MYNYDD PARYS

&

AFON GOCH

Mynydd Parys & Afon Goch Pages.indd 1 17/09/2014 17:18

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&
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The title *Mynydd Parys & Afon Goch Amlwch* is a reference to two distinct but inseparable locations, situated on the island of Anglesey, North Wales [1].

The *Afon Goch Amlwch River* (or the 'Red River Amlwch') is a small 'ecotoxic' [2] water channel, not more than a few feet in width, which is formed from leachate that gathers in the underground tunnels of the historic copper mine *Mynydd Parys* (or 'Parys Mine'). Emerging in the lower slopes of Parys Mountain (which is little more than a hill, standing 147m above sea level), the *Afon Goch Amlwch River* flows on land for some two kilometres, before passing through the town of Amlwch and into the Irish Sea. This small watercourse provides 'the single largest source of copper entering the Irish Sea' [3] with the result that the *Afon Goch Amlwch River* is one of the most highly concentrated toxic water channels in the UK. Although *Mynydd Parys* ceased to be an active copper mine at the end of the 19th century, and is now a recreational area popular with tourists and locals alike, the mine's great opencast pit and it's subterranean network of tunnels create the conditions necessary for leachate to form the *Afon Goch Amlwch River*, making this industrial relic 'one of the most polluting mines in the UK' [4].

For a brief period in the early decades of the 19th century, *Mynydd Parys* and the adjoining works of the Mona Mine became 'the world's most productive copper mine' [5]. The copper extracted was primarily used to sheath the hulls of ships, protecting the timber from rot caused by worms and limpets. Additionally, the rich mineral ores extracted from the Anglesey deposits could also be utilised for a host of industrial applications, including the manufacture of pigments used in various inks, paints and dyes [6]. Most of the copper ore mined in Anglesey was shipped to the coalfields of Swansea or Lancashire, where it was refined by heating the ore in large kilns – a process known as smelting. During the early industrial period, Amlwch was also host to a number of smelting works, which had a remarkable impact on the surrounding landscape because the process of smelting produced acrid clouds of acid rain. Not only did acidification of the atmosphere kill all plant life in the immediate area; local residents and miners frequently suffered from respiratory diseases such as silicosis and tuberculosis [7]. Whilst today the great opencast pit at *Mynydd Parys* resembles a romantic ruin, it is worth remembering that to the 18th century visitor the vista of the mine would have appeared as a scene of total devastation – literally an ecological dead zone.

If the industrial process of extracting and smelting copper exploited the natural resources of the landscape to the detriment of life forms in the surrounding ecosystem, then the working conditions at *Mynydd Parys* were equally exploitative of the labour force. The miners enjoyed no fixed tenure of employment and were forced to auction their labour, with the lowest bid typically securing the right to work. This oppressive bargaining system 'ensured that wages were kept to the minimum' [8]; should a team of miners underestimate the costs required to excavate a face upon bidding for the work, it was the workers themselves who met the deficit. Furthermore, the miners were permanently indebted to their employers, having to pay upfront for tools and supplies (explosives, candles, fuses etc.), all of which were sold to them at profit by the Parys Mine Company [9]. Throughout the first half of the 19th century, resentment over working conditions at *Mynydd Parys* was a continual source of unrest leading to a series of strikes and violent rebellions in Amlwch, which on more than one occasion had to be suppressed by the state militia [10]. Murray Bookchin's observation that 'the plundering of the human spirit by the marketplace is paralleled by the plundering of the earth by capital' [11] is aptly demonstrated by the example of *Mynydd Parys*. Instead of regarding the great opencast pit as a romantic relic of the industrial past, the site should be more accurately understood as a place of suffering and a continuing source of pollution – a residual wound in the landscape.

The residents of Amlwch have, through the course of many generations, grown accustomed to the presence of the *Afon Goch Amlwch River* in the landscape. The river flows through the town; in some places it passes invisibly, culverted by various shops and pubs. In other places, it meanders openly through housing estates, parks and gardens. Visit Amlwch and talk with the villagers there and you will hear them joke about the 'red river'. Some will tell you how they used to swim in the river as children, and that in the days after their clothes began to disintegrate. Others will laugh as they recall that when a child's bicycle was no longer needed it was dumped into the river, whereupon it dissolved within a month. In 2007, Amlwch had a scare when it was discovered that a concrete drainage adit, which allowed leachate to flow from *Mynydd Parys*, had been closed off and subsequently abandoned when the mine ceased production late in the 19th century. For decades the adit had held fast under the pressure of the dammed water, which had risen to form a small lake within the pit of the great opencast. When local caving enthusiasts from Parys Underground Group (PUG) [12] discovered the sealed passage, they quickly realised that if the adit gave way it would flood Amlwch with devastating consequences. An emergency plan to drain the great opencast pit was undertaken by the Environment Agency (EA) and a range of other partners [13]. Some 270,000m^3 of water was pumped from *Mynydd Parys* to alleviate the problem. Today, when tourists visit *Mynydd Parys* and stop to contemplate the tyres that lie at the bottom of the pit, they have little idea that this debris is all that remains of entire vehicles, which had been dumped into the lake of acidic leachate before it was drained.

The natural propensity of the rocks at *Mynydd Parys* to produce leachate from rainwater, resulting in a highly acidic copper sulphate solution which forms the basis of the *Afon Goch Amlwch River,* is an early example of the far reaching ecological consequences that mining can have on the environment. Whilst new technological and organisational forms of mineral excavation can generate capital in the short-term, the unacknowledged cost of environmental remediation may well prove to be a financial burden for future generations. Some 150 years after the decline of the Parys & Mona Mines, the *Afon Goch Amlwch River* continues to discharge significant amounts of pollutants into

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the Irish Sea (Cu: 10 kg/yr; Zn: 24kg/yr) [14], including highly toxic substances such as arsenic and cadmium. To put this problem into context, *Mynydd Parys* is only one of some 200 metal mine sites strewn across England and Wales [15]. Taking this into consideration, abandoned metal mines can be regarded as the most significant single source of metal pollution in UK river systems [16] today. Moreover, it would be a mistake to regard the problem of metal mine pollution to be solely a result of rudimentary working practices common to the technologies of the Industrial Revolution and thereafter. Presently, the environmental problems exemplified by *Mynydd Parys* are being re-enacted on an amplified scale at mines in South America and South East Asia, to the greater detriment of the environment. Given that the consequences of mining during the Industrial Revolution continue to adversely affect river systems in the UK some 150 years later, one wonders how many centuries it will take to repair the environmental damage caused by contemporary mining activities?

Given that *The European Water Framework Directive* [17] requires the UK to reduce its inputs of metal pollutants flowing into river systems before 2027, substantial new investment is required in order to develop and implement remedial technologies if this target is to be met. For the residents of Amlwch, their uneasy cohabitation with the *Afon Goch Amlwch River* may soon come to an end. In 2007 the marine technology company Siltbuster Ltd. successfully tested a pilot-scale water treatment facility, which extracted somewhere between 96-99% of the metals in solution, whilst the machine also neutralised the pH of the river water. However, with a further 200 sites across England and Wales still awaiting remediation, the environmental implications of metal pollution emanating from abandoned mines remains an issue of great urgency. Recent estimates put the cost of tackling this legacy of industrial pollution at £372 million (based on expenditure over an initial 10 year period) [18]. Given the severe nature of the metal pollution at sites such as the *Afon Goch Amlwch River,* the installation of expensive water treatment facilities which demand high levels of investment and energy to function, would appear to be the only viable solution. At less severely polluted sites, a number of environmentally sympathetic approaches are currently being tested with promising results. The use of reed bed filtration has been shown to be effective for treating coalmine pollution [19], though this approach requires a large landmass, which may not be available in steep upland mining areas. Some recycled industrial wastes can also be effective at filtering metals out of the water [20]; whilst treatment plants are being developed that harness the power of natural bacteria, transforming the dissolved metals into solid metal minerals, which could potentially be recycled [21]. These new methods of remediation may well provide an energy efficient and cost effective solution to the problem of metal pollution emanating from abandoned mines.

The example of *Mynydd Parys & Afon Goch Amlwch* can be considered a warning from history. The residual effects of metal mining can have far-reaching and costly implications for future generations. In the case of *Mynydd Parys*, it is clear that the financial burden of remediating the problems of environmental pollution caused by the *Afon Goch Amlwch River* is a debt that still remains outstanding at the outset of the 21st century.

Isn't it about time that the cost of environmental remediation was factored into the projected profitability of mining operations prior to the commencement of mineral extraction?

[1] [2] [3]

[4] [5] [6]

[7] [8] [9]

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[3] Younger & Potter (2012)

[4] Mayes et al. (2009)

[5] Rowlands (2002, p.29)

[6] Steele & Williams (2010, p.21)

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[8] Steele & Williams (2010, p.23)

[9] Steele & Williams (2010, p.23)

[10] Rowlands (2002, p.115-221)

[11] Bookchin (1986, p.85)

[12] *Parys Underground Group* (2013)

[13] Younger & Potter (2012)

[14] Younger & Potter (2012)

[15] Younger or Mayes

[16] Mayes et al. (2010)

[17] European Commission (2000)

[18] Jarvis and Mayes (2012)

[19] Dean et al. (2013)

[20] Warrender et al. (2011)

[21] Gandy and Jarvis (2012)

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PREFACE

The photographic plates chart the course of the *Afon Goch Amlwch River* from its source in the great open cast pit at *Mynydd Parys*; to the rivers eventual outflow at the now abandoned OCTEL chemical works in Amlwch town.

The *Afon Goch Amlwch River* is formed by the accumulation of rainwater, which leaches from the bottom of the open cast pit into the vast array of mine shafts (some 20km in total), which extend to a depth of 300m below the surface of the pit. As the rainwater passes over the porous rock it comes into contact with

$$FeS_{2(s)} + {}^{7}/_{2}O_2 + H_2O \longrightarrow Fe^{2+} + 2SO_4^{2-} + 2H^{+}$$

pyrite (FeS_2), commonly referred to as ‘Fools Gold’.

In the presence of oxygen and water (and with a little help from bacteria), the pyrite dissolves to form iron and sulphuric acid (H+ and SO_4^{2-}). This sulphuric acid solution also dissolves other minerals as it passes through the rocks, ensuring that the resulting leachate is not only highly acidic (pH 2.4) but also rich in toxic minerals, such as Arsenic and Cadmium.

The photographic series begins by documenting the rich mineral deposits and striking colours of the great open cast pit at *Mynydd Parys*. As the series progresses, the photographs gravitate towards the basin of the pit where tyres and the other remnants of whole vehicles, long since dissolved in acidic solution before the pit was drained in 2007, lie strewn.

In order to draw attention to the process of leaching, which culminates with the emergence of the eco-toxic *Afon Goch Amlwch River,* many of the photographs are accompanied by a scientific analysis of the minerals present within the frame of the image.

The method of photographing whilst simultaneously taking mineral samples is repeated in the second half of the series, as the photographs follow the 2km course of the *Afon Goch Amlwch River*, before it enters the Irish Sea.

The various soil and water samples taken on location were tested under laboratory conditions at the University of Hull, UK. The resulting data was then compared to the United Kingdom’s EQS (Environmental Quality Standard) limits for marine ecosystems and PEL (Probable Effect Levels) for invertebrates.

In the case of each sample, only the minerals that exceeded the environmental standards of EQS or PEL were displayed alongside the image. In the key that follows, which is located on the left side of the gatefold, the maximum safe limit for a given element in the ecosystem is represented by a circle 15mm in diameter. Minerals that are toxic are accompanied by a hazard-warning symbol.

In the centre of the gatefold, the mineral sample results are displayed as an array of coloured circles, which are drawn over a reduced opacity duplicate of the photograph. A reading, in which a given element is found to be present in the environment at twice the EQS or PEL maximum, will have a diameter double the size of the circle in the key (30mm). The circle sizes increase exponentially with orders of magnitude thereafter.

To complete the data results, a pH reading of the sediment or river water documented in the frame also appears on top of the reduced opacity image whilst the 'original' photograph completes the triptych on the right side of the gatefold.

It should be noted that any minerals found to be exceeding the EQS or PEL guidelines can be regarded as evidence of pollutants present in the environment at levels which are harmful to that ecosystem.

In the concluding section of the publication, abridged records of the Environment Agency’s (EA) mineral sample results, spanning a period of three years or more, are displayed in concertina as a continuous stream of numbers. Not only does this EA data verify the results of our own analysis, the sheer amount of data in this fold-out section serves to illustrate the volume of minerals leaching into the Irish Sea annually.

The EA samples were taken from two locations on the *Afon Goch Amlwch River*; the first data set was taken at a site known as the Dyffryn Adda adit, which is where the *Afon Goch Amlwch River* first emerges from its subterranean origins in *Mynydd Parys*. The second series of samples was taken from within the OCTEL chemical works and corresponds to the point where the water channel enters the Irish Sea.

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1 H Hydrogen																	2 He Helium
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium											13 Al Aluminium	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Caesium	56 Ba Barium	71 Lu Lutetium	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium																

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ENVIRONMENTAL QUALITY STANDARD

Environmental Quality Standard (EQS) is the concentration of a particular pollutant or group of pollutants in water that should not be exceeded in order to protect the environment.

PROBABLE EFFECT LEVELS

Probable Effect Levels (PELs) define concentrations of contaminants in sediments above which adverse biological effects would be expected.

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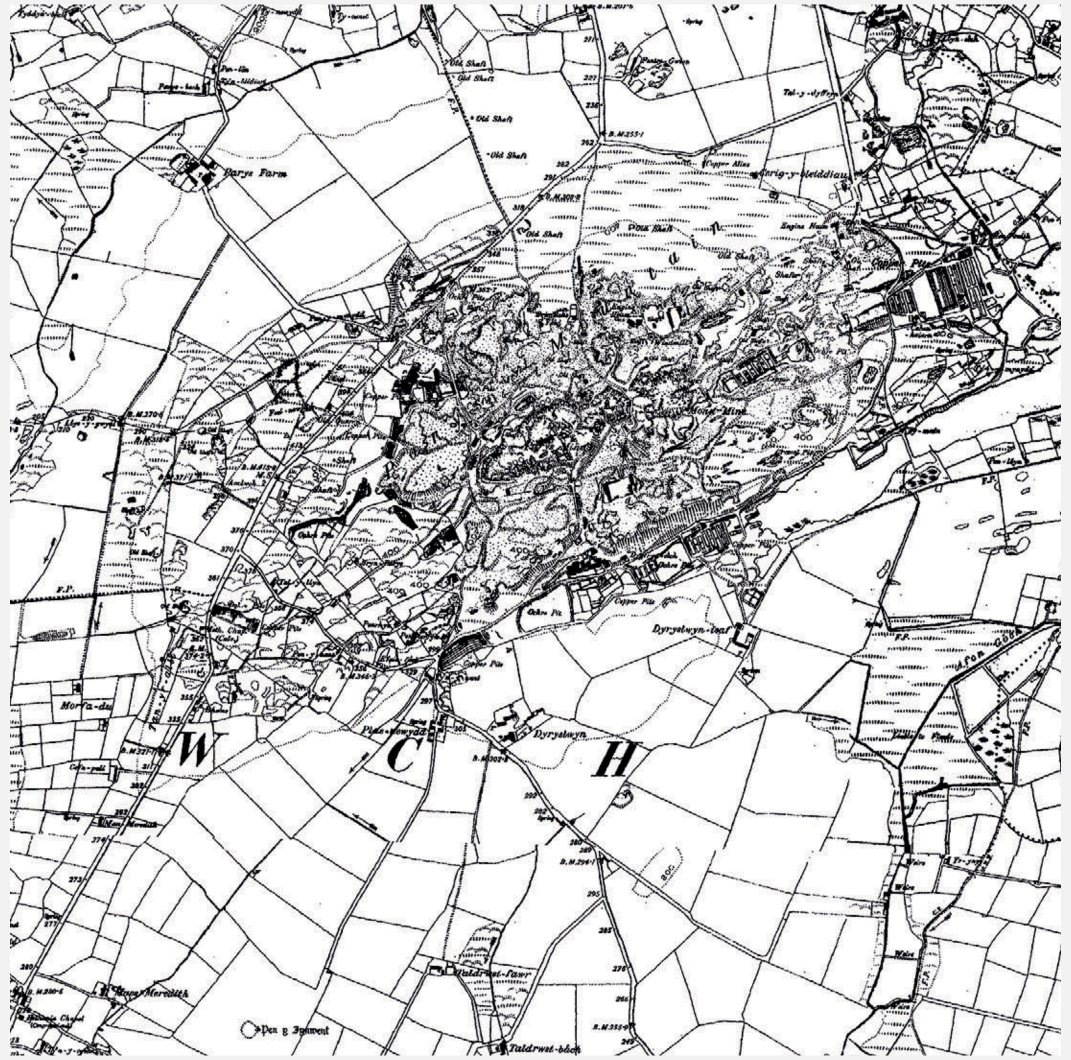
MYNYDD PARYS



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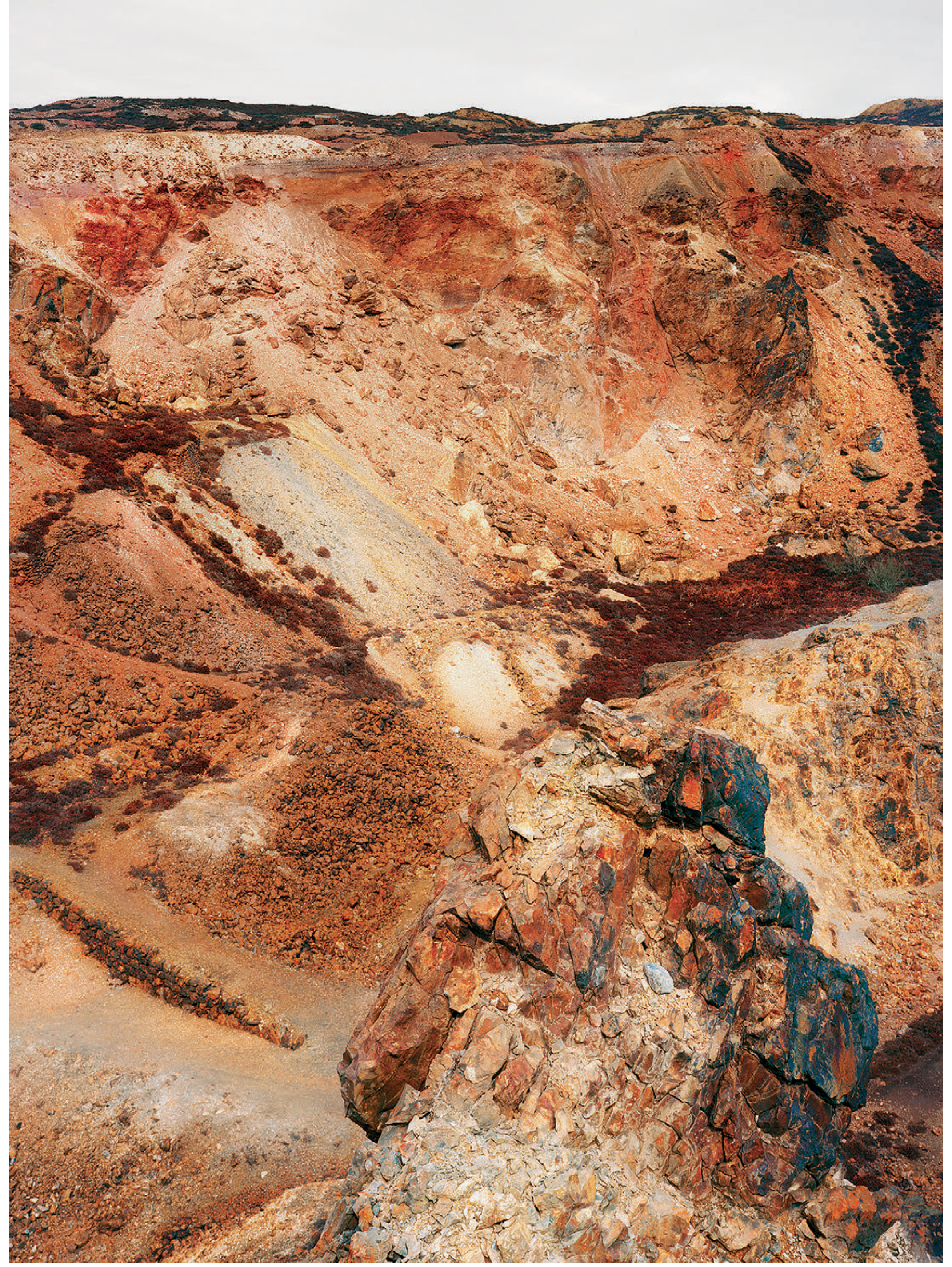

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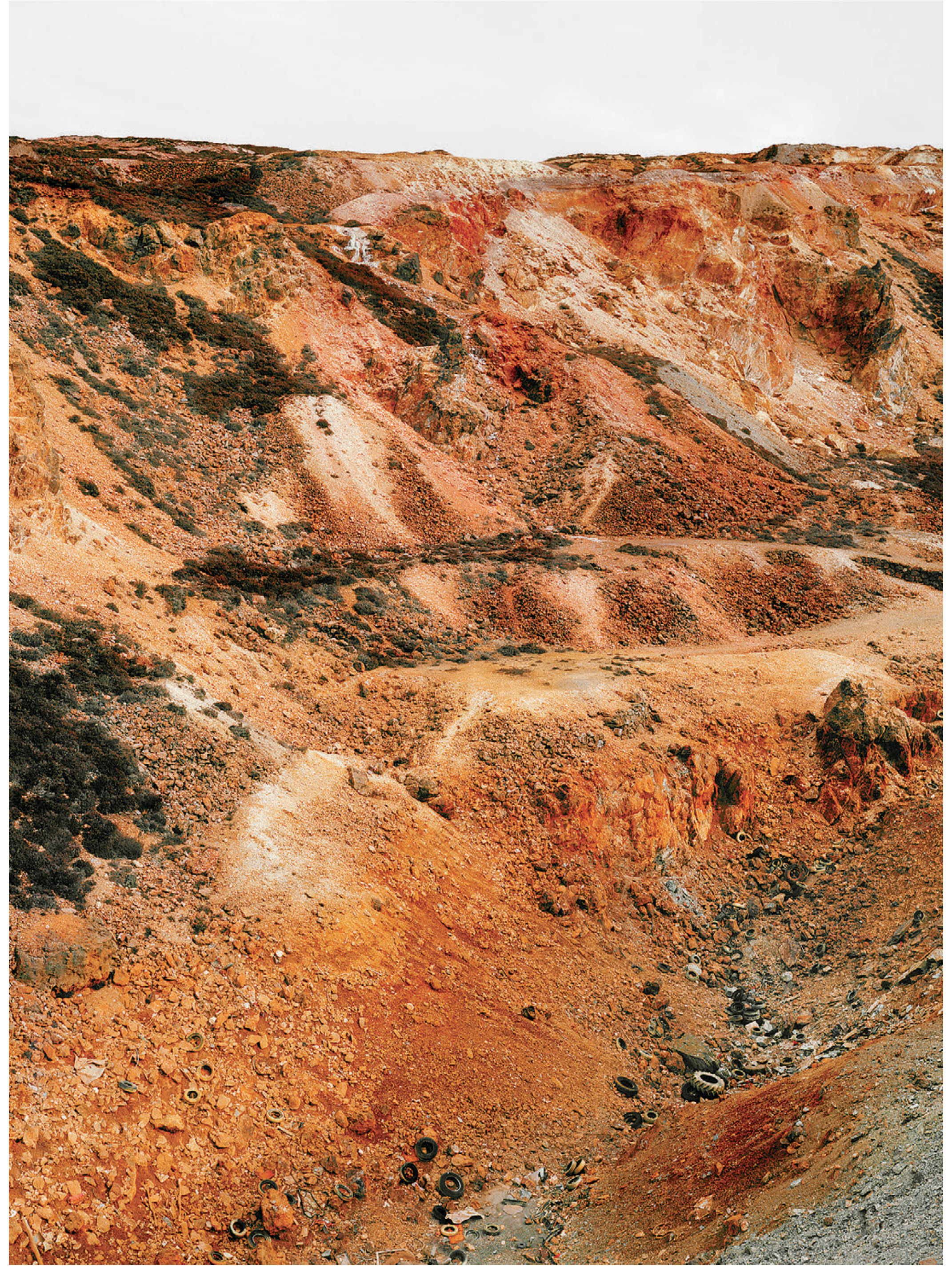

197 mg/L

Cu

17 mg/L

As

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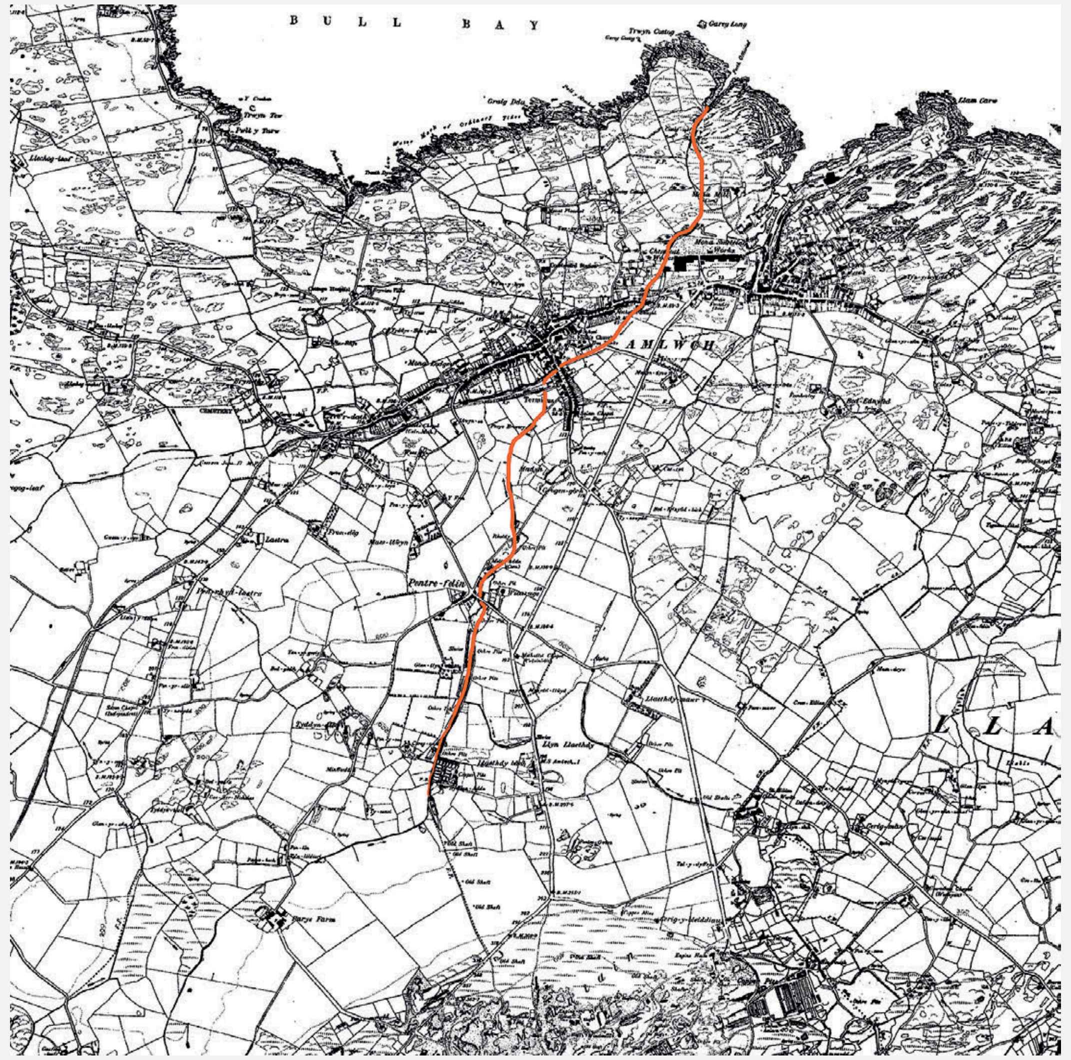
AFON GOCH



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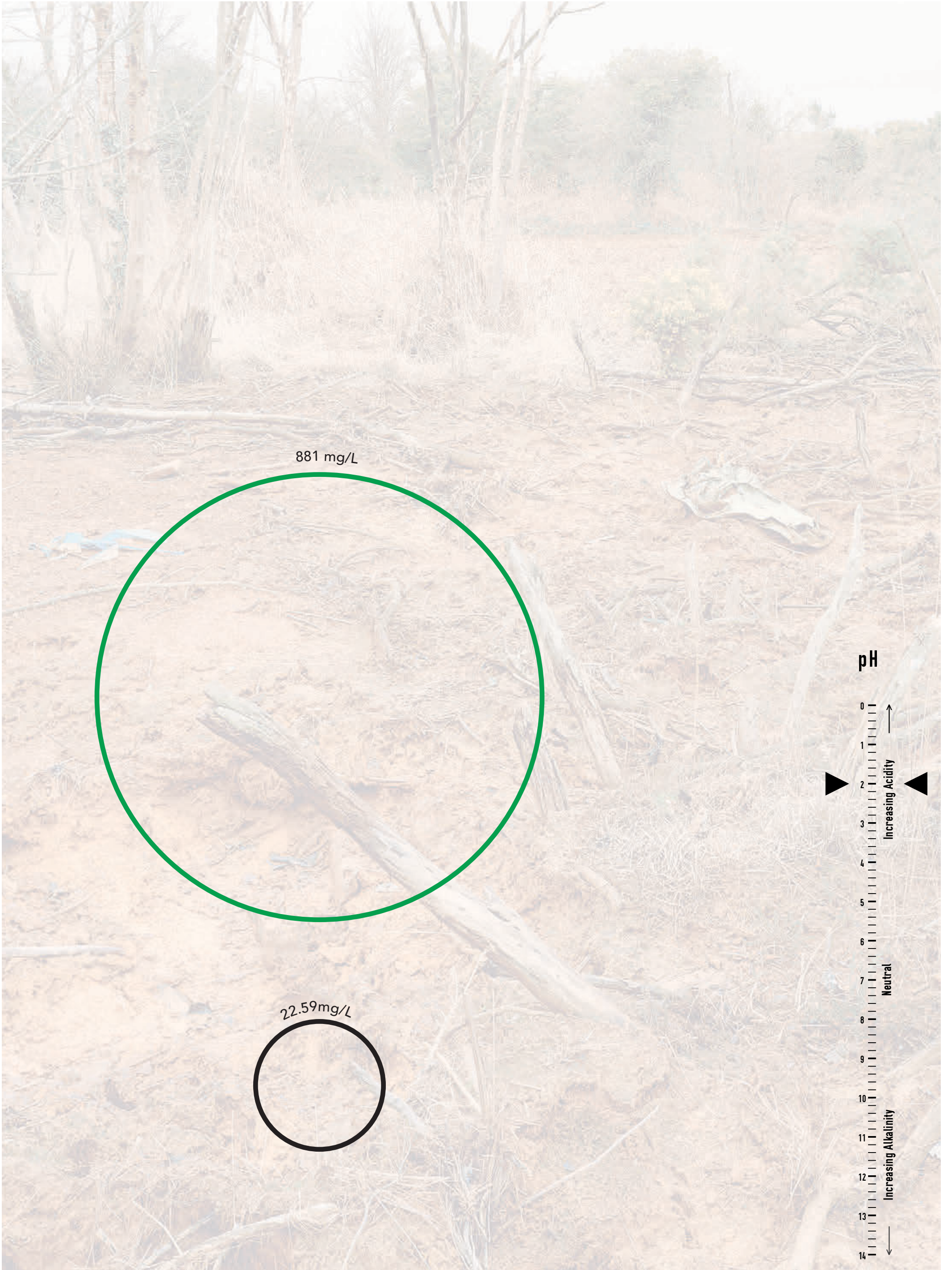
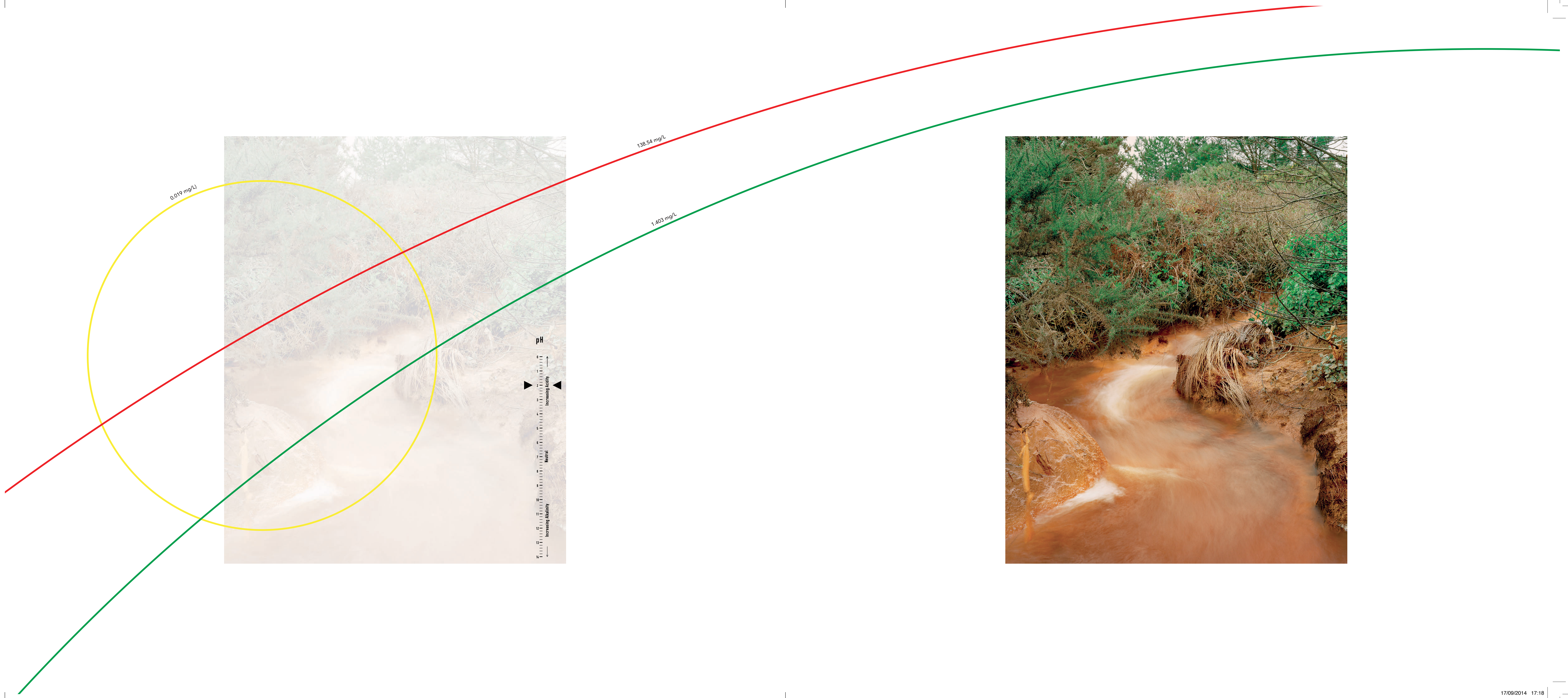
197 mg/L

Cu

17 mg/L

As





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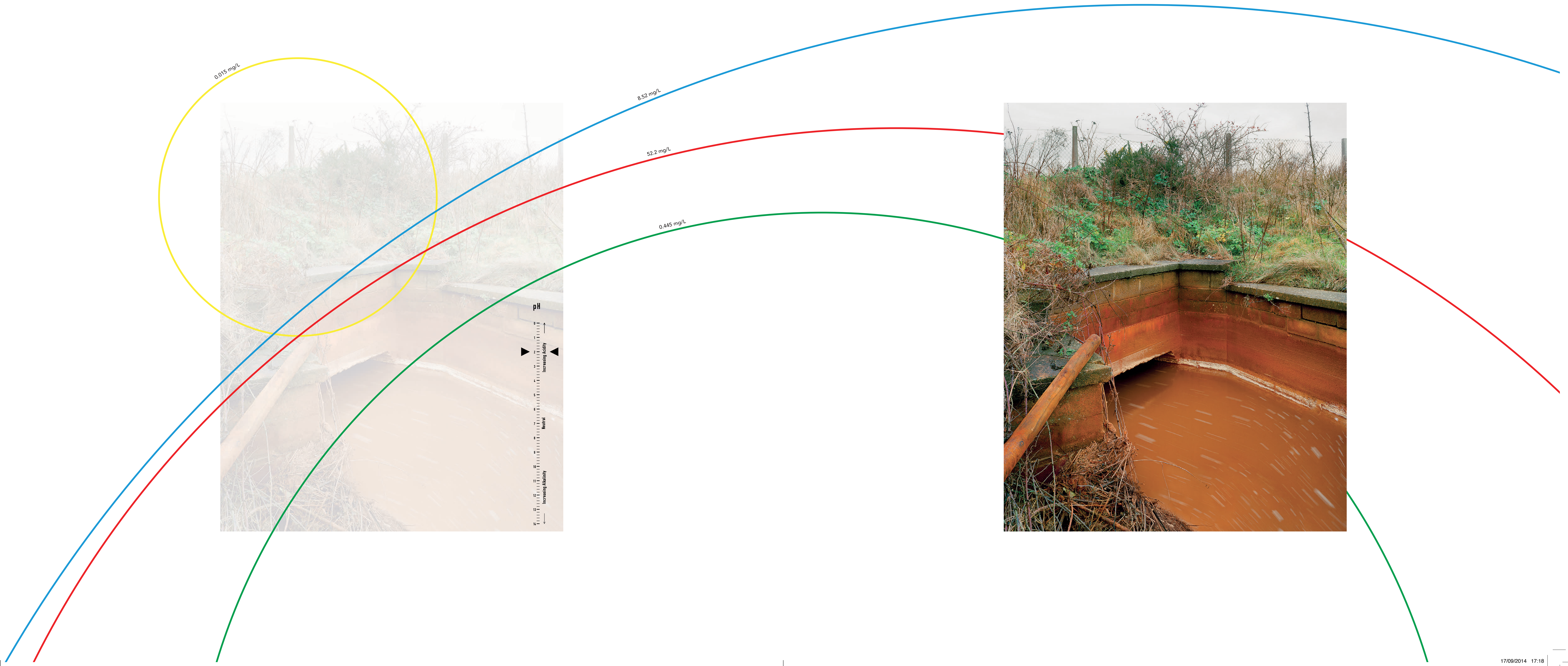

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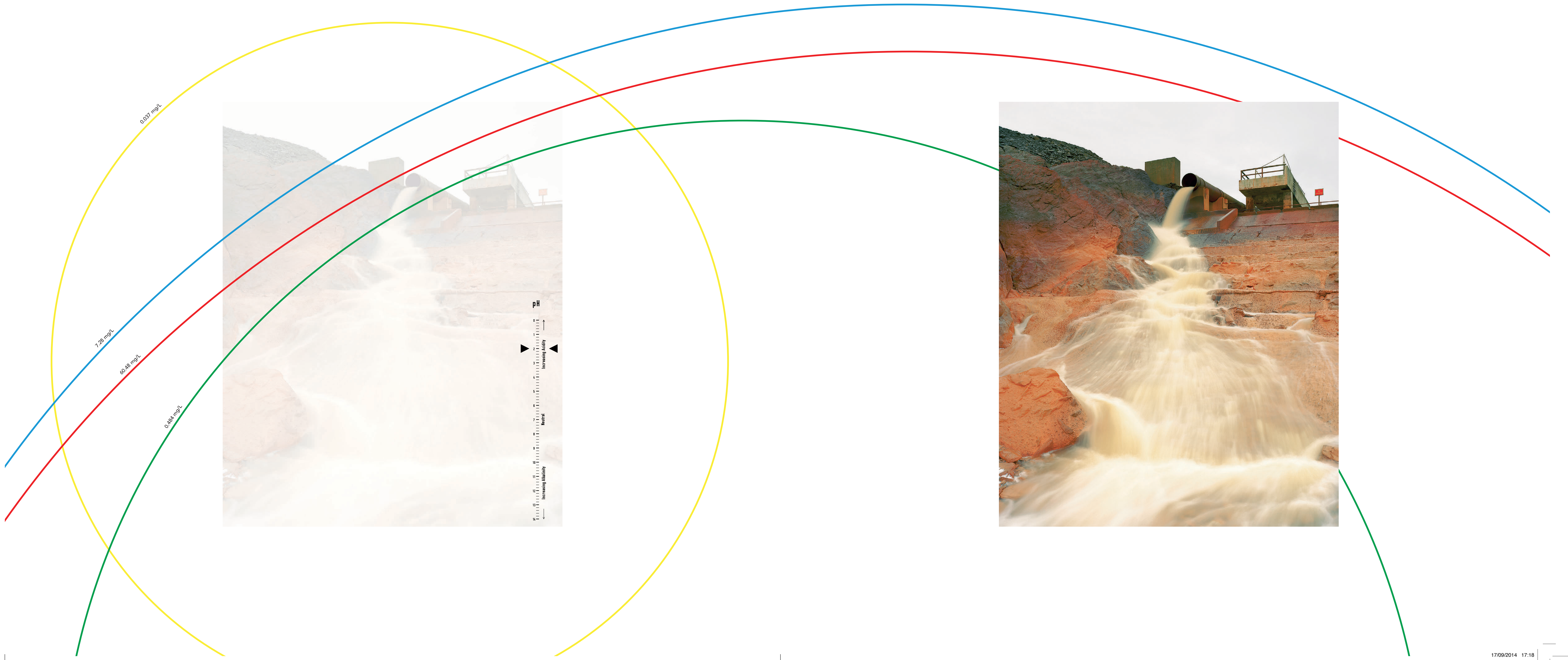
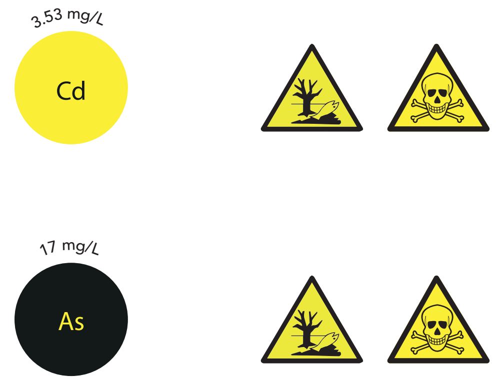
0.12 mg/L
Zn

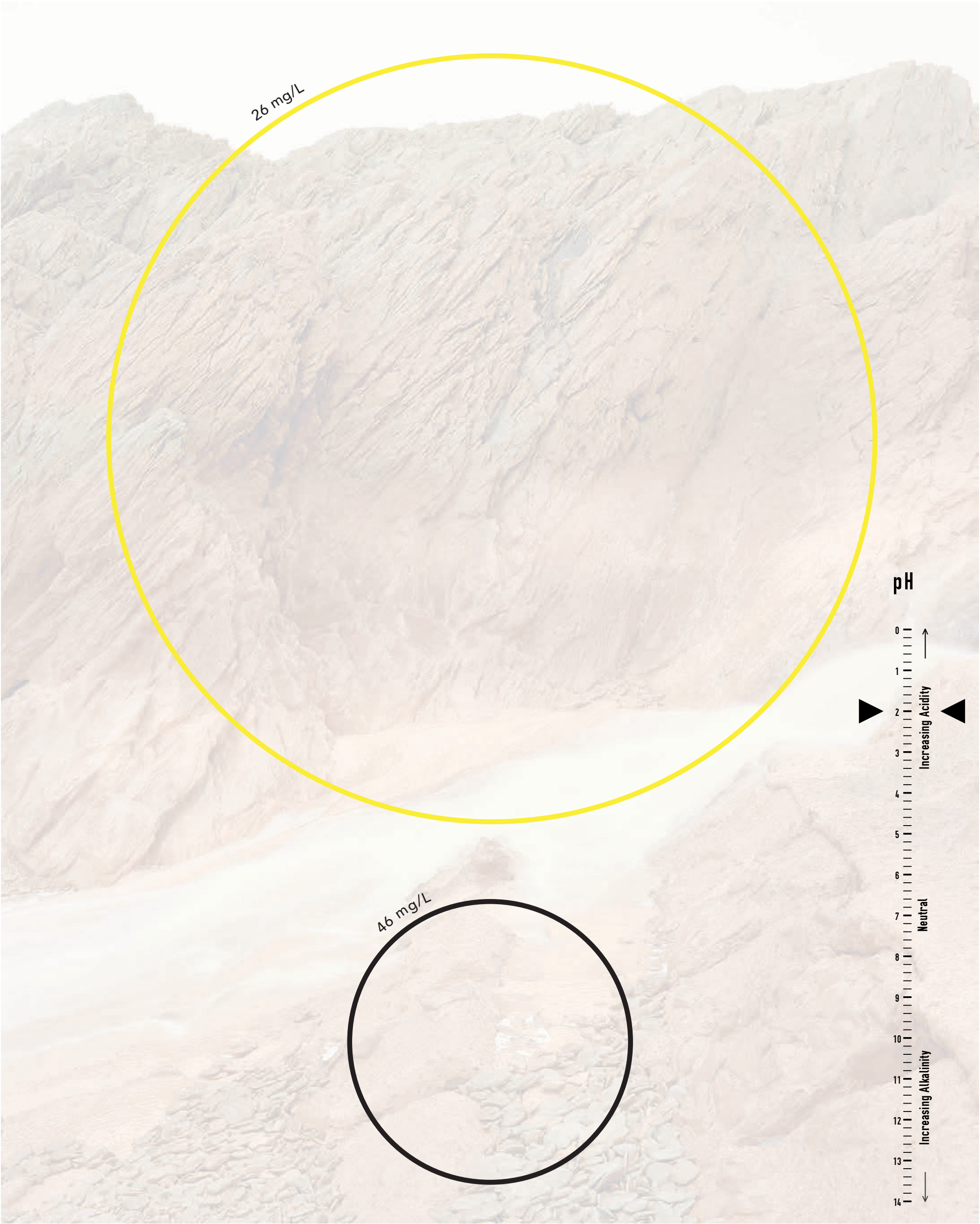
1.0 mg/L
Fe

0.013 mg/L
Cu

0.002 mg/L
Cd







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AFON GOCH AMLWCH (OSPAR STATS)

Annual tonnage of metals released to the Irish Sea

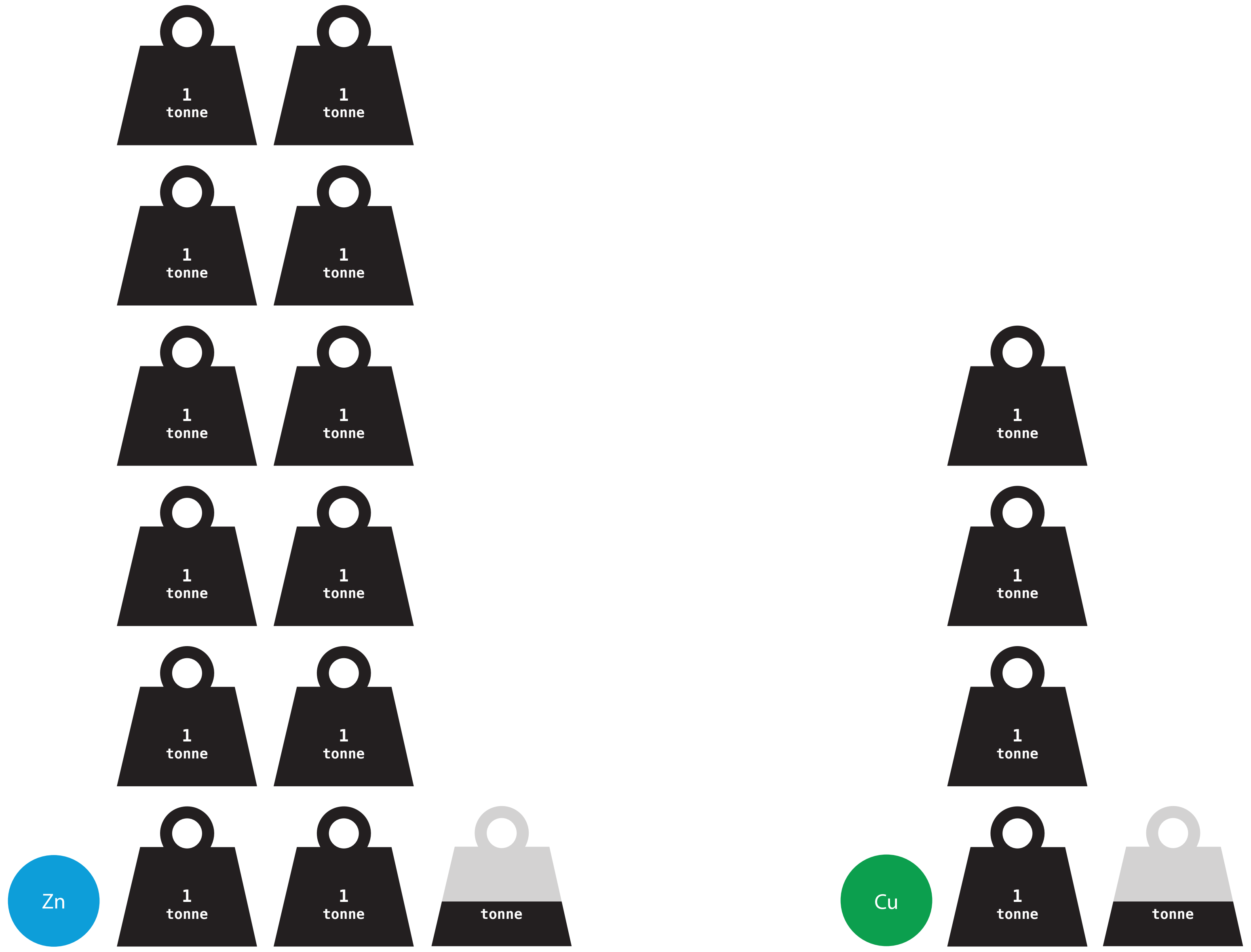

Image courtesy of ESRI, 2014

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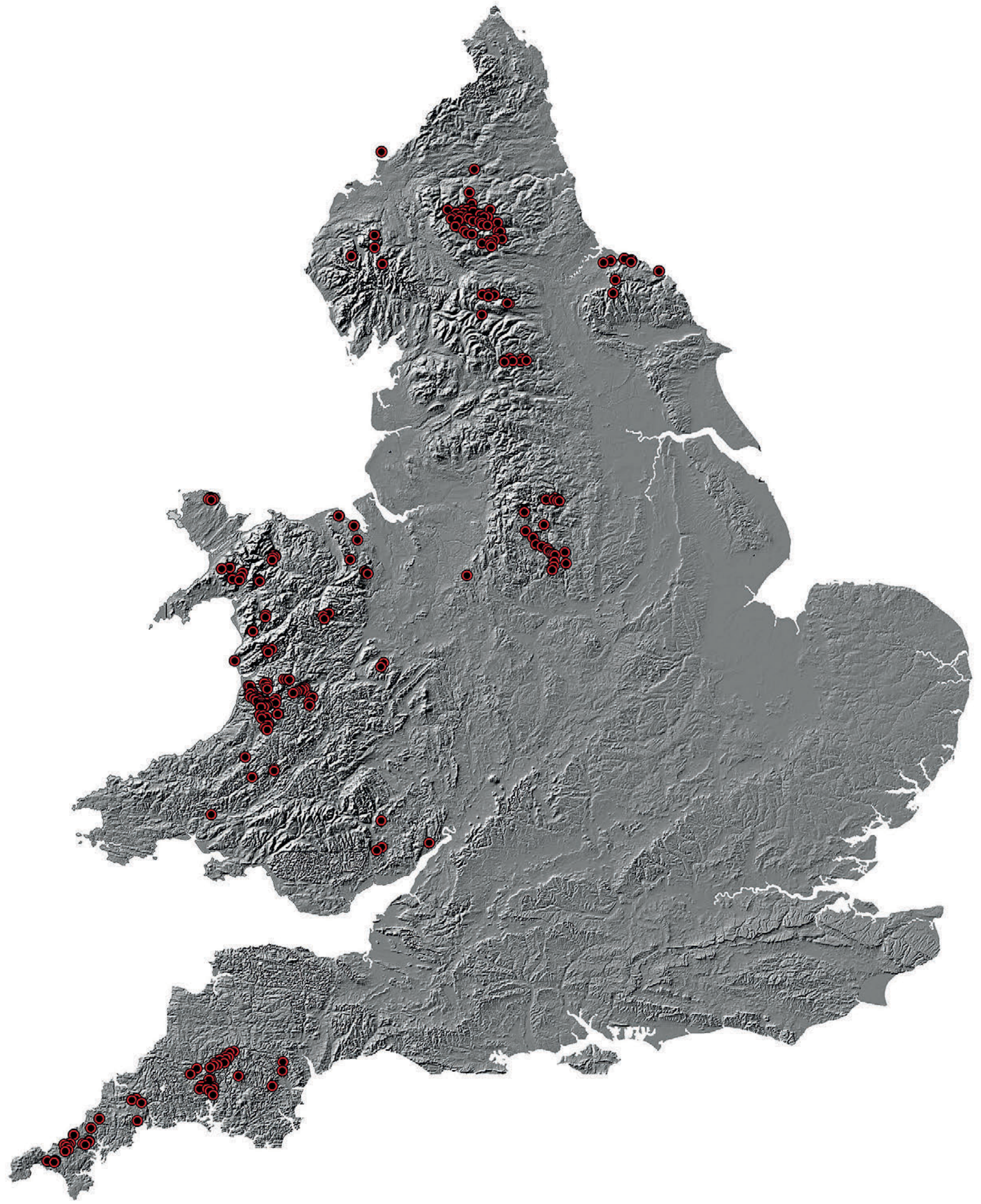

REGION	RIVER NAME	HIGHEST PRIORITY LOCATIONS REQUIRING REMEDIATION
Western Wales	Rheidol	Cwm Rheidol Adit 6 & 9, Tynyfron
Western Wales	Tywi	Nant Y Mwyn Upper and Lower Boat Adit
Western Wales	Gain	Afon Gain, Gelli Gain, Level Moel Yr Wden, Bwlch Y Fford
Western Wales	Goch Amlwch	Mynydd Parys: Dyffryn Adda Adit, Morfa Ddu Adit
Dee	Clywedog	Minera complex: Park Day and Deep Day Levels
Western Wales	Melindwr	Melindwr: Bwlch Adit, Goginan drainage
Western Wales	Llechwedd-Mawr	Llechwedd-Mawr: Copper shaft Adit A & B, East Level
Western Wales	Mawddach	Gwynfynydd Gold mine
South West	Carnon River	County Adit, Wheal Maid Tailings Dam
Western Wales	Meurig	Esgair Mwyn Tailings, Esgair Mwyn Adit, Nant Garw, Llwynllwyd Adit
Western Wales	Goch Dulas	Dyffryn Coch, Mona Adit, Mona / Henwaith Ponds, Southern Lagoon
Western Wales	Twymyn	Dylife
South West	Hayle	Hayle
Western Wales	Teifi	Cwm Mawr Adit, Cwm Mawr Stream, Abbey Consoles Stream 1 & 2
Northumbria	Saltburn Gill	Saltburn Borehole and Tributary discharges
Western Wales	Bow Street Brook	Mynydd Gorddu
North West	Newlands Beck	Force Crag Adit 0 & 1
South West	Lanivet Stream	Lanivet Mine discharge
Humber	Loxley / Hobson Moss	Loxley Bottom, Ughill, Stubbing, Storrs Bridge, Low Matlock, Studfield, Wisewood
North West	Crake (Yewdale Beck)	Coniston Mines

Sources of abandoned metal mine river pollution in England & Wales (after Mayes et al., 2009)

ENVIRONMENT AGENCY DATA

Dyffryn Adda Adit
02-03-2004 – 17-09-2013

Afon Goch Amlwch
23-04-2001 – 17-09-2013

EA mineral sample results:

Iron (Fe)	1.0 mg/L
Copper (Cu)	0.013 mg/L
pH (units)	pH 0-14
Cadmium (Cd)	0.002 mg/L
Sulphate (SO4)	An indicator of metal mine pollution
Arsenic (As)	0.120 mg/L
Aluminium (Al)	Toxic to fish under acid conditions
Nickel (Ni)	0.02 mg/L

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03-02-2004 2.71 0.159 2130 0.3554 508 44.4 0.171 03-08-2004 2.67 0.169 2630 0.3173 583 41.8 0.182 03-15-2004 3.0 0.168 1940 0.2530
453 75.7 39.9 0.193 03-22-2004 3.08 0.175 2400 0.1291 559 75.2 38.5 0.195 03-29-2004 3.04 0.176 2460 0.2520 574 70.2 36.6 0.196 04-05-2004 3.05
0.178 3020 0.1984 708 71.1 35.4 0.203 04-19-2004 2.98 0.177 2610 0.2215 547 67.9 31.6 0.186 05-04-2004 3.07 0.178 2450 0.1897 568 30.6
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