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Disaster in agriculture: or foot and mouth mobilities

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Abstract. This paper is an exploration of the dynamics of the outbreak of foot and mouth disease in the United Kingdom in 2001. Following Perrow's analysis of the catastrophic breakdown of technological systems, the author treats the UK agricultural system as a set of flows that are both tightly coupled and complex. This suggests that the stability of the agricultural system is precarious, and that when it is disrupted (as it was with the arrival of the foot and mouth virus) the consequences may be large scale and catastrophic. The foot and mouth outbreak, and more generally, aspects of global agriculture, are thus understood as 'normal accidents'.

Introduction

The US Army Corps of Engineers has been reengineering the Mississippi and its tributaries for nearly a century, cutting off meanders, building dikes, creating revetments, dredging it, and building dams on its tributaries.(1) This is engineering on a heroic scale. Only the Amazon and the Congo have larger drainage basins. The Mississippi's drainage area covers 1245 000 square miles, 41% of the continental USA. But if the scope of the engineering has been heroic, then so have the reasons for attempting it in the first place. The first and original object was to try to prevent large-scale flooding. There were six major floods between 1849 and 1927. It was the last of these that led to the Mississippi flood-control project in its contemporary form. A second major aim was to render the channel navigable. For this is one of the USA's vital economic arteries: 30 million tons of freight were carried in 1940, and over 400 million in 1984. Barges move through twenty-nine locks between Minneapolis and St Louis and carry a fifth of the USA's coal, a third of its petroleum, and countless other commodities. And third, the intention was to release the floodplain for agriculture and settlement. Since 1940 about four fifths of the original floodplain has been drained and is economically productive. Many tens or hundreds of thousands of people live in areas that were previously subject to flooding.

In 1993 it all went wrong. A combination of factors including high rainfall and already waterlogged ground led to a major flood. The Mississippi rose (at St Louis it was at flood level for 144 days), three billion cubic metres of water broke through the levées and seventeen thousand square miles of the previous floodplain were submerged; 26 000 people were evacuated, fifty died, and 53 000 homes were damaged. The direct economic cost of the disaster was in the region \$10 billion – \$12 billion. Indirect costs were much higher. Ironically but not coincidentally, a larger disaster was averted by the failure of the dikes, because this released pressure and flow downstream.

Why the disaster? I have mentioned the unusual weather: high rainfall, waterlogged ground, and an unusual rainfall pattern—all of these played a role. But so too did the flood-control works, the heroic efforts of the Corps of Engineers to avoid disaster in the first place. Question, then: did *they* fail? Any response to this question is controversial.

(1) This is the topic of a fine 1994 BBC *Horizon* programme, "After the flood". See also US Army Corps of Engineers (2003), Walker et al (1994), Larson (1996), and Johnson et al (2003).

The Corps and its supporters deny any failure. It had been asked to design and build a system that would control a flood 11% larger than the one of 1927 and this is what it had done. The 1993 flood *was* larger than the design allowed. It was a flood in a 100 years. Engineering, they argue, is a matter of cost and specification. If you were to spend enough money you could build a flood-control system that would only be overwhelmed, say, every 1000 years, but this is not what the Corps had been asked to do.

Critics, however, say yes it did, it did fail. Or rather, it is argued that it did not fail as an organisation as such, but that the whole *idea* of trying to control the flows of nature on such a gargantuan scale is flawed. Critics make this argument for two reasons. First, they note that in due course there *will* be the one-in-a-thousand-year flood. And, second, they suggest that river engineering does not just *control* floods but it also *contributes* to them in the first place, and that it does this in at least two ways.

First, if you shorten channels by taking away the meanders, then you increase the river's gradient and it flows more fiercely. But the river engineers add that it, the river, does not like this. It tends to want to return to its original state. So it is constantly trying to recreate meanders and slow itself up. It *tries* to wander about more. Hence the need for revetments—and the constant need to maintain these. Engineering is, so to speak, constantly struggling against (a particular version of) nature.(2)

And, second, wetlands act like blotting paper. They absorb water fast and release it slowly. If you take them away, then rainfall is delivered much more quickly into the river system. Flooding is more likely. You can, yes, engineer possible solutions to this problem. For instance, you can, as the Corps of Engineers has done, create dams on tributaries. Indeed you can allow controlled flooding, as is done on the Colorado, and on the lower reaches of the Rhine in the Netherlands (see Directorate General of Public Works and Water Management, 1999, page 17). But the critics argue that the system is not self-correcting. In due course something *will* go wrong.

My topic is not river engineering as such, but I start with this story because it very directly and materially illustrates several crucial issues that arise in the social and technical engineering of the *materialities of flows and mobilities*. First, it straightforwardly exemplifies a widely appreciated modernist paradox. On the one hand, there is the technical and social capacity to intervene and remake the environment on a large scale. Indeed, there are good reasons for doing so. The economic success of the USA, not to mention the lives and livelihoods of many of its citizens, are in part a consequence of the work of the Corps of Engineers. But, on the other hand, it illustrates the way in which the capacity to intervene also has its downside. Attempts to avoid disadvantage and disaster also help to generate the very conditions for disaster in the first place. The cliché is that we live in a 'risk society' (Beck, 1992; Beck et al, 2003).

Second, I like the story precisely because it is very literally about flows and mobilities. Though it has its limits as a metaphor, it also helps me to think about flows that are, so to speak, less literal, or at any rate less easily seen. My contention is that we are not terribly good at doing this. In particular, I suggest that we are not terribly good at understanding the materialities and the paradoxes of those flows, the dikes and the revetments of globalisation, the precarious barriers and immobilities that are also entailed in the social engineering of flow. Some of the paradoxes here are obvious. Notoriously, capital flows whereas (perhaps because) people are stopped. But the barrier conditions for, shall we say, world trade, are complex, subtle, and fraught with more

(2) I want to avoid the assumption that there is a natural state of being, a 'natural' nature out there. No doubt there are many different natures, and this is one of them, one that has been created in the process of trying to engineer the river.

or less invisible risks. And this, for a particular case, that of the flow of animals and animal products, is my topic.

This, then, is my bottom line, and I borrow it from Marxist-inspired geographers such as Massey (see Massey, 1999). Flows *require* barriers. The barriers help to increase differences in level, high and low, the differences in level provide the energy that, for instance, drives world trade. Barriers keep out people, but they also distinguish between the different kinds of nonhumans. And they are risky and ambivalent not only for those who are excluded, but also for those privileged enough to live on the now-drained flood plains.

My argument is that the 2001 foot and mouth epidemic in the United Kingdom illustrates the ambivalent dangers of large-scale fluid engineering. Foot and mouth, then, is my topic.

Global flows and barriers

The particular strain of foot and mouth that came to the United Kingdom in 2001 (there are lots of others) was first identified in Central India in 1990. How did it arise? No one knows. But viruses mutate, and those that mutate successfully parasitise their way along other displacements and flows. For foot and mouth the following are important: wind (though usually fairly locally); the movement of infected animals (any distance); direct contacts between animals (close proximity); shared pasturage; the distribution of meat or meat products that circulate through the networks of trade (again any distance); and human contact when people have been previously in close contact with infected animals (variable, but usually fairly local).(3)

Really effective microorganisms do not kill their hosts, at least not very quickly (see Diamond, 1997; McNeill, 1979). They need to infect more than one other host before they do so. And foot and mouth, though considerably nastier than the common cold, especially for pigs and cows which often suffer very severely, mostly does not kill its hosts(4). It is very successful, and it is also very, very infectious. So if the carriers and the flows that it needs for its movement are available, it spreads. As I have noted, the specific strain that came to Britain in 2001 appeared in central India, in 1990 (The Royal Society, 2002, page 44). By 1995 it had spread across much of India, and by 1998 it had inserted itself into the international trade in animals and meat products and was moving much more quickly. It had turned up in Malaysia, in a number of the impoverished countries of East Africa, and in Iran, Iraq, and Turkey. By 2001, instead of coexisting with other versions of foot and mouth in areas where the condition was endemic it had appeared in a number of countries that had been free of foot and mouth for a number of years, including South Korea, Japan, and the United Kingdom.

Global material flows imply the (attempted) creation of global and equally material barriers. Some of these barriers have to do with microorganisms. The foot and mouth virus is unwelcome anywhere, but it is most particularly unwelcome in countries that have been certified 'disease free'. But such classifications do not exist without an elaborate apparatus for their production. So what is that apparatus?

The answer takes us into a series of international organisations including especially the EU, the World Trade Organisation (WTO), and a body called the OIE,

(3) People do not catch the disease though they may act as vectors (carriers) for the virus.

(4) Sue Wrennall notes (private communication, Lancaster University) that the phrase 'mostly doesn't kill its hosts' perhaps derives from scientific discourse, and misses out on the materialities of the disease and possible ways of nursing it. Nursing an animal through the disease may be possible, and indeed economically necessary in the Third World if the farmer has very few animals. The situation is very different in the First World. For a careful history of the evolution of foot and mouth in the United Kingdom from nuisance to serious pest see Woods (2004).

the Organization International des Épizooties.[5] In their different ways the EU and the WTO try to regulate trade. Both are committed to the absence of specific trade barriers (though, as we know, this implies fierce barriers in other places). To the extent that trade involves animals and microorganisms the two organisations follow the advice of the OIE. The OIE lists notifiable animal diseases both in order to limit their spread and to help in their eradication. It is not too much of an apparatus or an organisation in its own right. Though it was set up in the 1920s it is pretty much dependent on the advice and the expertise of selected national veterinary laboratories. One of these, a world reference laboratory for foot and mouth, is the Institute for Animal Health at Pirbright, near Woking, in the United Kingdom.

With the help of its reference laboratories, the OIE looks at each country (or sometimes each region within a country) and each disease to determine if it is present. For foot and mouth countries fall into one of three classes. In descending order of merit these are: (a) disease free *without* (routine) vaccination; (b) disease free *with* vaccination; and (c) disease endemic.[6] This classification is hugely consequential because it regulates trade, the flows of animals and meat products. Countries (or areas) that are disease free without routine vaccination may export their animals anywhere. Those that not are much more restricted. They may send meat to disease-free and nonvaccinated countries, but only if that meat is taken off the bone under specified conditions. But to play this game in the first place, to aspire to disease-free status, the OIE also needs to be persuaded that a country has reliable systems for disease surveillance, reporting, control, and eradication—together with an independent state veterinary service (The Royal Society, 202, page 40). Some states, it is clear, do not even qualify to play.

Which are the countries that are disease free without vaccination? The answer is unsurprising. In recent years these have been the member states of the EU, the USA and Canada, a number of Pacific rim countries including Australia and New Zealand, and, though more precariously, Argentina. Where there is wealth, and the agricultural practices and state apparatuses to match, then there is no foot and mouth. And neither is there (need for) vaccination under normal circumstances.

The OIE/WTO rules of trade act like a dike around these privileged areas. Animals may flow out but not in. This division between the inside and the outside brings several kinds of economic advantage for those within. First, as we have seen, trade is relatively unregulated, much freer. One consequence is that markets are larger and animals and animal products are worth more. A series of consequential investments follow on from this. In particular, animals are bred—and fed—for productivity. Second, the costs of the disease itself are avoided and, in particular, the loss in weight and in milk production that follow infection. Third, the cost of vaccination is avoided. Indeed, it was on this basis that a disease-free nonvaccination policy was adopted in 1991 by the whole of the EU. Before this date this was the policy of only the United Kingdom, Ireland, and Denmark.[7] In preparing for the Single European Market the EC commissioned a cost–benefit analysis of this strategy. This came down in favour of stamping the disease out, and working up contingency plans for the expected occasional outbreaks.

(5) This is discussed in The Royal Society (2002), and especially chapter 3.

(6) Vaccination is important for this classification because, at least until very recently, the laboratory tests for foot and mouth have been unable to distinguish between animals that have suffered from the disease, and those that have been vaccinated. This is starting to change, and scientific innovations (which make it possible to distinguish between structural and nonstructural proteins) may have substantial implications for the flows of world trade. (See The Royal Society, 2002, page 99).

(7) For details of the evolution of British policy and its links with specific scientific and agricultural interests, see Woods (2004).

And, indeed, at least until 2001 this policy turned out to be economically justified. Between 1991 and 2001 there were four small epidemics, one in Italy and three in Greece. These cost about €30 million to eradicate, whilst routine vaccination would have cost €1 billion (The Royal Society, 2002, page 90). After 2001 the calculations look rather different. The 2001 epidemic in the United Kingdom cost around €4 billion, and if indirect costs are included, perhaps up to about €11 billion.

The inference is obvious: this is the risk society at work. To move to a vaccination-free policy was like draining wetlands and building on them. It brought benefits but it increased the likelihood that the dikes would be breached, that the virus would pour into the European space and that, once it had done so, it would spread more easily. Hydraulic engineers and sociologists of disaster sometimes talk of the 'levée effect'. This is the false sense of security that grows among those who live behind the dikes, the loss of memory of the downside implied in the ambivalent contract with control. The foot and mouth free zone of the EU generated its own levée effect.(8)

Manning the dikes

My overall suggestion is that there has been too much building on the viral floodplain. But to think this through we need to understand why the viruses are so keen to flood in. The answer is that the animals that are carrying them are also keen to get in—or that people are keen to move those animals. And arguably it is getting easier for them to do so. Here is the Royal Society ruminating on the problem:

> "The price of a kilogram of meat in the markets of Istanbul was five times that on the Eastern border areas of Iran during that [1998–2000] period; this demand gradient, coupled with improving political relations between Turkey and Iran as well as improved road infrastructure, led to an increase in trade, often illegal (The Royal Society, 2002, page 44).

So the largest part of the answer is: economics, including illegal economics, linked up with the circulations of transport. Other sources of leakage include personal imports, waste food products that end up perfectly legitimately within the virus-free zone, and the effects of meteorology. [There is strong evidence that an outbreak on a single farm in the Isle of Wight in 1981 was caused by viruses blown 250 km across the Channel from Brittany (The Royal Society, 2002, page 22).]

So the rules say otherwise, but the flow of unlicensed animal products is real. And here the job of the US Army Corps of Engineers is child's play compared with that of the Customs and Excise and the State Veterinary Service (SVS). At least with dikes and flows of water there is likely to be a line that can be traced on a map between the water and the land. The places where leaks might spring are geographically obvious. Not so for viruses and contaminated meat products. These may pop up almost anywhere. The potential size of the problem is stunning: around 2.5 million containers arrive in the United Kingdom each year.(9) I do not have a figure for the number of containers inspected but it is probably no more than 100 000 (DEFRA, 2002, page 29), and in any case most of the time public discourse is much more preoccupied with other illegalities—classified drugs or economic migrants—than it is with illegal economic foodstuffs. Then again there were more than 42 million air passenger movements between the United Kingdom and non-European destinations in 2001 (National Statistics, 2001)—many, therefore, from countries with endemic foot and mouth. A disease-free vaccination-free policy is indeed fraught with risk.

(8) Similar effects may be generated with fires and firebreaks. See Davis (1996).

(9) See House of Commons Committee on Agriculture and House of Commons Committee on Environment Food and Rural Affairs (2001, 31 October, answer to question 36).

Leaking: Cheale's abattoir

Foot and mouth was discovered in the United Kingdom on Monday 19 February 2001 in Cheale's abattoir in Brentwood, Essex. Built on the flood plain, it may also be imagined as a set of flows and mobilities in its own right. Animals were trucked in, held in small fields (lairage) for a few hours or days, and driven into the sheds for slaughter.[10] The men who move the animals from the lairage to the sheds are drovers. In the middle of the morning of 19 February, Thomas Vidgeon, a drover, noticed that some sows were squealing in pain and finding it difficult to walk. He called the abattoir's Official Veterinary Surgeon, Craig Kirby. Kirby had walked round the lairage on Friday and noticed that some of the sows seemed lethargic. Now he found that many had blisters, some burst and infected, on their snouts and their feet (DEFRA, 2002, page 12). He straightaway knew that this was either swine vesicular disease or foot and mouth: in pigs the two are clinically indistinguishable. Either way this was very bad news. Both conditions are highly infectious, notifiable to the SVS, and on the OIE's 'List A'. If either were confirmed, the United Kingdom would immediately lose its precious disease-free, vaccination-free status. Kirkby declared the premises infected, stopped the slaughter and the movement of animals, carcasses, and people, and called the SVS. Two vets came from Chelmsford, and the three of them started to inspect the animals and supervise the process of disinfecting people and premises. They also took samples for laboratory testing. At 5 pm the samples were ready. A Ministry of Agriculture, Fisheries and Food (MAFF)[11] employee got into his car, and drove them round the M25 to the Institute for Animal Health in Pirbright. An e-mail was not opened, and no one knew the samples were on their way, so laboratory testing only started with start of business on 20 February. By midday foot and mouth was confirmed. All animal movements in the vicinity of Brentwood were stopped.

Tracing the leak: detective work

But where had the infection come from? An answer to this question took very complicated and very large-scale detective work. Thousands upon thousands of animals had come into the abattoir, and meat products, possibly infected, had been sent to many destinations. Hundreds of vehicles and people had moved through the premises. And many, many, more animals had been in contact with those people and their vehicles. How to trace all this?

Abattoirs keep records. The records at Cheale's were in good order but they were handwritten (*FMD 2001* 2002, page 57). It took forty-eight hours to plough through them. And when this was done it became clear, though this was no surprise, that animals had come from all over the country, from 600 locations in all: a set of mobilities and flows on the flood plain.

They attended first to pigs. The paperwork showed that the pigs with the infection had originated on one of four farms on the Isle of Wight, or in Buckinghamshire, Suffolk, or Yorkshire. These were quickly visited, but revealed no sign of infection. Obviously the animals had caught the disease at the slaughterhouse. The net widened as the vets started the laborious process of inspecting animals on all the farms that had sent pigs to Cheale's over the previous two weeks. These farms were spread all round

[10] Here is the process. One: they are stunned. Two: they are killed with a shot to the head. Three: they are pithed. Four: they are hung up on an overhead conveyer. And then, depending on the animal, they are gutted, sliced in two, their brains and spinal chords are removed, they are butchered, and then the cuts may be deboned too.

[11] MAFF was absorbed into a larger ministry, the Department for Environment, Food and Rural Affairs (DEFRA) after the UK general election on 7 June 2001, in part as a response to the foot and mouth crisis.

the country. The SVS prioritised those farms licensed to feed their animals pig swill. And what they found is common knowledge. When they arrived at Burnside Farm in Tyne and Wear near Newcastle upon Tyne on Thursday 22 February they discovered active infection on a large scale. A few pigs showed no symptoms, but many more were suffering from the disease, and yet others showed signs that they had recovered from it. The SVS was to conclude that 90% of the pigs had, or had suffered from, the disease. Clearly the outbreak had been going on for weeks. But how had it started?

Painstakingly, the vets worked through a whole series of possibilities: animals, people, air, vehicles, discharges, materials, waste disposal, illegal rubbish dumping, and Newcastle Airport, among them. An obvious source was the piglets bought in to be fattened. The Waugh brothers had bought piglets from eighty-five farms, and the SVS checked them all. There was no sign of infection. They looked at the pattern of movement on and off the farm. The Waugh brothers were not very sociable and the farm was well fenced and inhospitable: there were few visitors. Had the infection been blown from a nearby farm? The answer was no. When the vets looked they found infection on a number of other farms, but it was clear this had come on the wind *from* Burnside and not the other way round.

Then they looked at the feeding arrangements, the source of the swill fed to the pigs. The Waugh brothers collected waste from bakeries, hotels, restaurants, schools, and a military facility in the area. (Their paperwork, and so the list of establishments, was not complete.) The law said they could not feed this directly to their pigs, because it might be infected with a range of viruses including foot and mouth. First it had to be heat treated. So what they did, or were supposed to do, was to leave it in containers on the edge of their property to be taken for treatment to a nearby farm. Then it was returned in different containers to go to the pigs. That was the theory. The practice was clearly somewhat different. The SVS found *untreated* food in the containers for the *treated* food. They also found:

> "... evidence of cutlery in the pig troughs and pens at Burnside Farm. Catering waste normally contains some cutlery but it would be unusual for this cutlery to survive the processing operation and end up in the processed waste fed to livestock" (DEFRA, 2002, page 19).

The evidence was circumstantial. The Waugh brothers acknowledged no wrongdoing. But given the physical distribution of the infection among the animals and their feeding arrangements the evidence was overwhelming: the pigs had been infected by unsterilised waste that had, somehow or other, included illegally imported meat products.[12] And this was where the trail ended: in a set of unsubstantiated and sometimes racist rumours about illegal imports.

The flood

The SVS is not very large and it was struggling. Briefly the vets breathed a provisional sigh of relief. There was some chance that the outbreak could be contained. As we know, this hope was short lived. A quick version of the story runs so.

The infection had jumped, as an aerosol of virus, to a few farms near Brentwood, and a larger number close to Heddon-on-the-Wall. But when the vets looked at the paperwork of one of the Northumberland farms at Ponteland they discovered that nineteen sheep had been sold from the Ponteland farm at Hexham market on Tuesday 13 February (note the date: nearly a week *before* the infection was discovered in Essex). Three had gone to a butcher and six to a Lancashire farm, but the other ten had been

[12] On 28 June 2002 Bobby Waugh was found guilty of a series of offences, including the failure to alert officials about the state of health of the pigs on the farm, and feeding pigs unprocessed waste. See Wilson (2002).

bought by a dealer (*FMD 2001* 2002, page 51). He had taken these and 174 others to Longtown Market near Carlisle, in Cumbria, on the Scottish border on 15 February. And here, at the market, their paths had crossed with those of at least other 24 500 other sheep. This was the number of animals that had pased through the market between 14 and 23 February. And those 24 500 sheep had in turn been sold to 181 buyers from all over England and southern Scotland. This, it was clear, was a disaster in the making. A national ban on movement was imposed on the 23 February, but the vets knew it was too late. And so it proved. On 24 February the disease was discovered on a farm of a dealer at Highampton in Devon who had bought sheep at Longtown. And then the epidemic really started. Five cases were reported on Monday 26, six on Tuesday 27, nine on Wednesday 28, five on Thursday March 1, nine on Friday 2, fourteen on Saturday 3, and thirteen on Sunday 4, sixty seven since the initial discovery of the disease. These were spread across eighteen counties, with large concentrations in Devon, Cumbria, and Dumfries and Galloway, as well as Tyneside and Essex. Suddenly there were twelve separate and epidemiologically distinct outbreaks around the country. This was no longer a trickle but a flood, and a flood that had started many days before the national ban on animal movements, many days before anyone knew that the dyke had been breached. Why had a leak turned into a flood?

There are some instructive contingencies. The first is the inactivity of the Waughs. Had they called in the vets two weeks earlier the leak might have been stopped then and there. But they did not. This leads to the second contingency. Foot and mouth infection is particularly virulent in pigs. When they contract the disease it is clear that they are ill, and they also emit the virus in huge quantities. So Burnside farm was emitting a plume of virus capable of infecting animals quite a number of miles downwind. This is how sheep and cattle on the Ponteland farm caught the disease. But here a third contingency kicks in. Foot and mouth is often difficult to detect in sheep. Unless farmers are looking for it they may not suspect it at all. The animals may only be marginally ill. So whatever one's views about the Waughs, there is no particular reason to complain about the Ponteland farmer. He did not know his animals were seriously ill, and neither did the trader who moved his sheep on to Longtown. And then there is a fourth contingency: the time of year; the late winter and the early spring. The virus survives for longer outside its hosts if the weather is cool and damp.

So far so good—or bad. But now the real puzzle. Why were there so many animals on the move on the British flood plain? Why was an abattoir in Essex taking pigs from Northumberland? Why were dealers from Devon buying sheep on the Scottish Borders?

First, on the question of abattoirs, it is partly a matter of numbers. They are limited in number, and animals often have to travel long distances to slaughter. In 1970 there were about 2000 slaughterhouses in the United Kingdom. In 2001 there were just 411 (The Royal Society, 2002, page 51). Why? The answer is controversial, but it involves both economics and politics. One: the food wholesale and retail industry has become centralised and big supermarket purchasers want to deal with a limited number of suppliers. Two: it has become costly to negotiate the networks of UK and EU legislation, and every slaughterhouse needs a resident vet. With BSE and other food scares, rules of hygiene have become strict and costly, and the paperwork is considerable. The consequence is that many abattoirs have closed their doors because it just does not pay.[13]

[13] See, for instance, Fort (2001). There is an anti-EU version of this story: that EC regulations are strangling British abattoirs. And then there is an anti-UK government story, which says that MAFF has used EC regulations for its own ends. For a detailed, anti-MAFF account, see Kennard (2001).

Second, on the movement of sheep. Again the answer is economics and politics. Sheep trading and droving are scarcely new professions, but in the United Kingdom, sheep are moved long distances for a number of reasons. First, many are bred on upland areas, and are brought down for sale in spring and autumn. Second, the economics of the industry are dependent upon large-scale national and international movements. Most of those who eat lamb do not live near the farms on which the sheep are reared, and tastes for cuts vary from one location to another (Cumbria Foot and Mouth Disease Task Force, 2002, page 37). The industry has been national and international for at least 100 years. Third, as I have just suggested, the number of abattoirs has been greatly reduced. 'Local' lamb may come from the locality, but there is a high probability that it has travelled hundreds of miles between the farm and the butcher. And, fourth, there is the effect of the Common Agricultural Policy. This is not the place to explore this controversial institution, but the essential point is quickly made. Much sheep farming income (50% for upland flocks) comes from the CAP (The Royal Society, 2002, page 12). This works through 'headage', a payment per animal. Farmers who did not reach their headage quota on the due date, 1 March, are penalised. And, though there is debate, this is probably one of the more important reasons for the massive movement of sheep during the early part of the year. In 2001 perhaps *two million* were traded in January and February, in part because farmers topped up their quotas (*FMD 2001* 2002, page 30). This was the set of flows that, more than any other, carried the foot and mouth virus, and turned the leak into a flood.

Conclusions

Between 19 February and 30 September 2030 premises, including slaughterhouses but especially farms, were declared infected, and their animals were culled. Preemptive culling was carried out on a further 8131 premises.[14] Nearly six and a half million animals were slaughtered, and their carcasses disposed of, producing profound grief for many farmers, iconic pictures of pyres for those who followed the disaster through the national media, and the never-to-be-forgotten smell of burning for those who live in the north of Cumbria or in Devon. The government incurred about £3 billion direct and indirect costs, and on some estimates the epidemic cost in the region of £8 billion (*FMD 2001* 2002, appendix A). This heroic effort was, in the end, rewarded with success. The United Kingdom regained its disease free status on 15 January 2002 (three months after the last case) and this was ratified by the OIE on 22 January.

Almost no one died as a direct consequence of the epidemic. But in many areas people were marooned for weeks or months on their farms. The countryside was effectively closed to visitors for much of the spring and summer of 2001. The tourist industry, and more generally the rural economy, was severely damaged. Many were hurt economically, socially, personally, spiritually. And many questions were asked. Why are we doing this? Is this a good way to live? Is it not time for rural economies to move on?

There are many, varied, and controversial answers to all of these questions. Some, for instance, incline to the view that the government response to the crisis was captured by the agricultural industry, and call for more joined-up policymaking and, more generally, for a holistic approach both to agriculture, and to the overall rural economy.[15] Others, both academic and otherwise, have argued that the disaster can be

[14] The culling policy was developed on a somewhat ad hoc and indeed controversial basis in the early weeks of the outbreak, on the basis of epidemiological advice. For further details and discussion of this see Bickerstaff and Simmons (2004).

[15] See, for instance, *FMD 2001* (2002) and amongst academic commentators, Ward et al (2004) and Campbell and Lee (2003).

treated as a system failure—and was indeed experienced as such by many of those involved.[16]

My analysis, in terms of the materialities of flows and mobilities, leads me in the latter direction. Here the flood-control metaphor has its merits. It nicely dramatises the dynamics of the risk society and the precariousness of what may otherwise appear to be advantageous sociotechnical arrangements. It draws attention to the barriers and the dikes behind which we shelter from the flows. But this is where, in this straightforward form, it reaches its limits. This is because we are dealing not with one flow, the flow of a virus, but a pattern, a web, of partially connected and different flows with criss-crossing barriers, and it is the intersection of these different flows and their levées that produces the potential for leaks. Trade, economics, personal movements, policy regimes, even safety and hygiene systems, *all* of these are regimes of flow, all foster mobilities, all imply barriers, and all of them, their intersections and the intersections between their barriers, play their part.

There are other metaphors for the risk society. One that is helpful comes from the writing of Perrow (1999). He is concerned with sociotechnical systems such as chemical plants, air traffic control systems, and nuclear power stations, and he works by distinguishing two dimensions. Dimension 1 is *coupling*. Some systems, he writes, are *tightly coupled*. Things flow rapidly through them—or at any rate too rapidly or awkwardly to allow successful intervention. By contrast others are loosely coupled. In these the flows are slow, or shaped in a way that permits intervention. Dimension 2 is *complexity*. Some systems are complex because the flows ramify off in all sorts of directions, and there are many connections, side channels, mobilities. Others are linear, not complex. Here the flows are relatively straightforward and tend to move in one direction.

Perrow goes on to make the following crucial observation. When things go wrong in systems where the flows are *both* quick *and* complex then the consequences are unpredictable, difficult to control, and are likely to get out of hand. This overflowing is what he calls a *normal accident*, normal because it can be expected. The classic case is a nuclear power station. When something goes wrong it goes wrong quickly, and is liable to ramify unpredictably through the system. There is a high risk that such turbulent flows will break through the barriers that are supposed to keep them in place. Three Mile Island was a close call, and at Chernobyl this actually happened.

Perrow's final observation has to do with the level of hazard. If the consequences of a failing system and its escaping flows are dangerous then, he says, we need to take a *political* decision not to create such a system in the first place. This is his view of nuclear power. It is only a matter of time, he says, and something will go wrong with catastropic consequences. Witness Chernobyl.

Some doubt Perrow's conclusions. They argue that a culture of safety can overcome the intrinsic dangers of tightly coupled and complex systems, and the cases they point to—for instance air traffic control—are indeed impressive.[17] However, the extent to which a high-reliability culture can ensure safety is questionable. In a complex system with rapid flows, normal accidents are always waiting to happen, and happen they will—as various air traffic accidents suggest.[18] But suppose for a moment that they *are*

[16] See, for instance, Poortinga et al (2004). And in the context of policy, see *FMD 2001* (2002, page 7).

[17] This contrasting approach is called high-reliability theory. See, for instance, Roberts (1989; 1990a; 1990b) and Roberts et al (1994).

[18] See the frightening and instructive study by Sagan (1993) on nuclear weapon safety in the United States Air Force. Sagan started his study believing that a high-reliability culture could contain the dangers inherent in complex and hazardous systems, but changed his view in the course of his study.

right. What happens if we apply the whole argument to the various material flows of agriculture: to beasts, microorganisms, people, money, trucks, and feed? These various flows are certainly *complex*, indeed unknowably so, and often they move fast too, too fast for intervention. The barriers holding them apart are unpredictably reliable. As we have seen, the virus was spread around the country before anyone knew that it had even arrived. In agriculture we are dealing, then, with a system that is prone to normal accidents. The foot and mouth outbreak *is* a normal accident, nothing more, nothing less.

Now include the argument about culture. Is there a culture of safety in the industry? The question is unanswerable in general. At Cheale's for instance, the response is no doubt yes. This was a well-run outfit, with good drovers, a competent and responsible vet, and its paperwork was in good order. At Burnside farm, self-evidently, the answer is no. The Waughs were not, shall we say, deeply committed to a culture of safety. So here is the obvious conclusion: notwithstanding the homilies and the policies, and notwithstanding their partial success, *it is not possible to engineer a culture of safety across the whole of the agricultural system*. The very idea is utopian. What may, perhaps, be possible in a nuclear power station (though Perrow tells us that this is uncertain) is inconceivable for agriculture.

Actually, the reality is somewhat worse than this. This is because good practice in one part of the system, a culture of safety, has potentially disastrous side effects elsewhere. Why do animals move so much in the United Kingdom? We have seen that this is for various reasons, but one of them has to do with hygiene and food safety. After the late 1980s customers got worried about eating meat products that might be contaminated by the prions that had leaked into the flows of feed, of animals and human food. Exports were affected. So how to keep the prions out? As we know various policies were implemented.[19] One was the tighter regulation of slaughterhouses. This is one of the reasons that many closed their doors, and one of the reasons that animals now have to move longer distances to slaughter. Arguably, then, the response to the BSE scare, the creation of safer flows in the food chain, actually contributed to the size of the foot and mouth epidemic.[20]

Where, then, does all this leave us? How might we think about this system, the 'risk agriculture' in which we are implicated? There are many possibilities, but Perrow's analysis is a useful tool for thinking about material flows, barriers, and vulnerabilities.

Flows that move too fast for intervention, and flows that ramify and connect together in unpredictable ways—these are the precursors to breakdown and, if the stakes are high enough, to catastrophe as well. But there is something else here too, which has to do with *uniformity*. The hydraulic engineering implied in controlling and delineating flows is also part of a process of standardisation. The hope is that *what flows* can be controlled, specified, and held stable. Healthy animals can be kept healthy, and feedstuffs can be kept virus (or prion) free. Refrigerated meat can be kept apart from inappropriate bacteria on its way from the slaughterhouse to the dining room table. This is one part of the engineering of fluid uniformity, the creation of what Latour (1990) calls 'immutable mobiles'.

Another part of this engineering is the hope, the aspiration, to regulate the relations between the flows of materials in particular and chosen ways, such that there are proper *barriers* (for instance, to keep viruses and animals apart), or there are appropriate

[19] For a fine account of the BSE crisis see Hinchliffe (2001), and also, in a more summary form, Hinchliffe (2000).

[20] That safety systems may lead to lack of safety is well recognised by those in the safety industry. It is one of the reasons why experts are often sceptical about safety panaceas proposed by well-meaning outsiders after accidents. This is discussed by Perrow who notes that safety systems may add to the complexity of the system, and so to its unpredictability.

exchanges (for instance, the interactions between attenuated strains of viruses in vaccinations and the animals themselves). In contemporary industrialised agriculture all of this fluid engineering, the engineering of flows, barriers, and exchanges, is attempted to an ambitious degree. The aspiration is to standardise flows and exchanges on a global scale. As a part of this, the attempt is made to render whole regions of the world uniform too—for instance, drained of the foot and mouth virus. The empirical case—and Perrow's analysis—suggest that this is possible, but only precariously. The complexities of the intersections of the endless regimes of flow and the patchiness of any culture of safety, suggest that many parts of global agriculture are normal accidents that are waiting to happen. But if this is right, then it might be wise to think about a global fluid mechanics that is less prone to breakdown, less dependent on such leaky barriers. It might be sensible to imagine an agriculture that is less vulnerable, less dependent on the aspiration to uniformity, and one that depends less upon surveillance and the need for centred visibility.[21]

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[21] The reference is to Scott's magnificent *Seeing Like a State* (1998). But see also Bickerstaff and Simmons's (2004) comments on the relationship between the centering characteristics of epidemiology and those of state policy in which the former, unlike the complexities of veterinary practice, offered the capacity for overall control (and a version of visibility) sought by the latter.

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