
16/007A	NC I	NC including dredged arisings from settling lagoons.
16/007B	Woods east of ETF	NG/NC paste.
16/007C	Main burning grounds	Explosives: NG/NC paste, tetryl, RDX, TNT, Torpex, devices (in bells)
16/007D	Dargavel Ponds	Not known
16/007E	Georgetown	Proving of scrap and projectiles from Ammo Breakdown. Lead recovery hearth.
16/007F	Main burning grounds	Propellants
16/007G	Main burning grounds	Paper, packaging and CCCs
16/007H	Main burning grounds	Explosives: NG/NC paste, tetryl, RDX, TNT, devices (in bells)
16/007J	Boghall	Proving of scrap
16/007K	Main burning grounds	Propellant and white phosphorus
16/007L	Main burning grounds	Proving of scrap
16/007M	NC III	Proving of scrap
16/007N	NC III	Proving of scrap
16/007P	NC III	Proving of scrap

**Table 3 – Burning grounds**

Burning grounds C, F, G and H were the subject of a previous ground investigation (RO ESG, Dec. 1995). The investigation found that the made ground contained elevated levels of barium, boron, copper, iron, nickel, lead, sulphate, tin and zinc. Isolated elevations of arsenic, cadmium, chromium and selenium were also reported. Explosives contamination was widespread and included NC, NG, RDX, TNT, picrite, picric acid and tetryl. The underlying natural soils were not generally found to be contaminated.

Burning ground E in Georgetown was sampled during the Georgetown investigation and was found to be one of the more heavily contaminated areas in that part of the Site. In particular, elevated concentrations of lead, copper and nickel were reported. Small amounts of waste material arising from this burning ground have been deposited on the opposite side of the road.

Two trial pits were excavated at Burning Ground J (Boghall) in 2002 (BAE Systems, Aug. 2002). Made ground was 0.4 m thick and comprised gravel with much ash and clinker. Laboratory analysis indicated elevated levels of arsenic, lead, copper, zinc and barium but did not confirm the presence of explosives residues.

Combustion is not always complete during open burning; it is to be expected that residual ash contains explosives residues. Discrete pieces of explosives may also have arisen from spillage during transportation. Other contaminants, including boron and barium are likely to have been a result of the burning of pyrotechnics and incendiary devices. (Aluminium was not found at significantly elevated levels during the burning grounds investigation (RO ESG, Dec. 1995) despite the disposal of large amounts of Torpex over the years.) Rocket propellants in particular contain appreciable quantities of lead and copper salts.

Although not found during the burning ground investigation, the use and storage of kerosene and fuel oils presents a contamination risk, as does the burning of waste solvents at the main burning ground. Asbestos has been used widely around the factory and may be present on some burning grounds as a result of the proving of pipes and other plant and equipment.

The main burning grounds were used for firing and burning of various items of ordnance and it is possible that discreet devices are present in the locality.

#### **7.4.2. Boghall Dump and Vegetation Tip**

Boghall Dump is situated in the northern part of the Site and covers an approximate 1.7 ha area of the former Factory III NG Section. A second smaller tip, the 'Vegetation Tip' with an area of 0.25 ha is located to the north of the crossing of Dargavel Burn and Nethermill Road.

In 2002, the two tips were the subject of a site investigation comprising 12 No. trial pits and a topographical survey (BAE Systems, Aug. 2002).

It is likely that waste began to be deposited at Boghall during the 1960s. The waste disposal site did not require licensing at this time because the factory was operating under Crown Immunity. In the 1970s, specific areas of Boghall were dedicated for asbestos disposal. Much of the waste asbestos would have come from the lagging around steam pipes that were being gradually replaced during the 1970s and 1980s. Anecdotal evidence suggests the asbestos may have been placed in purpose-built trenches at the base of the site.

In 1990, Boghall Dump was granted a Waste Management Licence under the Control of Pollution Act (COPA) 1974. Royal Ordnance internal instructions suggest that the Dump was licensed to accept a variety of materials including demolition waste, vegetation, paper and glass, but not asbestos, other than in rigid sheets. The Licence has since been surrendered.

Each tip was monitored for landfill gases on a quarterly basis. Although no historical data are available, communication with SEPA suggests that methane and carbon dioxide were not appreciably above background concentrations during the period that the tips were licensed.

At the present day, an indication of the types of wastes deposited in both tips is given by the exposed down-slope faces. At Boghall the down-slope face can be seen between four mounded NG process buildings that have been covered over with tipped material. For the most part the wastes comprise demolition materials including boulder sized fragments of reinforced concrete. Smaller amounts of the materials are also evident including tyres, timber, metal sheet, empty drums and empty tins of wood preserver and paint. The top surface of Boghall Dump is formed by ash and clinker which is mounded in places.

Tipped materials seen in trial pit arisings were predominantly demolition materials (concrete, brick, timber, corrugated metal and asbestos sheet) and ash. Red bags of fibrous asbestos (confirmed as amosite) were recovered in 4 No. pits towards the main gate of the tip at depths less than 1.0 m.bgl. A white fibrous material found at 1.0 m.bgl in TP8 was confirmed by laboratory testing as NC. The sample analysis also revealed slightly elevated concentrations of nickel and zinc.

The surface of the Vegetation Tip comprises ash and clinker but unlike Boghall it is heavily vegetated with apparently healthy tree saplings. Items visible in the exposed face adjacent to Dargavel Burn include burnt shale, telegraph poles, empty drums and numerous sections of metal pipe.

Trial pits indicate that tipped materials include demolition materials of a similar nature to Boghall. Although asbestos pipework and sheeting were observed, bulk bags of fibrous asbestos were not. Samples analysed in the laboratory contained slight elevations of copper and zinc. One sample contained a significant amount of tetryl.

The depth of Boghall Dump was not proved in the majority of trial pits at depths of up to 4.8 m. Based on the topographical survey and a factory survey carried out in 1941 the volume of waste is approximately 48,000 m<sup>3</sup>.

The Vegetation Tip was proved to be approximately 2.5 m deep near the centre and covers an area of some 0.25 ha. Based on an average thickness of 1.5 to 2.0 m the volume of waste is between approximately 3,750 and 5,000 m<sup>3</sup>.

### **7.4.3. Ash Dumps**

For most of Bishopton's history, coal was burnt to provide steam for the factory at rates in excess of 1,000 tonnes per week. The principal solid waste products from the burning of coal are Furnace Bottom Ash (FBA), or clinker, and Pulverised Fuel Ash (PFA). It is likely that all the waste ash produced in the various boilers has remained on site either in designated dumps or been used as a base beneath roads and railways, and elsewhere.

The major constituents of ash are aluminium, iron and silicon forming a glassy matrix. Typically, carbon, potassium, sodium, magnesium and sulphate are present at percentage levels. More importantly, in terms of contamination, ash contains trace amounts of heavy metals and PAHs.

Samples containing ash appeared to account for the majority of elevated metal and PAH concentrations identified in the Georgetown ground investigation (see Section 7.5).

Ash is present in significant quantities at the following locations, as shown on drawings in Appendix 5:

- **Georgetown, south of the Picrite Lagoons** – This area was designated as an ash dump during WWII and became the main disposal area in the following years eventually covering an area of approximately 4.3 ha. Plate 3.2 in Appendix 3, dated 1947 shows the early operation of the dump. Ash was deposited between the perimeter road and the adjacent railway line both of which are raised by up to 1 m relative to surrounding ground levels. The ash tip to the north of Fulwood Road is generally flat lying whereas the tip to the south is domed to approximately 2 m above the perimeter road and railway line. Both areas are sparsely vegetated by apparently stunted birch trees (see Plate 6.6, Appendix 6).
- **South-east of Ammunition Breakdown** – This ash dump is smaller but similar in appearance to the main dump in Georgetown. Waste ash was deposited in a triangular area of approximately 1.3 ha bounded by the perimeter track, an internal road and an unnamed stream. A borehole installed near the centre of the tip (BAE Systems, 2002) proved 2.5 m of ash.
- **Boghall Dump** – See Section 7.4.2.
- **Near Northbrae Gate** – At the time of the walkover, ash was mounded between parallel roads over an area of approximately 0.4 ha. The mounds were up to 3 m high in places.
- **West of 'The Cathedral'** – At the time of the walkover, mounds of ash covered an area of approximately 0.2 ha in front of the Cathedral. The mounds were up to 3 m in height. Smaller amounts of topsoil and general waste were also observed in this area including coal, bricks and empty containers.
- **Roads and railway lines** – Ash and clinker have been used extensively for road surfaces and probably as a sub-base for tarmac/concrete roads and building foundations. More substantial deposits are present beneath long lengths of the perimeter road which have been raised above the surrounding ground level by up to 2 m. The firebreaks in Georgetown are also made up of ash deposits, raised relative to surrounding ground level. Trial pits and boreholes excavated through these firebreaks indicated thicknesses of between 1.3 and 1.8 m.

#### 7.4.4. Picrite Lagoons

Seven lagoons were used for the disposal of limestone/lime neutralised sulphuric acid effluent from the Picrite Section.

The resultant slurry (calcium sulphate and water) was pumped to the lagoons, the solids allowed to settle out and the supernatant left to drain away from the unlined

lagoons or evaporate to atmosphere. Periodically, when the material had dried sufficiently, solids were excavated and mounded on adjacent land and the lagoons reused for settling.

The lagoons were divided into two sets: the northern set comprises lagoon Nos. 1A, 1B, 2 and 5, the southern set comprises No. 3A/3B, 4A and 4B. The lagoons cover a total area of approximately 5 ha.

Plate 6.7 (Appendix 6) shows Lagoon No. 3A/3B. An excavated face of Lagoon No. 5 is shown in Plate 6.8.

The lagoons' environmental problems and potential solutions have been the subject of a number of investigations carried out by RO (1990, 1993), RO ESG (May 1995), Aspinwall (1989, 1990) and BAE Systems (2003). These reports should be referred to for more detailed information relating to the hydrology, hydrogeology and chemistry of the lagoons and surroundings.

A survey undertaken by Aspinwall (1989) indicated that the supernatant liquor drained from the lagoons into surface water and groundwater via sheet flow (particularly during wet weather), drainage ditches, drainage pipes and through the peat. Locally, this caused a degree of groundwater and surface water pollution, particularly by ammonia and sulphate.

Historically, the operation of the lagoons has caused tree death, particularly to the south and west of lagoon Nos. 3A/B, 4A and 4B. This was probably as a result of supernatant with residual acidity overflowing from the lagoons, and leachate from the solids mounded to the sides.

In the early 1990s it was suggested by CRPB that high levels of ammonia found in surface and groundwater at the perimeter of Southbarr Landfill Site were a result of liquor from the picrite lagoons.

The investigation in 2003 proved generally between 1.0 and 2.2 m of lagoon solids overlying peat and Linwood/Paisley Formation. Laboratory analysis indicated that principal contaminants of concern were ammonia, sulphate, picrite, alkalinity and variable pH.

#### **7.4.5. Sulphur Dump**

Sulphur was the raw material for sulphuric acid manufacturing carried out at the factory in the 1940s and 50s.

Lumps of elemental sulphur are apparent at the surface on an area of ground to the east of rail magazine No. 35/001K and vegetation appears stressed. It is suspected that this is an area where raw materials, wastes and/or excess sulphur was stored. The sulphur is visible on aerial photographs (see Plate 3.6, Appendix 3) and appears to be spread over an elliptical shaped area of approximately 0.5 ha. The Sulphur Dump was located on the footprint of a Rectifying and Pump House of Georgetown No. 2 Factory.

Trial pits excavated in the general area of the Dump (RO ESG, Oct. 1996) appeared to indicate that it does not extend far below ground, perhaps as little as 1 m.

Laboratory analysis of soils at the surface indicated significant levels of sulphur and sulphate, and low pH.

#### **7.4.6. Refuse Coup and Incinerator**

Building No. 16/012 is referred to in building registers as a 'Refuse Coup and Incinerator'. This suggests that general non-explosive waste was stored and burnt in an enclosure or cage in this location. The building is shown on a plan dated 1972 to be located at the southern end of the picrite lagoons. An aerial photograph dated August 1947 (see Plate 3.2, Appendix 3) shows disturbed ground in this vicinity.

Ash making up this part of the perimeter road contains much glass, metal and brick at the surface.

Potential contaminants associated with this activity are largely dependent on the types of waste burnt or deposited but are likely to include a wide range of non-metals, metals and hydrocarbons.

#### **7.4.7. Scrap Metal Storage**

Scrap metal has been stored at several locations throughout the factory (shown in Appendix 5), the main storage area in recent years being to the east of the main burning grounds. Many of the scrap compounds are on hardstanding, although the main scrap compound and the lead compound have un-made surfaces.

Soil beneath these areas may have elevated levels of metals such as lead, copper, chromium and zinc, although generally restricted to shallow depth. Compounds may have been used for the storage of explosive contaminated scrap prior to burning, or scrap metal containing traces of other substances such as solvents and acids.

#### **7.4.8. Miscellaneous Areas of Waste Storage and Disposal**

In addition to those mentioned above, there are a number of areas of the factory where significant quantities of waste are stored or have been disposed of. They are as follows

- **South of picrite lagoons** – Waste materials have been deposited below ground in and around a small pond between the main ash dump and the picrite lagoons. Items visible at the surface include drinks cans, dustbins, bottles, angle bar, timber, chicken wire, cable sleeves, and empty drums (former contents unknown). Waste in this area may have arisen from the nearby former 'Refuse Coup and Incinerator' (see Section 7.4.6).
- **Netherfield Station Tip No. 1** – An area to the south of the Station has been used to deposit waste above ground. Objects visible include concrete fragments, corrugated iron, many railway sleepers and other timber, oil cans, bottles (possibly laboratory waste), paint tins, unidentifiable 25 litre drums, sheet glass and metal buckets (see Plate 6.9, Appendix 6).
- **Netherfield Station Tip No. 2** – Waste has been mounded between the former broad-gauge railway (now road) and Dargavel Burn. The materials deposited comprise much clinker and demolition waste with corrugated iron,

paint tins, glassware, numerous drums, timber, felled trees, cables, chairs and corrugated asbestos sheet (see Plate 6.10, Appendix 6)

Smaller quantities of waste such as demolition materials and drums have been deposited widely in the factory and are shown in Appendix 5.

#### **7.4.9. Potential Made Ground Associated with Former Mineral Workings**

The outlines of the main Dargavel Brick Works excavations as shown on historical maps, compare well with the current outlines of Dargavel Ponds A, B and C. It is therefore unlikely that any voids in this area have been filled.

Two smaller excavations marked on the opposite side of Dargavel Road in the Stores Yard did not subsequently become water bodies. These voids were filled with other materials that may now present a contamination source.

The sand pits marked on historical maps in the side of NG II Hill were probably small-scale. It was probably not necessary to backfill these excavations prior to construction of the buildings in this area.

The former brick field in Factory III may have been backfilled prior to the construction of buildings in the vicinity of building No. 28/305D.

### **7.5. Georgetown**

The potential contamination sources associated with former operations at Georgetown are detailed in the Georgetown desk study (RO ESG, Apr. 1996). The report also highlights potential contamination sources resulting from activities undertaken in the area after the closure of Georgetown, such as the burning ground, explosives magazines and ash dumping.

The subsequent site investigation (RO ESG, Oct. 1996) was designed to broadly determine the nature and extent of fill materials across the area and to identify any contamination present in soils and groundwater.

The siteworks entailed the excavation of 193 No. trial pits, 20 No. boreholes, 32 No. probe holes, and the analysis of approximately 400 No. soil samples. For reporting purposes Georgetown was divided into 7 No. areas. A summary of the findings in each area is presented as follows:

**Area 1** – Land outside the factory fence to the west of the AFV Depot and Rail Magazines. No explosive contamination was identified. Slightly elevated PAHs, copper, barium, arsenic, mercury, nickel and zinc were found at shallow depth in made ground.

**Area 2** – Rail Magazines. Low levels of NG and tetryl were found near Dargavel Burn. Slightly elevated arsenic, mercury, selenium, nickel, zinc and barium, and significantly elevated lead, zinc, barium and copper, were reported. The sulphur dump was found to be a hot-spot of contamination by sulphur, sulphide and soils there were found to have a very low pH. Asbestos (chrysotile and crocidolite) was found in made ground.

**Area 3** – AFV Depot. Slightly elevated levels of arsenic, mercury, selenium, copper, nickel, boron and barium were reported, as were significantly elevated levels of copper. Chrysotile was found to be widespread in the made ground.

**Area 4, 5 and 6** –Georgetown No. 1 Factory. High levels of picrite (and small quantities of NG) were found in samples taken near the picrite lagoons. Significant concentrations of arsenic, lead, copper and sulphate were found to be widespread in this area. Asbestos was also found to be widespread. Other metals such as zinc, boron, barium were found at marginally elevated concentrations. Contamination was generally restricted to the upper horizons of made ground, particularly around fire-breaks, railway lines, the burning ground, and dumps comprising high proportions of ash and clinker.

**Area 7** – Far south-western strip of Georgetown No. 1 Factory, outside the RO factory fence. No significant contamination was found in this area.

Marginal elevations of lead, chromium, copper, nickel and ammonia were identified in groundwater samples.

No explosive devices were found during the investigation, but there remains the potential for such devices to exist.

## **7.6. Outside the Site**

### **7.6.1. Reilly Quarry Landfill**

Reilly Quarry Landfill Site (see also Section 5.3.1) is located immediately adjacent to the western boundary of the Site and presents a potential risk to the Site in terms of landfill gas and leachate.

The potential for landfill gas migration is very low because of the types of the waste deposited into the Quarry (predominantly soil and demolition waste) and the impermeable nature of the intervening basalt. For the same reasons, the potential for migration of leachate in groundwater is also limited.

Under a legal agreement between BAE Systems and Tarmac, treated surface water from Reilly Quarry is discharged into Dargavel Burn within the Site boundary. The discharge enters the Site near the former Northbrae gate and joins Dargavel Burn upstream of the main burning grounds.

### **7.6.2. Southbarr Landfill**

Southbarr Landfill (see also Section 5.3.2) accepted similar types of wastes to Reilly Quarry, i.e. soil and construction/demolition waste. The potential for hazardous gas migration onto the Site is low in view of the fact that significantly elevated concentrations of methane or carbon dioxide are not normally recorded around the perimeter of the landfill site.

Leachate migration onto the Site is possible but there are indications that the groundwater and surface water flow directions are to the north-east, away from the Site.

Existing groundwater monitoring boreholes along this section of the Site boundary do not show any signs of leachate migration although background groundwater chemistry is very variable.

### **7.6.3. Agriculture**

The primary land use surrounding the watercourses upstream of the Site is agriculture. Potential contaminants include nitrates, phosphates and, to a lesser degree pesticides and herbicides. Septic tanks, silage storage and animal waste may present a source of organic pollution.

Discharge consents have been issued for septic tanks at Formakin (200 m to north of Site) and Barochan House (400 m south of Barochan Hill).

### **7.6.4. Craigton Burn Upstream of the Site**

The sewage works to the south-east of Bishopton Rail Station discharges into Craigton Burn before it enters the Site.

A discharge consent has also been issued for an oil interceptor on a garage forecourt 150 m upstream of the Site.

## 8. INITIAL CONCEPTUAL SITE MODEL

### 8.1. Introduction

A Conceptual Site Model (CSM) is a simplified representation of environmental conditions that enables an understanding of a site and its surroundings to be formulated. It describes the possible relationships between contaminants (sources), pathways and receptors and so underpins the entire risk assessment process. The development of a CSM also highlights data gaps, (identifying the data that is required to be collected through site investigation) and is iterative with further data collection phases.

The CSM provided in the following paragraphs has been developed with regard to the guidance provided in Environment Agency report NC/99/38/2 and other referenced documents.

### 8.2. Source Types

This assessment has identified a number of potential contamination sources largely resulting from the industrial use of the Site. These are detailed below:

Description	Location and geometry	Contaminants
Minor constituents of made ground including ash, clinker, blaes and tarmac.	Throughout Site associated with buildings, roads, rail lines and underground services	Metals and PAHs
Spillage and leakage associated with process and storage buildings/areas	Shallow soil immediately beneath and outside production and storage buildings/areas, particularly next to entrances and around drains	Explosives, also lead, phosphorus, acids, solvents, carbamite, TPH, inorganics, extreme pH.
Spillages and leakages during transportation of materials	Shallow soil adjacent to roads and railways and process drains	Predominantly explosives, and TPH
Spillages and leakages associated with effluent lagoons	Shallow soil surrounding NC, NG, picrite and tetryl effluent lagoons	Explosives, inorganics and extreme pH
Bulk chemical storage	Various above and below ground storage tanks and drum stores	Predominantly acids and solvents
Burning grounds	Soil at 14 No. burning grounds	Explosives, metals, PAHs, TPHs, SVOCs & VOCs and asbestos
Asbestos-containing materials used for steam pipe lagging	Shallow soil beneath steam mains	Asbestos
Asbestos-containing materials in building fabric	Shallow soils in Georgetown, elsewhere mainly adjacent to buildings	Asbestos
Electrical sub-stations	Soil near oil sumps next to sub-stations	TPH, PCBs
Ash dumps	Main ash dumps, sections of perimeter road, Fire breaks in Georgetown	PAHs, metals
Sulphur dump	Shallow soil at Sulphur Dump in Georgetown.	Sulphur, sulphate and low pH
Coal Storage areas	Surface material	PAHs, metals, sulphur, potentially combustible material

Description	Location and geometry	Contaminants
Controlled and uncontrolled waste disposal	Contents of Boghall Dump, the Vegetation Tip, Netherfield tips 1 & 2, soil around Refuse Coup, former mineral workings in FI GP and around Dargavel Ponds	Asbestos, metals, TPHs, PAHs, explosives
Fuel storage areas (diesel , fuel oil, hydraulic oil, petrol and kerosene)	ASTs and USTs including filling and dispensing areas.	TPHs, PAHs, SVOCs & VOCs, lead
Scrap metal storage	Soil within scrap compounds. Small compounds in production sections and large compounds for 'proved' scrap.	Explosives, TPHs, PAHs, metals, VOCs
White phosphorus filling	Shallow soil in the vicinity of the White Phosphorus Section	White phosphorus, explosive devices, paints
Ordnance breakdown	Explosives residues and explosive devices in Ammunition Breakdown Section and main burning grounds	Explosives and explosive devices
Ordnance storage prior to breakdown	Designated former process building slabs in Factory III, and AFV Depot in Georgetown	Explosive devices
Ordnance associated with Georgetown filling factory	Shallow soil in Georgetown	Explosive devices
Grounds maintenance	Around the main administration building and laboratories	Pesticides and herbicides
Soil gas	Predominantly in the vicinity of peat deposits.	CH <sub>4</sub> , CO <sub>2</sub> , depleted O <sub>2</sub>

**Table 4 – Sources**

A number of devices with depleted uranium (DU) components were tested in the ETF, but the nature of the material and the testing carried out was such that release of radioactive material into the environment is not plausible. For this reason, DU is not considered as a source in the CSM.

The Site was targeted by the Luftwaffe on at least one occasion. The bomb disposal squad recovered 6 No. unexploded bombs and, being an explosives factory, would have conducted a thorough search for any remaining ordnance.

It is considered unlikely that German air-dropped unexploded ordnance remains on the Site and highly unlikely that such ordnance will be discovered in the future. Therefore, German air-dropped unexploded ordnance it is not considered as a potential source in the initial CSM.

### 8.3. Pathways

Based on the findings of this assessment, the following pathways will exist at the Site following redevelopment:

Pathway	Description
Inhalation, direct contact, ingestion	Human exposure to soil e.g. in residential gardens, open space and landscaped areas
Vapour/gas migration in unsaturated zone and underground services	Migration of vapours and gases from contaminated soil and groundwater
Detonation, deflagration, burning	Whereby harm can be caused by explosives, explosive devices, white phosphorus and combustible material
Migration in unsaturated zone	Leaching of contaminants and migration of NAPLs. Soil gas migration.
Surface water runoff	Entry of dissolved and suspended contaminants directly into surface watercourses
Drains	Migration of contaminants in former process and surface water drains, and preferential flow paths along service routes
Shallow groundwater	Migration of contaminants via shallow groundwater
Direct contact	Pathway for contaminant exposure to building materials

**Table 5 – Pathways**

### 8.4. Receptors

Based on the findings of this assessment, the following receptors will exist at the Site following redevelopment:

Receptor	Description
Humans	Residents and workers within the Core Development Area. Workers in the Environmental Test Facility. Users of Recreational Open Space. Neighbouring residents.
Groundwater	Shallow groundwater in superficial deposits and bedrock
Surface Water	Dargavel Burn, Craighton Burn, Cordite Burn, Picrite Drain, Lin Burn and their tributaries. Dargavel ponds.
Property	Proposed buildings within the Core Development Area. Retained buildings outside the Core Development Area. Crops and livestock.

**Table 6 – Receptors**

Construction workers are receptors to contamination but are not considered in the CSM. The UK framework for contaminated land assessment is based on potential adverse health effects resulting from long term exposure to soil contamination. This is because, in the majority of cases, chronic exposure to contamination is more significant than acute exposure, and because the occupational risks are already required to be addressed by the Health and Safety at Work Act 1974 and related legislation.

Flora and fauna has been excluded from the CSM because there are no designated ecosystems on the Site. However, it is acknowledged that there a number of protected species present including bats, water voles, badgers and otters.

## 8.5. Summary of CSM and Potential Pollutant Linkages

The sources, pathways and receptors have been described in the preceding sections. Although each of these elements can exist independently, they only pose a potential risk where they are linked together, so that a particular source (contaminant) affects a particular receptor through a particular pathway. The term pollutant linkage (PL) is used to describe a particular combination of source-pathway-receptor for the preliminary risk assessment.

The data gathered to date indicates that a number of PLs are present at the Site with respect to the receptors outlined above. These are described in the following paragraphs.

### Humans

Humans in the Core Development Area will be potentially exposed to soil contaminants, for example in residential gardens (including via home-grown vegetables), school playing fields, parks and landscaped areas within a commercial development. Ingestion and direct contact are considered plausible for the upper 0.5 m, whereas soil up to 1.0 m depth is considered relevant for vapour inhalation pathways, or deeper where permeable ground conditions are present.

The general public are potential receptors in areas proposed as Recreational Open Space.

The Retained Land, encompassing the ETF, will be enclosed by a 2 m security fence alongside a security patrolled perimeter track preventing human access to this area other than by ETF personnel and authorised visitors. As such, exposure characteristics for workers within the Retained Land will be related to the types of activities that they are likely to be undertake in a working environment. In addition, there are some areas within the Retained land that are used more intensively than others, and so even within this zone the frequency and duration exposure characteristics will differ in different parts of the facility.

Neighbouring properties include Bishopton village adjacent to the Site to the north and east, and various other individual dwellings within 100 m of Site boundary.

### Groundwater

Infiltration of rainwater through soil and leaching of soluble contaminants with subsequent migration through the unsaturated zone is considered to be the main pathway by which contaminants could enter groundwater. NAPLs can migrate to groundwater directly through the unsaturated zone.

Groundwater exists at shallow depth (usually around 0.5 to 1.5 m) in superficial deposits. Shallow groundwater flow is likely to be predominantly towards the nearest local watercourse.

### Surface Water

The majority of surface water at the Site drains eventually into Dargavel Burn, leaving the Site at the southern boundary. Tributaries that flow through the Site into Dargavel Burn include Craigton Burn, Cordite Burn and Picrite Drain. The western edge of the Site may drain around Southbarr landfill into Lin Burn.

According to SEPA, Dargavel Burn upstream of the Site is Class A2 – Good.

Pollutant linkages exist whereby leached contaminants can enter surface water via groundwater, where the flow is indicated to be dominantly shallow. Direct entry is also possible via surface water run-off, site drainage and preferential flow paths in service routes.

### **Property**

Pollutant linkages have been identified where contaminated soil is in direct contact with property, such as proposed buildings in the Core Development Area, retained buildings in Recreational Open Space and Retained Land, and underground services.

## **8.6. Limitations and Uncertainties**

The CSM is based on our understanding of the environmental setting of the Site and the potential for contamination sources to exist. However, there are data gaps that introduce uncertainties in the initial CSM described above. In particular, there are uncertainties surrounding the following:

- The nature and extent of made ground and contamination sources.
- The potential for leaching of potential contamination sources
- The shallow groundwater flow regime.

## 9. PRELIMINARY RISK ASSESSMENT

### 9.1. Introduction

Risk assessment is the essential starting point in managing risks. It provides a structured mechanism for identifying potential problems and making judgments about the consequences.

The purpose of this first stage of risk assessment is to develop a conceptual model for the Site (see Section 8) and establish whether or not there are any potentially unacceptable risks. There are four key stages to assessing such risks:

- **Hazard identification** – establishing contaminant sources, pathways and receptors (the conceptual model)
- **Hazard assessment** – analysing the potential for unacceptable risks (what linkages could be present, what could the effects be)
- **Risk estimation** – trying to establish the magnitude and probability of the possible consequences (what degree of harm might result and to what receptors, and how likely is it. This is usually determined by site investigation)
- **Risk evaluation** – deciding whether the risk is unacceptable

### 9.2. Criteria for Preliminary Risk Assessment

The criteria for deciding if there are potentially unacceptable risks depends on the individual site under consideration and the context of the risk assessment.

The purpose of this report is to determine whether contaminated land poses a constraint to the proposed redevelopment of the Site. Land considered for a change of use, such as Bishopton, is dealt with under the planning regime (whether contaminated or not) with the local planning authority being the regulator. Planning Advice Note 33 'Development of Contaminated Land' provides specific guidance in relation to the role of the planning system in addressing the problem of historical contamination. PAN33 directs planning authorities to be aware of the provisions of Part IIA of the Environmental Protection Act 1990 (The Act) and to ensure that their decisions are consistent with it. This has, therefore, been the basis of the technical assessments undertaken.

Under the Act, 'contaminated land' has a specific definition which relates to the Site being in such a condition from substances in, on or under the land that significant harm is being caused or there is a significant possibility of significant harm to be caused; or pollution of controlled water is being or likely to be caused. Controlled waters are as defined in s30A of the Control of Pollution Act 1974 (as amended) and includes groundwaters and surface waters.

In this context, an unacceptable risk would be where significant pollutant linkages were present at the Site once developed.

### 9.3. Summary of Potential Risks and Recommendations

The PPLs identified in Section 8 have been evaluated in relation to the criteria outlined above and the following PPLs are considered to give rise to potentially unacceptable risks.

Potential pollutant linkages have been identified relating to controlled waters, property and humans, which are all Part IIA receptors. Therefore, if these pollutant linkages were confirmed as existing and found to be significant then the land would meet the statutory definition of contaminated land and, as such, would require to be remediated to ensure that the Site is made suitable for its proposed new uses.

However, the initial conceptual model makes certain assumptions about many of the PPLs which cannot be verified through the existing information, namely that:

- Contamination sources are present and available to proposed site users at concentrations that could cause harm.
- Contaminants are present and leachable, and to an extent that could cause pollution;

In order to refine the conceptual model and fill these data gaps, it is proposed to undertake a site wide intrusive investigation as detailed in the Stage 1 Site Investigation Outline Strategy Report (BAE Systems Environmental, 2005).

The purpose of the proposed investigation is to undertake phased investigations with the first stage concentrating on establishing if the potential pollutant linkages do in fact exist.