Copper in the spoil may bond with sulphur to produce copper sulphide, and reacts with ferric sulphate and water to produce copper sulphate, iron sulphate and sulphur. The sulphur then may bond with oxygen and water to produce sulphuric acid as can be seen in the final equation.

$$Cu2S + 2\ Fe_2(SO_4)_3 + 2H_2O \Rightarrow 2CuSO_4 + 4FeSO_4 + S$$

$$2S + 3O_2 + 2H_2O \Rightarrow 2H_2SO_4$$

From these equations it can be seen that many of the compounds are reproduced, which means that some of these reactions are cyclic. This can make it difficult to stop the reactions, which needs to be achieved fully, to completely reclaim the site.

The effects to humans are very small, apart from the mine workers, who may have inhaled metals through the colliery dust and would have been at far greater a risk underground. The effects of the metals on vegetation can be more damaging. Only species tolerant to the metals and their compounds will be able to locate on the spoil and the species present can identify which contaminants are present. The level of plant mortality depends on the composition of the soil, nitrate levels, organic content, for example. For animals, problems arise when levels in cells or blood rise to toxic levels, having a direct effect on their health. Very little can be done to remove metal particulate matter from a stream.

The area around Prestongrange consists of coarse grass, consistent with that of a coastline, and there is therefore no reason to suspect any high concentration levels are present in the subsoil. If problems were to occur with high metal concentrations, then 'specialist' vegetation may be used to reclaim the area. Examples of such plants include the sweet clover (*Festuca arundinacea*) and tamarisk (*Tamarix pentandra*).

Brick, Tile and Glass

The historical production of bricks at Prestongrange is the best preserved industrial monument with the exception of the Cornish beam engine. The remaining Hoffman Kiln and the foundations of the 'beehive' kilns show the extent to which this industry grew at Prestongrange. The brick, tile and porcelain industry is not as widely known as coal mining for its contaminative effects, but the chemicals used in finishing products and the heat generated through firing can have a detrimental effect on the environment.

Clay was not dug at Prestongrange, it lies too close to the coast and the underlying rock is Carboniferous in age; it was imported from the Upper Birslie Plantation.[10] The site of Prestongrange was used due to its coal resources and Morrison's Haven, at that time a gateway for exporting numerous products from all over the Lothians. Later, the harbour became useful for importing china clay from the south of England, a cheaper and higher quality of clay.[11]

The extracted natural clay from the area around Upper Birslie is known as 'Fireclay' and the formula is [in most cases] $Al_2O_3.Si_2O_2.2H_2O$ being a form of Kaolinite clay. It comprises approximately 40% aluminium oxide, 45% silicon oxide and 15% water. Also included in the clay varying but small concentrations of iron, magnesium, titanium sodium, potassium and free silica.[12]

The metals contained in the clay may be released into the environment and cause their own problems but the main by-product is hydrogen fluoride (HF). This substance which can attack concrete, glass, cast iron and other products containing silica. It is used to increase the porosity of ceramics, polish glass and enamelling which are all processes used in industries that have been located at Prestongrange. Hydrogen fluoride in plants can cause mutations of the roots[13] which may lead to death of the plant. At the Prestongrange brickworks there appears to be no indication of any detrimental effect on the vegetation around the kilns. Where the concrete around the Hoffman Kiln and beehive kilns is cracked, vegetation is attempting to break through from beneath the surface indicating the subsurface is in a reasonably healthy condition.

Aluminium and silica (originally in the form of an oxide) may be leached out of any waste deposited in spoil heaps, and is therefore a potential hazard to the surrounding environment. Heavy metals have been dealt with, but aluminium is also a concern as it may combine with water and oxygen to form hydroxides and acids which in high enough concentrations kill plants.

Glass is also a product of silica and silicates. The production of glass is reported to have taken place at Morrison's Haven from 1697 but lasted only a few years.[14] The process of making glass involves mixing silica (in sand), potash, zinc, and metals for colouring, for example, iron (green) and cobalt (blue). Once mixed, the mixture is heated to extremely high temperatures up to 1600 degrees Centigrade. [15]

Using chemical elements such as iron, cobalt and selenium

in the production of glass leads to problems of heavy metal contamination and thermal pollution in the soil beneath the surface. If there is heavy contamination, as has been seen in St Helens, Lancashire, then it may be necessary to remove some or all of the contaminated material from the site, or treat it with bioremediation techniques on the site in question.

The long history of the Prestongrange colliery site and Morrison's Haven means that there has been much activity on the site and the movement of the ground material means that any contaminants are more than likely untraceable back to one particular industry.

Figure 8 Beehive Kiln

Sulphuric Acid

There are records of sulphuric acid (oil of vitriol) being produced in Prestonpans from 1749 when John Roebuck and Samuel Garbett opened a plant. The primary use of the acid was for the bleaching of linen as experiments had found it to be faster than any other product of its time.[6]

The production of sulphuric acid was hazardous and the health effects on the workforce and the surrounding area could be very damaging. Advancements in methods since the days of Garbett and Roebuck means that production is now safe and environmental concerns are addressed, but the

environmental impact of production in the eighteenth and nineteenth century received little or no attention.

Sulphuric acid is produced via one the following equation sequences.

- *Sulphur burns in oxygen (air) to form sulphur dioxide*

$$S + O_2 \Rightarrow SO_2$$

The gaseous acid is then put into solution, where it reacts with water to form sulphurous acid:

$$SO_2 + H_2O \Rightarrow H_2SO_3$$

Using further oxygen, the sulphurous acid is then oxidised to form sulphuric acid:

$$H_2SO_3 + O \Rightarrow H_2SO_4$$

- *Dissolving sodium trioxide in water*

$$2S + 3O_2 \Rightarrow 2\,SO_3$$

$$SO_3 + H_2O \Rightarrow H_2SO_4$$

Neither of these procedures are one hundred per cent efficient and therefore gases escape into the environment having health effects on both humans and vegetation. The effects of sulphuric acid on humans are extreme. Small drops internally are usually fatal and inhaling the vapour may cause serious lung damage.[16]

Further to this, combined with the production of salt, other harmful chemicals are produced. Sodium chloride (found naturally in seawater), when mixed with sulphuric acid forms sodium bisulphate and hydrochloric acid.[17]

$$NaCl + H_2SO_4 \Rightarrow NaHSO_4 + HCl$$

If sulphuric acid enters a watercourse it will most likely kill all species even at low concentrations and remains in water afterwards as a sulphate.[18] This is also true of hydrochloric acid.

The effect of acid rain is well documented and sulphuric acid is one of its components. Much research has been undertaken into methods of remediating areas affected by acid rain and is available through numerous sources. However, it is not likely to have been relevant at Prestongrange as the local sulphuric acid industry has not been recorded as being present at the Prestongrange site and the production of salt is unlikely

to have produced quantities of acid sufficient to cause environmental harm.

Thermal Pollution

Thermal pollution is not a widely known type of pollution but it can cause change in ecosystems and effect ecology. Heat generated from the brick kilns, and to a lesser extent salt pans, created temperatures up to 1600 degrees Centigrade.

There are no natural watercourses adjacent to where the brick kilns stood, only groundwater. This however will still have an impact on the ecology. Warmer water, and therefore soil, leads to a decrease in dissolved oxygen levels, a decrease in photosynthesis rates and the death of some organisms leads to a higher biochemical oxygen demand.[19] The heat generated would evaporate all water out of the ground within the top few centimetres making life very difficult for shallow rooted plants, mosses and lichens close to the kilns.

Ash from Cockenzie Power Station

When coal is burned to produce electricity, the residual ash left is known as pulverised fuel ash. This substance is grey in colour and has been dumped (legally) along the shoreline from the power station west to the lagoons located to the west of Prestongrange Industrial Museum. (Way-leave along the baronial lands on the foreshore has been given for an ash slurry pipe that is covered over and provides an excellent scenic walkway.) The ash can be found around Morrison's Haven, on the open coastline and also around the area where previously there were railway lines between the beehive kilns and the beam engine – it has indeed been used to level the area now pleasingly covered with grass.

Pulverised fuel ash has much the same properties as coal spoil as it is just the residue after coal has been burned and therefore contains similar contaminants including chlorine, sodium and heavy metals. The ash, however, is relatively inert and in its stable state, as at Prestongrange, is unlikely to cause any environmental problems.

The Local Industrial Railways

Prestoungrange at the time when the colliery, brickworks and Morrison's Haven were fully operational, had railway lines running across the works and to the Haven. Railway land can be highly contaminative, but risks to humans and plants are

less than contaminants from other industries. Oil leaked by engines may have contributed hydrocarbon contamination to the ground but the volumes of any oil dropped around the works are likely to be relatively small and in their liquid phase. The oils will most likely have been saturated by soil or ballast.

If oil were to penetrate the soil there would be a detrimental effect on organisms within the soil and for the soil itself. The effects of oils on the environment have been well documented and information is available from the Scottish and English Environment Agencies[20, 21]. Oil coats the surface of water bodies, thereby reducing the light penetrating the water. This means that algae and plants cannot photosynthesise as effectively and reducing the oxygen level of the water. This combined with the direct action of coating animals and fish may kill whole communities. If the oil releases vapours and large volumes are allowed to build up then there may be risk of explosions, but only if concentrations reach 1% by volume.

Due to the large scale of development at the Prestongrange site, many areas would have been covered with made surfaces preventing oil reaching the natural sub-soil. The lack of freshwater lakes or streams also means that there will have been little or no adverse effect to wildlife. Also, the nature of industry located there contributed contaminants far worse than oil dropped by railway vehicles.

Figure 9 Eastward view of Morrison's Haven, Prestonpans showing land reclamation process

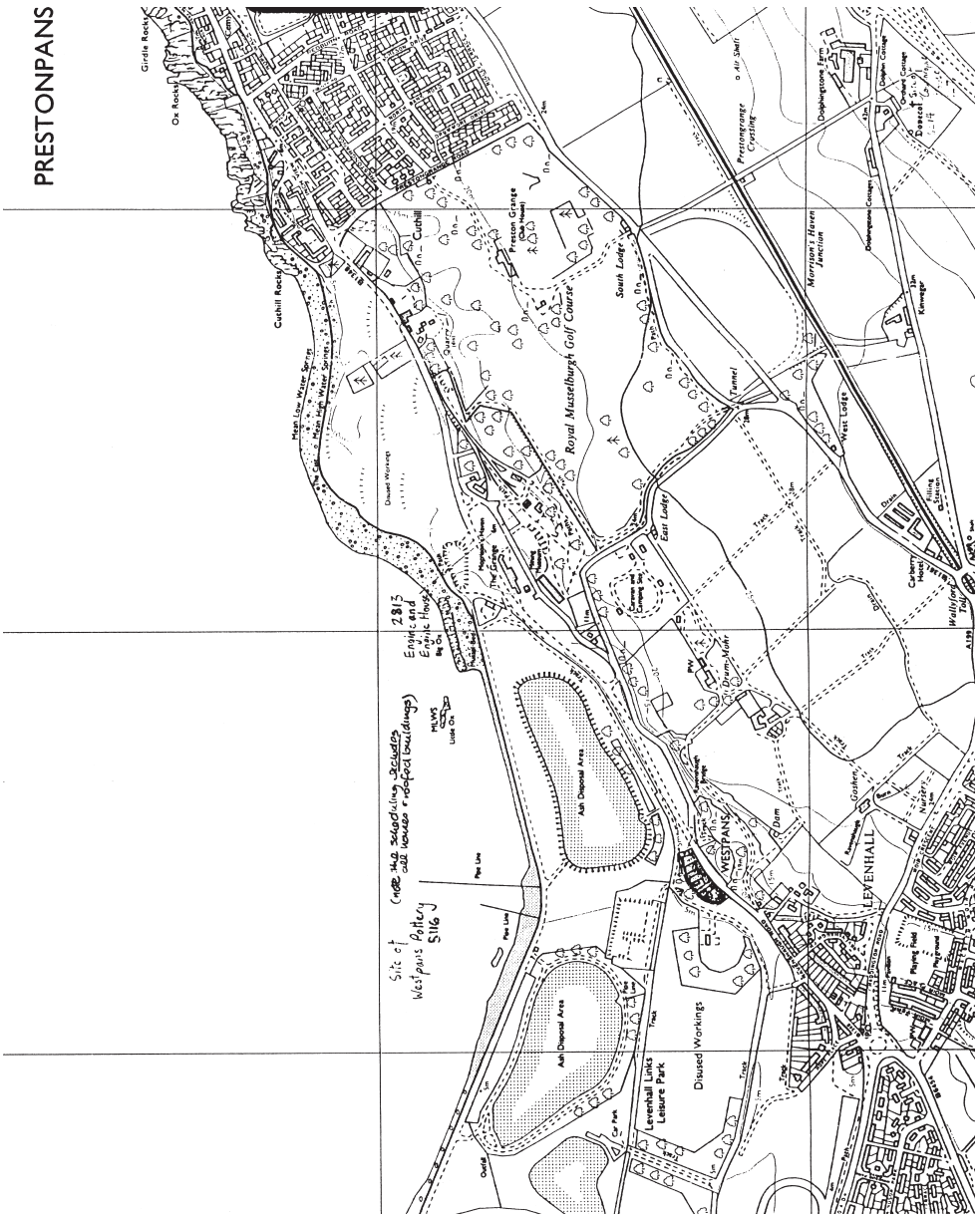

Figure 10 Map showing area where ash has been infilled at Morrison's Haven and new Coastline (compare frontispiece in 1853)

Conclusion

The long past of the Prestongrange Colliery and brickworks and other associated industries had the potential to leave ecological problems for the following decades, even centuries. However, the lack of intensity, arising from a ceasing of activity before the onset of the late twentieth century, has meant that the site remains in a relatively clean state. Work has been carried out to level the site and remove the railway lines and there is the obvious demolition of the beehive kilns, which is an archaeological tragedy. The infilling of Morrison's Haven in 1957[18] was also a tragedy, the Haven being a potent symbol of the site's rich industrial past. Covering of the area with ash from Cockenzie power station has meant that many traces of local industry have disappeared.

The revegetation of the area to the south of the beam engine has undoubtedly helped the site recover from the industrial processes and the site is now undergoing natural processes of reclamation to bring the areas of contamination by coal back to life.

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5. CONCLUSIONS

The Prestongrange works have been fully industrialised for the past 500 years and has the potential to be a highly contaminated site. The environmental impact of industrial activity, however, appears to very small in comparison to what might have been. The areas around the brick kilns and the colliery equipment and the area to the south of works have been layered with colliery spoil and pulverised fuel ash. To reclaim that it was necessary to cover the area with clean topsoil and revegetate it, achieved with alder, birch and grass. Other species have appeared which is a benefit to the area showing the reclamation work carried has clearly been successful and the shallow sub-soil is reasonably healthy.

Overall, the Prestongrange site and the area around Morrison's Haven is in good condition. There is little known about what exactly has been used to fill the Haven. Bricks from the demolition of the beehive kilns and ash from the power station are obvious sources. Whatever has occurred in the past will not be remembered for the pollution caused but for the monuments that remain such as the Cornish beam engine and Morrison's Haven as well as for the history told out in the studies of which this is the tenth.

These historical and analytical studies are already providing the basis for Schools' educational visits to the Museum and for artists to create murals and to reproduce Prestonpans pottery and brickworks artefacts in the years ahead. As the hoped for increase in tourism materialises visitors will find a clean environment in which to enjoy themselves and to appreciate the industrial history of Prestoungrange.