# DAM PROBLEMS

*Contents:* A role-play simulation concerning the environmental problems involved in building a large dam.

*Time:* Homework plus 2 periods.

*Intended use:* GCSE Biology, Integrated Science and Environmental Science. Links with work on conservation and human interaction with the environment. See below for comments on the level of the unit.

*Aims:*

- To complement work on conservation and human impact on the environment
- To develop awareness of the need to consider the long-term social and environmental consequences of development projects
- To develop awareness of the need for negotiation and compromise in real-life decision-making
- To provide opportunities to practise communication skills, in particular the analysis of information, the preparation and presentation of an argument, discussion and negotiation.

*Requirements:* For each student: General Briefing Sheets. Role notes for students according to the role being played (see below). Summary Tables: one copy per pair of students.

For a class of 32, the numbers of each type of sheets needed would be as follows:

| | |
|---|---|
| General Briefing (GB1, GB2, GB3) | 32 copies |
| Briefing for the Minister of Energy (ME) | 8 copies |
| Briefing for the Sociologist (EB1.1, EB1.2) | 8 copies |
| Briefing for the Land Use Consultant (EB2.1, EB2.2) | 8 copies |
| Briefing for the Ecologist (EB3.1, EB3.2) | 8 copies |
| EIA Summary Tables | 16 copies |

This is quite a demanding unit, and teachers may feel it is more suitable for use with students of higher ability. However, in school trials it was successfully used with mixed-ability groups; the main problem is the extent of reading involved, but trial teachers found it was worth taking the trouble for the motivation and interest the unit generated.

## Procedure

1 Introduce the simulation and issue each student with copies of the General Briefing sheets, which should be read beforehand, perhaps for homework.

2 Divide the students into groups of eight, with two students for each role (Minister of Energy, Sociologist, Land Use Consultant, Ecologist). Note that the Minister of Energy is a key role and will require students with appropriate personal qualities. It is suggested that the teacher reads the Minister of Energy briefing before allocating this role. Issue each student with the appropriate briefings and tell them to read them in preparation. This could be done at the beginning of the double period in which the simulation is to take place, or homework time could be used. If the class does not divide neatly into groups of eight, some groups could have three students per role.

3 Ask each pair of students in advisory roles (Sociologist, Land Use Consultant, Ecologist) to work together to fill in the appropriate parts of the EIA Summary Table, and to decide on their preferred site. Meanwhile the two students in the Minister of Energy role should be preparing their role and deciding the approach they will take at the EIA Meeting.

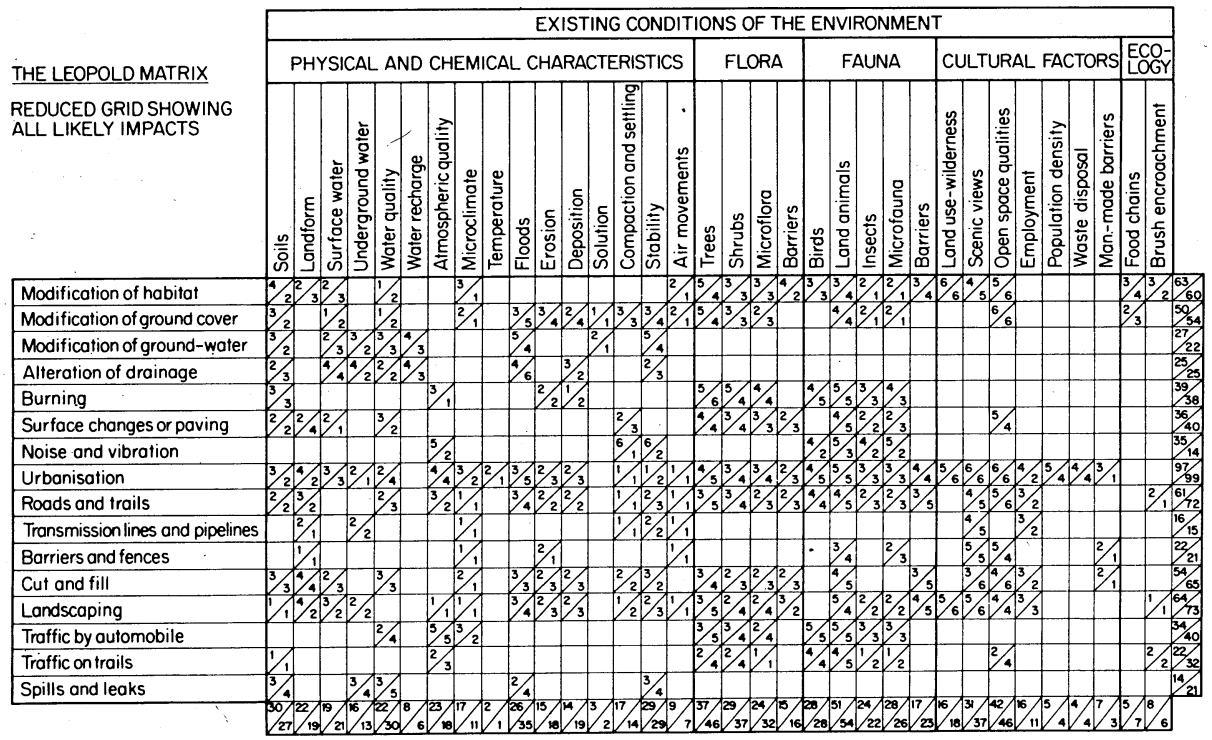
4 Having prepared their cases, the four pairs of students representing the four roles should come together for the EIA Meeting. The meeting should begin with each 'expert' giving a two-minute report on their recommendations to the Minister. The group should then try to reach a decision together, though the final say belongs to the Minister of Energy. The EIA Summary Table can be used to structure this discussion. Inevitably some compromise will be needed, and in this case recommendations should be made about steps to be taken to reduce environmental impact.

5 Finally the different groups can come together for a class discussion of the decisions reached.

## Background Information for the teacher

### 1 Environmental Impact Assessment

The exercise carried out by the students is a highly simplified version of an EIA. In real life there are of course many more factors to consider. The table below shows an example of a Leopold Matrix which considers 16 actions and their possible impact on 34 environmental categories. Note that the Summary Table in the classroom exercise is a highly simplified Leopold Matrix.




*A condensed grid of the Leopold Matrix for an area of development near Southampton. These results are from an undergraduate environmental science student's project (Jennifer Lisk).*

### 2 Choice of energy technology

At some point mention should be made of other energy technologies, in order to keep hydroelectric power in perspective. HEP is considered a relatively 'clean' energy technology, but even so many potential problems can be identified, as this simulation shows. A comparison might be made with nuclear power technology, and it might be pointed out that an EIA approach would probably identify many environmental and safety problems associated with this form of electricity generation too.

### 3 Experience from other HEP projects

Many of the points raised in the Briefings are based on experiences gained from large-scale HEP projects worldwide. The following examples may be useful as background information for the teacher:

*Resettlement problems* The proposed Three Gorges Dam in China will displace 1 400 000 people. When the Volta Dam project in Ghana was planned, it was intended to provide each displaced farmer with 12 acres of land. In fact, the land preparation got so far behind that only 8000 acres out of a proposed 54 000 were ready after flooding. As a result, many people had to rely on food handouts since they had no fields to grow crops.

*Impact on fisheries* The construction of the Aswan Dam in Egypt led to removal of nutrient-rich silt and detritus from the Nile, with disastrous effects on fisheries downstream.

*Impact on the rain forest* The world's rain forests are disappearing at a rate of 100 000 square kilometres a year. It is estimated that more than 80 000 plant species exist in the Amazon rain forest, yet only a handful have been screened for economic importance. Species of known value include: *Rauwolfia*, the source of a drug used to treat high blood pressure; Brazil nut; black pepper.

It is important to avoid giving students the impression that people in developing countries have no regard for the environment. For example, the teacher might like to refer to the huge popular Chipko movement in India for the preservation of Himalayan forests. Tree felling has been banned and millions of new trees have been planted.

Several countries, for example China, have promoted 'micro-hydro' projects involving a series of small dams rather than a single large one. Such projects avoid many of the environmental problems referred to in this unit.

## Further resources

A range of environmental publications is available from: World Wildlife Fund, Education Department, 11-13 Ockford Road, Godalming, Surrey GU7 1QU.

Publications on small-scale hydropower are available from: Centre for Alternative Technology, Machynlleth, Powys SY20 9AZ.

Two very good films are available on the problem of the destruction of the world's rain forests. They are:

*Fate of the Forests* (Shell). Runs for 27 minutes and is available on free loan as film or videocassette from: Shell Film Library, 25 The Burroughs, Hendon, London NW4 4AT.

*The Living Rain Forest* (BP/BBC). Runs for 30 minutes and is available on free loan as film or videocassette from: BP Film Library, 15 Beaconsfield Road, London NW10 2LE.

*Acknowledgements* This unit was developed in co-operation with World Wildlife Fund and Dr Paul Driver of W. S. Atkins Group. The Leopold Matrix on page ii is reproduced by permission from *Ecological Evaluation for Conservation* by I. Spellerberg (Edward Arnold).

# DAM PROBLEMS

## General Briefing

### 1 Introduction

Electricity generated from water is known as hydroelectric power, or HEP. HEP usually involves building huge dams and creating large reservoirs. This can seriously affect the environment. In this unit you will be looking at this problem.

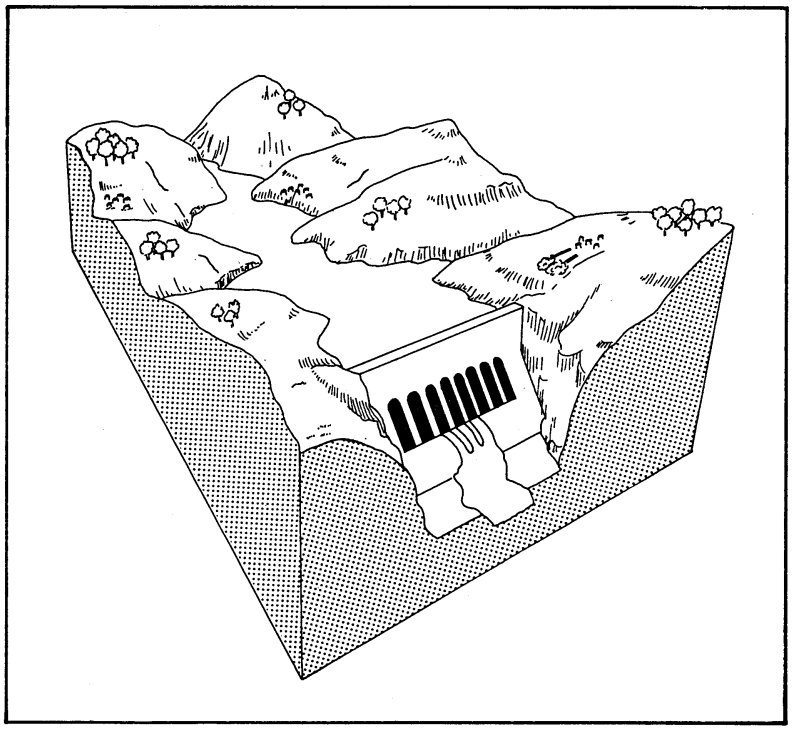


*Figure 1 A drawing of an HEP dam and reservoir*

Working in groups, you will be looking at the possible effect on the environment of three different HEP schemes. You will be making what is known as an **Environmental Impact Assessment**, or **EIA**. The purpose of an EIA is to give the decision-makers (politicians, industrialists and others) advice. The EIA gives advice on the likely environmental impact of different schemes. This advice is used when deciding which scheme to go ahead with.

There are four people in your EIA team. There are three scientists from the country's biggest university, and a politician. They are:

1 An **ecologist** who will look at the impact of the three HEP schemes on forests and fisheries

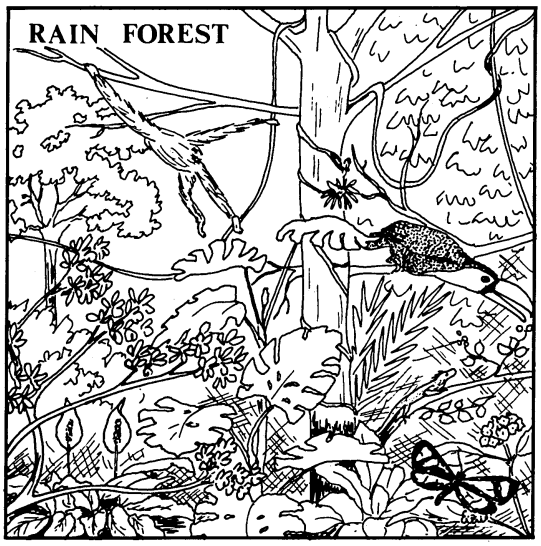
2 A **land use consultant** who will look at impacts on the way land is used, and soil erosion problems of the three schemes

3 A **sociologist** who will look at impacts on people's health and homes.

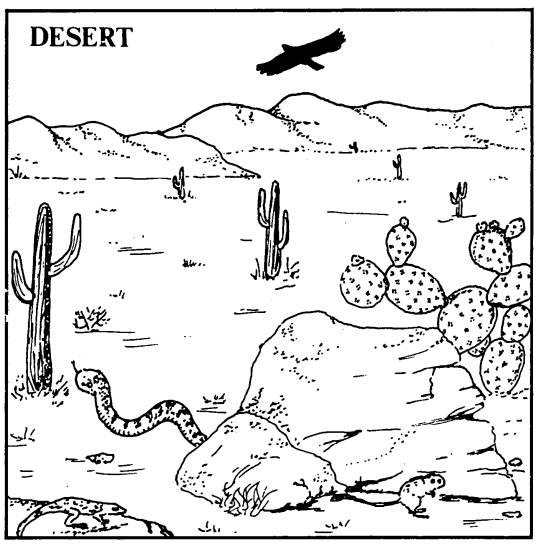
4 A **politician** (the Minister of Energy) who will make the final decision about which scheme should get the go-ahead.

## 2 Proposed sites of the three schemes

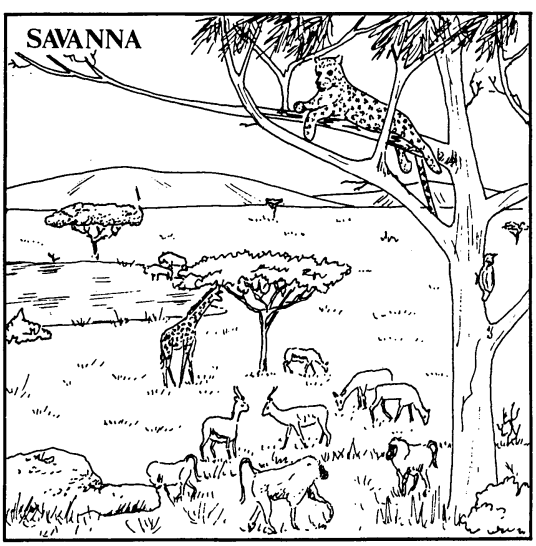
The sites of the three schemes are described below. The pictures below show something of the landscape and plant and animal life.




**Site 1** in the rain forest (jungle). Originally 10 per cent of the country was rain forest. Now it is only 2 per cent.




**Site 2** in the desert. Originally 45 per cent of the country was desert, but it has increased to 60 per cent.




**Site 3** in the Savanna (tropical grassland). Originally 45 per cent of the country was savanna. Now it is 38 per cent, some having become desert.

The map on sheet GB3 shows the country and the three sites.

## 3 The country and the three sites

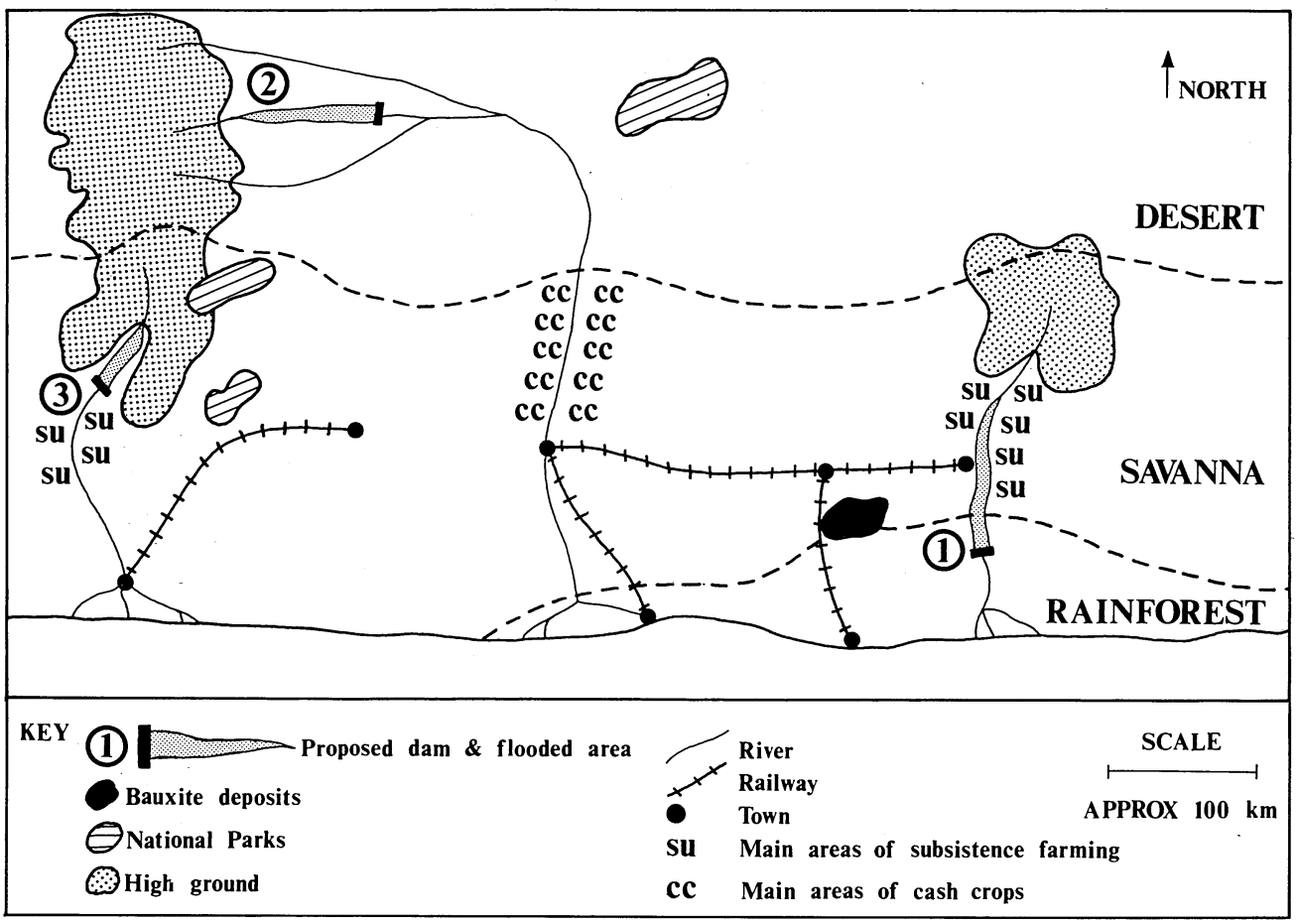



*Figure 3 The three proposed dam sites*

### The country's need for hydroelectric power

The country's present electricity demand is 100 megawatts (MW). At present this electricity is supplied by diesel generating units whose maximum output is 120 MW. It is expected that demand for electricity in the cities will grow rapidly in the future.

What is more, large deposits of bauxite have recently been found (see map). The government wants to use this bauxite to make aluminium. Making aluminium needs electricity. A new aluminium factory would need 200 MW.

Each of the three schemes can generate over 200 MW.

### EIA team terms of reference

The Minister of Energy has asked the EIA team to advise the government on the best HEP scheme.

As well as considering environmental impacts, the EIA team should also consider economic factors. They will need to think about where the aluminium factory will be built. This will of course depend on the HEP scheme chosen. The factory will need large amounts of cooling water as well as bauxite and electricity.

## Briefing for the Minister of Energy

You will need to listen to the arguments of the experts at the EIA Report Meeting. Each expert will give a two-minute report of their recommendations. You will then need to work with them to decide on which site should be used. The final decision about which site should get the go-ahead is yours. You should know that Site 1 is unlikely to be recommended because of the serious environmental impact it would have. The situations at Sites 2 and 3 are more complex. Whether you agree to leave Site 1 untouched will probably depend upon your character!

- Site 1 is in your constituency and if developed could be a good vote-catcher. Are you more concerned about the next election than making a sound decision based on environmental considerations?
- On economic grounds, Site 1 is the best choice because it is near to the bauxite deposits and the railway (see map). Which is more important to you — your country's economic development, or looking after the environment?
- Do you have a big ego? Your family has lived in the area of Site 1 for many years. A 100 metre high dam could be a monument which future generations would remember you by!
- Are you corruptible? You have contacts with the bureaucracy, local industry and multi-national corporations and you could easily take electricity from the grid and sell it off cheaply to industry at the expense of the general public.
- Do you simply like a good argument? If so, you may want to try to pick holes in the arguments used by the scientists at the meeting.
- On the other hand, you may realize that developing Site 1 would be a disaster for the environment. In this case, you will want to help the scientists choose between Sites 2 and 3.

**How you play it is up to you!**

While the others in your group are preparing their reports, think carefully about how you will play the role.

### Expert's Briefing 1

## The Sociologist

You have been asked to advise on the best site for the HEP dam. There will be two other experts advising at the final meeting. These are an Ecologist and a Land Use Consultant. The three of you will advise the Minister of Energy on the best site.

To prepare for the final meeting, you should read the notes in this report.

After reading the report, fill in your parts of the EIA Summary Table. Then decide which you think is the best site.

At the final meeting, you will make a two-minute report to the Minister, giving your recommendations. The other two experts will then give their reports. You will then need to work together to decide on which site should be used. You may not all be able to agree, in which case you might have to settle for your second-best site, provided certain conditions are met.

You should be warned that the Minister of Energy may have a strong preference for Site 1. It is in her/his constituency and if developed it could be a good vote-catcher. On economic grounds too, Site 1 is very promising, because it is near to both the bauxite deposits and the railway.

**Your main concerns are:**

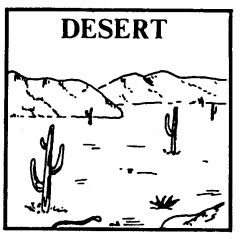
1 Resettlement of people affected by the building of the dam
2 The malaria problem and how it could be affected by building a dam.

### Resettlement

Site 1


- 2000 Indians live on the site. They have lived in the area for many years and may have great problems moving to a new area, even if they are willing to go.
- Forced removal of the Indians could result in violence. This could bring international criticism of your country's record on human rights.
- If they are moved elsewhere, the Indians will need compensation in terms of money and land.
- There are many different species of plants in the rain forest. Some of them may have important uses in agriculture, medicine and industry.
- The Indians have a close knowledge of the rain forest and can help your country use these plants.

Site 2




- There are a number of oases in the area of Site 2 where people grow oil palm, ground nuts, fruit and grains.
- If the dam was built on this site about 2000 people would need to be resettled.
- If resettled, the people would need compensation in terms of money and land.

Site 3


- There are no villages in the area and so there would be no resettlement problems.

## Malaria

Malaria is one of the most serious diseases in the world. Despite efforts at controlling it, over one million people die from malaria each year. Mosquitoes spread malaria. Shallow, stagnant pools of water and humid conditions provide an ideal habitat for mosquitoes. In tropical countries the edges of HEP reservoirs often provide such conditions.

Malaria can be controlled by controlling the mosquitoes. This can be done by:

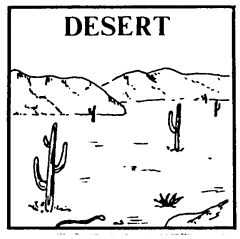
(a) *Using pesticides* These can result in other problems, such as destruction of wildlife.

(b) *Biological control* Certain birds, bats, frogs, and fish eat mosquitoes. These can be encouraged by protecting the vegetation around the reservoir, and by stocking the reservoir with appropriate fish species.

Site 1

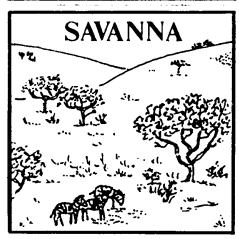

- Rain forests are humid all through the year. This would result in serious malaria problems.
- The reservoir would have a large number of inlets. This would create large areas for mosquito breeding.

Site 2




- Arid conditions mean it is unsuitable for mosquitoes. No malaria problems are expected.

Site 3




- The reservoir would have few inlets and would not be as good a breeding ground for mosquitoes as Site 1.
- However, strict measures would still be needed to control the disease.
- When the reservoir was lowered, mud and pools would be exposed. These would provide ideal breeding grounds for mosquitoes. They would have to be avoided, by making sure the level was never lowered for more than a few days.

## Summary Table

Fill in your part of the EIA Summary Table. In each 'Impact' box, put whether you think the impact of the HEP scheme would be **high**, **medium** or **low**. If you think there are any ways the impact can be reduced, show this in the other box.

**Which site would you choose?**

**Expert's Briefing 2**

# The Land Use Consultant

You have been asked to advise on the best site for the HEP dam. There will be two other experts advising at the final meeting. These are an Ecologist and a Sociologist. The three of you will advise the Minister of Energy on the best site.

To prepare for the final meeting, you should read the notes in this report.

After reading the report, fill in your parts of the EIA Summary Table at the end. Then decide which you think is the best site.

At the final meeting, you will make a two-minute report to the Minister, giving your recommendations. The other two experts will then give their reports. You will then need to work together to decide on which site should be used. You may not all be able to agree, in which case you might have to settle for your second-best site, provided certain conditions are met.

You should be warned that the Minister of Energy may have a strong preference for Site 1. It is in her/his constituency and if developed it could be a good vote-catcher. On economic grounds too Site 1 is very promising, because it is near to both the bauxite deposits and the railway.

**Your main concerns are:**

1 Changes in patterns of land use
2 Soil erosion in the areas where the reservoirs collect rain water.

## Land use patterns

There are three types of land use which concern you:

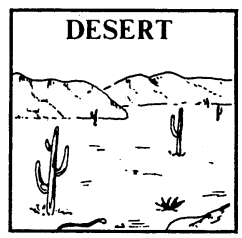
(a) Hunter-gathering in the rain forest.
(b) Subsistence farming in the savanna in the area marked **SU** on the map. Subsistence farmers grow food crops such as millet to feed themselves and their families. Subsistence farming does not need irrigation.
(c) Cash crop farming in the savanna in the areas marked **CC** on the map. Cash crops like cotton and rice are sold overseas to earn foreign currency.

Site 1

- 2000 Indians live in the area. The dam and reservoir would completely destroy their hunter-gatherer land use pattern and their way of life.
- Not only rain forest would be flooded if the dam were built at Site 1. Large areas of farmland further north in the savanna would also be affected.
- This flooding in the savanna would displace subsistence farmers further north into drier, more drought prone regions.

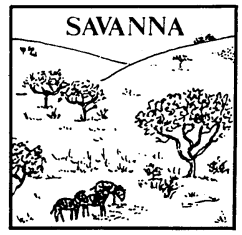

Site 2

- About 2000 people living and farming in oases would be displaced by the dam. (The sociologist may have something to report about this.)
- Downstream from this site, cash crops are grown. They would not be affected by the dam.



Site 3

- There is no farming in the actual area of Site 3, so no problems would occur here.
- Downstream of the dam site there are large numbers of subsistence farmers at present.
- If the dam was built it would be possible to control the flow of river water, making irrigation possible downstream.
- With irrigation, cash crops can be grown. The Government might be tempted to grow these crops to earn foreign currency to pay for the dam. This would displace the subsistence farmers further north to drier, more drought-prone areas.
- You feel it is essential that if the dam is built at Site 3 the Government agrees not to displace the subsistence farmers.




## Soil erosion

Your main concern here is the amount of silt (fine mud) carried by the river leading to the dam. Silt carried by the river quickly settles behind the dam wall. Over a short period, the silt will rise and soon reduce the amount of water the reservoir can store. This will reduce the electricity-generating capacity of the site.

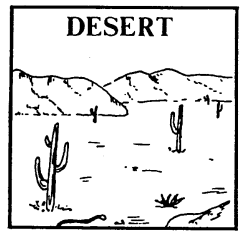
How much silt the river carries depends on the land where the river rises (the catchment area). If there are plenty of trees, there is little problem, because they help to keep the soil in place. Where trees have been cut down, soil will be washed away by rain and silt loads in the rivers will be high.

Site 1

- At present there is excellent forest cover on the hills upstream of Site 1. The river silt level is therefore very low and there would be no problems.


Site 2

- The silt load in the river at this site is very high and would cause disastrous silting-up. This is because there are large cattle ranches in the river's catchment area. The forests have been cut down to make space for the ranches.
- The only way to prevent silting-up would be to plant new forests in the catchment area. However, these would take at least twenty years to grow. (It is planned to have the HEP site operating within four years.)




Site 3

- The silt load in the river at this site is high, though not as high as at Site 2. The reason for the lower silt load is that the land upstream of Site 3 is owned by small-scale subsistence farmers. These farmers take care to plant trees to prevent soil erosion.
- With careful planning, further soil erosion prevention would be possible. It should be possible to reduce the silt load enough to build the dam within six years.


## Summary Table

Fill in your part of the EIA Summary Table. In each 'Impact' box, put whether you think the impact of the HEP scheme would be **high**, **medium** or **low**. If you think there are any ways the impact can be reduced, show this in the other box.

**Which site would you choose?**

### Expert's Briefing 3

## The Ecologist

You have been asked to advise on the best site for the HEP dam. There will be two other experts advising at the final meeting. These are a Sœciologist and a Land Use Consultant. The three of you will advise the Minister of Energy on the best site.

To prepare for the final meeting, you should read the notes in this report.

After reading the report, fill in your parts of the EIA Summary Table at the end. Then decide which you think is the best site.

At the final meeting, you will make a two-minute report to the Minister, giving your recommendations. The other two experts will then give their reports. You will then need to work together to decide on which site should be used. You may not all be able to agree, in which case you might have to settle for your second-best site, provided certain conditions are met.

You should be warned that the Minister of Energy may have a strong preference for Site 1. It is in her/his constituency and if developed it could be a good vote-catcher. On economic grounds too, Site 1 is very promising, because it is near to both the bauxite deposits and the railway.

**Your main concerns are:**

1 The effects of flooding on wildlife
2 The impact on fisheries further downstream.

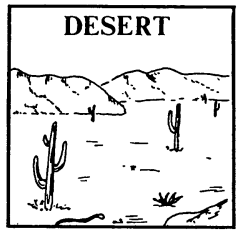
### Effect of flooding on wildlife

Site 1

- Your country's rain forest is fast disappearing already.
- If Site 1 was developed, a lot of the remaining area of rain forest would be lost.
- Tropical rain forests are known to have the widest range of plant and animal species of all the world's natural regions.
- Losing rain forest would mean the loss of many species of plants and animals.
- Some of the plant species in the rain forest could have important future uses in agriculture, medicine and industry.


Site 2

- Few plants and animals live in the desert.
- If Site 2 were developed, you believe there would be no serious loss of plant and animal species.




Site 3

- If Site 3 were developed a number of plant and animal species would be lost, though not as many as for Site 1.
- However, within the flood area of Site 3 there is a rare wild plant. This plant is highly nutritious and grows well in very dry regions. It could be bred to produce a valuable drought-resistant food crop which would grow in the desert.
- If Site 3 was developed, it would be vital to find these plants beforehand. They could then be moved to grow in the Savanna National Parks.

## Impact on fisheries further downstream

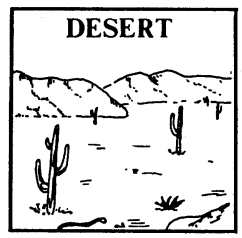
You are worried that building a dam could have a serious effect on fish further down the river. This in turn could affect the many people who depend on fishing for a living.

Site 1

- The river collects decaying vegetation as it passes through the rain forest. This vegetation provides nutrients for the fisheries further downstream.
- If the dam was built at Site 1, these nutrients would settle out in the reservoir and never reach the fisheries. This could have a disastrous effect on the numbers of fish.

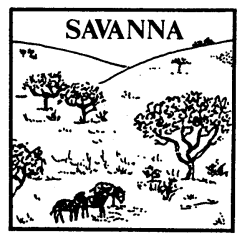

Site 2

- Site 2 is located on one of three tributaries to the river.
- A species of fish which is important to local fishermen has its spawning (egg-laying) grounds in the tributary above Site 2.
- The fish migrate from further downstream to spawn in these grounds each year.
- Building the dam at Site 2 would wipe out the stocks of this important fish, because they would not be able to travel up and down the river.
- The only way to prevent this would be to build fish ladders over the dam.
- Building the dam at Site 2 would also affect the amounts of nutrients in the silt carried downstream by the river.
- This *could* affect the fisheries further downstream. It would be important to carry out further investigations of silt loads before building the dam here.




Site 3

- The fisheries downstream from Site 3 have already been destroyed by pollution from the city on the estuary. Building the dam here would therefore have no effect on fisheries.




## Summary Table

Fill in your part of the EIA Summary Table. In each 'Impact' box, put whether you think the impact of the HEP scheme would be **high**, **medium** or **low**. If you think there are any ways the impact can be reduced, show this in the other box.

**Which site would you choose?**

# EIA Summary Table

| | *ECOLOGIST* | | *LAND USE CONSULTANT* | | *SOCIOLOGIST* | |
|---|---|---|---|---|---|---|
| **Site 1 (Rain forest)** | *Effect on wildlife* | *Effect on fisheries* | *Land use patterns* | *Soil erosion* | *Local communities (resettlement problems)* | *Malaria* |
| Impact of HEP schemes | | | | | | |
| Are there ways to reduce any impact? If so what are they? | | | | | | |

| | *ECOLOGIST* | | *LAND USE CONSULTANT* | | *SOCIOLOGIST* | |
|---|---|---|---|---|---|---|
| **2 ert)** | *Effect on wildlife* | *Effect on fisheries* | *Land use patterns* | *Soil erosion* | *Local communities (resettlement problems)* | *Malaria* |
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| | *ECOLOGIST* | | *LAND USE CONSULTANT* | | *SOCIOLOGIST* | |
|---|---|---|---|---|---|---|
| **Site 3 (Savanna)** | *Effect on wildlife* | *Effect on fisheries* | *Land use patterns* | *Soil erosion* | *Local communities (resettlement problems)* | *Malaria* |
| Impact of HEP schemes | | | | | | |
| Are there ways to reduce any impact? If so what are they? | | | | | | |

# Glass

*Contents:* Reading, questions and optional practical work on the manufacture, uses and recycling of glass.

*Time:* 2 periods (more if glass is made).

*Intended use:* GCSE Chemistry and Integrated Science. Links with work on sodium carbonate, calcium carbonate and silica.

*Aims:*

- To complement work on carbonates
- To show something of the technology of glass manufacture and fabrication
- To develop awareness of the many uses of glass, and the problems and opportunities involved in recycling it
- To provide opportunities to practise skills in reading, comprehension, the application of knowledge, and certain practical skills.

*Requirements:* Students' worksheets No. 410. A selection of items made from glass would be a useful aid. Requirements for the optional practical work are given later.

If the optional practical work making glass is to be used (see below), it is suggested that it should precede the use of the students' worksheets.

## Making glass in the laboratory

It is simple and rewarding to make glass in the school laboratory. Making soda glass requires impractically high temperatures, but lead borate glass can be made at bunsen burner temperature.

The experiment could be done as a class practical, though in view of the relatively large quantities of lead oxide involved teachers may prefer to demonstrate it, unless the laboratory has excellent ventilation facilities.

### Method

7.5g lead(II) oxide, 3.5g boric acid and 0.5g zinc oxide are placed in a plastic bag and thoroughly mixed.

**CARE: The mixture is poisonous.**

The mixture is heated strongly in a porcelain crucible on a pipeclay triangle.

While melting the glass mixture, a casting plate is prepared by heating a metal plate on a second tripod using a yellow bunsen flame. When the glass mixture is molten, it is carefully poured onto the hot casting plate using a pair of tongs. Small glass beads are formed which can be tipped onto a heat-resistant mat and examined when cool.

*Coloured glass* can be made by adding tiny quantities (just a few grains) of metal oxide to the glass mixture before melting. Suitable oxides include iron (III) oxide (for brown glass), manganese (IV) oxide (pink), cobalt (II) oxide (blue), and copper (II) oxide (turquoise).

The porcelain crucibles can be cleaned by soaking overnight in aqua regia.

## Notes on some of the questions

*Qs 1 to 3* The advantages of glass include the facts that it is relatively cheap, transparent, durable, chemically inert, impermeable, easily shaped into different forms, easily cleaned and therefore reusable, and resistant to heat. The elemental analysis of soda-lime-silica glass is remarkably similar to that of the Earth's crust. Hence there is a virtually limitless raw materials supply. Its main disadvantage is its brittleness, and the fact that when broken it forms dangerous sharp fragments. Furthermore, it is not biodegradable. Plastics are the materials most commonly used to replace glass. Examples are polythene bottles, perspex windows (for example, in aircraft) and plastic spectacle and contact lenses. But plastics are difficult to make perfectly transparent, and can seldom be recycled.

*Qs 4 to 10* Glass is a serious form of litter because it does not degrade naturally, and when broken it is dangerous to humans and animals. Unbroken glass containers can act as animal traps: small mammals enter empty bottles, attracted by traces of the original contents, but cannot get out again because of the slippery sides. Fragments of glass can also cause forest fires, by acting as a lens and focusing the Sun's rays onto combustible material.

It is worth spending a little time discussing the question of recycling, particularly if students have experience of Bottle Banks.

Other recyclable household materials include metals, particularly aluminium, and paper, though for economic reasons there are few large-scale collection schemes in operation. Plastic containers are difficult to *reuse* because they cannot be heat sterilized, and it is difficult to *recycle* them by melting because of the wide range of different colours and different plastics materials in use. It is worth discussing with students whether economics and convenience should be the only factors determining whether recycling is viable, and the extent to which environmental factors should override these others.

*Qs 11 and 12* The Float Glass process, developed by the British firm of Pilkingtons, took seven years and cost £7 million (over £50 million at today's prices) to develop. It is now used on licence all over the world. The use of a liquid on which to form the glass ensures the absence of the blemishes inevitably present on the surface of a solid. The liquid chosen needs to remain in the liquid state between about 600°C and 1050°C, so that the glass may be satisfactorily formed and cooled. It also needs to be denser than glass.

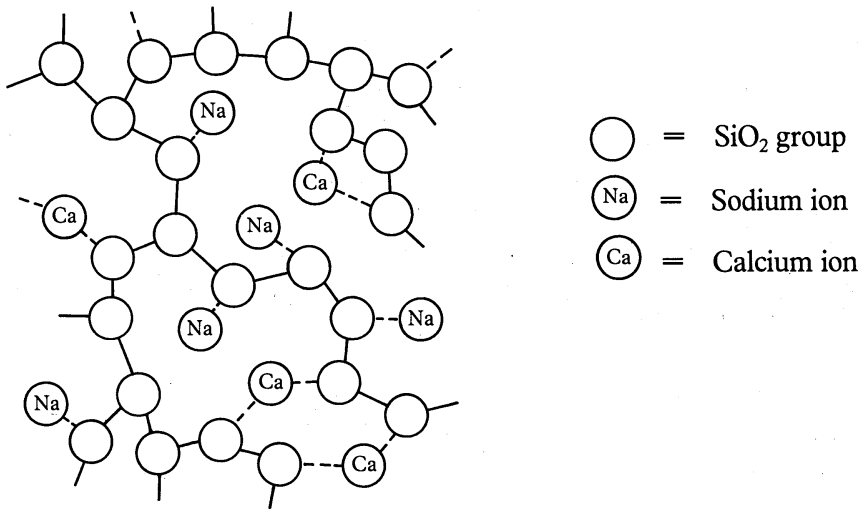
*Q. 13* Windows are often coated on the outside to reflect solar radiation and keep the building cool in summer. They may also be coated on the inside to reflect warmth back into the interior of the building, helping to keep it warm in winter.

*Q. 14* Glass fibre is used as a reinforcing material for strengthening plastic, and is also finding application in the reinforcement of cement, where it is a safe substitute for asbestos.

## Notes on the structure of glass

Depending on the ability of the students involved, the teacher may wish to make some mention of the molecular structure of glass.

When the ingredients that make glass are heated to 1500°C, they melt forming a liquid. The liquid is then cooled rapidly so that the atoms and ions do not have enough time to form a regular crystal structure. Hence glass consists of a collection of silicon and oxygen atoms bonded together, with sodium and calcium ions associated in a disordered way with the negatively-charged silica groups (see diagram).




Because of the absence of crystalline order, glass can be regarded in some ways as a 'supercooled liquid', although sadly the story that panes of glass in very old buildings are thicker at the bottom than the top belongs to fiction rather than fact.

## Extension work

*Recycling glass* There are plenty of opportunities for home-based work. For example, students could keep a record of the amount of glass (a) reused (returnable containers), (b) recycled (through Bottle Banks), and (c) discarded in their home in a typical week.

## Further resources

The Keep Britain Tidy Group Schools Research Project, based at Brighton Polytechnic, has produced a resource pack on glass which includes practical work, worksheets, demonstrations and audio-visual materials, with particular emphasis on glass as litter and on recycling. It is available from: The Keep Britain Tidy Group, Bostel House, 37 West Street, Brighton BN1 2RE.

*Acknowledgements* Figure 1 supplied by The Glass Manufacturers Federation; Figure 4 is adapted from *Science Unit 2: Glass* (Keep Britain Tidy Group Schools Research Project).

# GLASS

Glass was first made by the Egyptians over 3000 years ago. Only small amounts could be made so it was a precious and valuable material. As ways of making glass improved, larger quantities could be made. Today automatic machines produce millions of bottles and jars every day. In fact, 6400 million bottles and jars were sold in Britain in 1980!

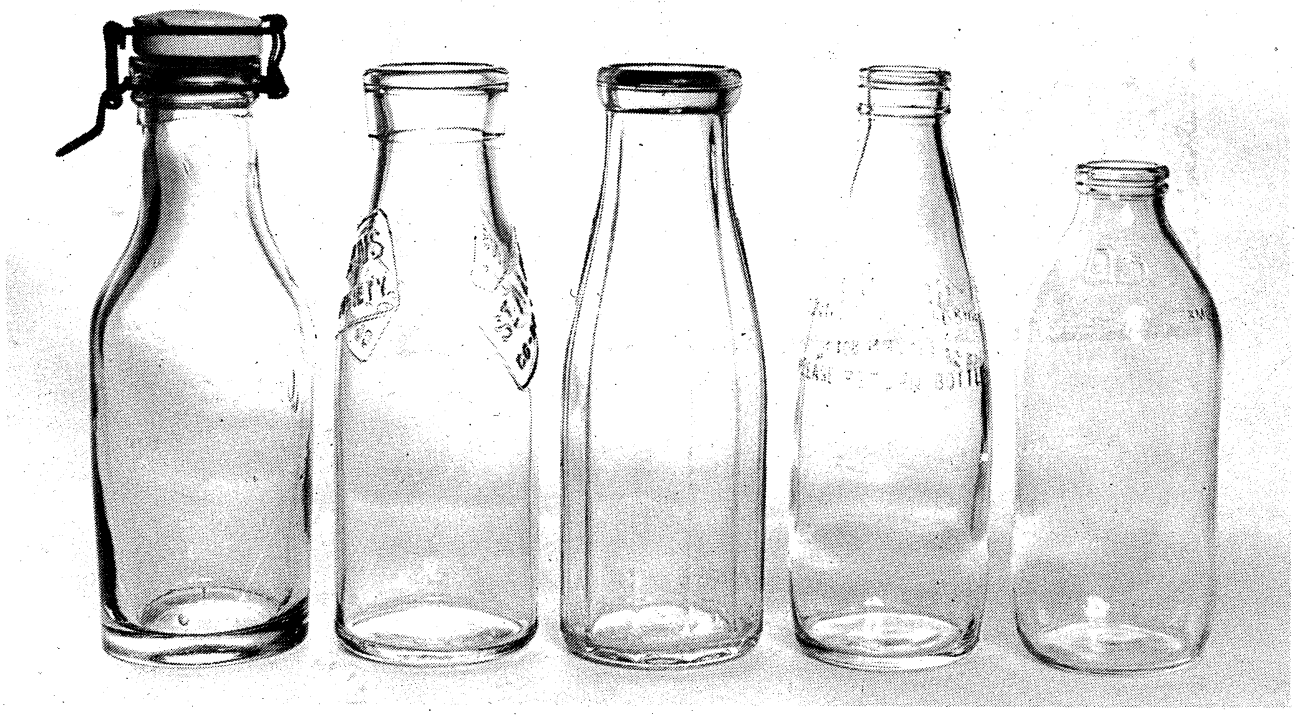


*Figure 1 How the glass milk bottle has changed over the years*

## What is glass used for — and why?

How many things can you think of which you use, or see, every day that are made of glass?

Draw up a table like the one below, and list as many different glass items as you can. Give the reasons why glass is used for each item. Mention any disadvantages you think glass has. One example has been done for you.

| *Item* | *Reasons why glass is used* | *Disadvantages of glass for this use* |
|---|---|---|
| Windows | fairly cheap, transparent, fairly good insulator | Breaks easily |

*Questions*

1 *What you do you think are the three main* general advantages *of glass as a material?*

2 *What do you think are its two main* disadvantages?

3 *Give two items from your list which are sometimes made from a material other than glass. What advantages does this other material have?*

## How is glass made?

There are many kinds of glass, but the most common is soda-lime-silica glass, or soda glass for short. Figure 2 summarizes the way it is made.

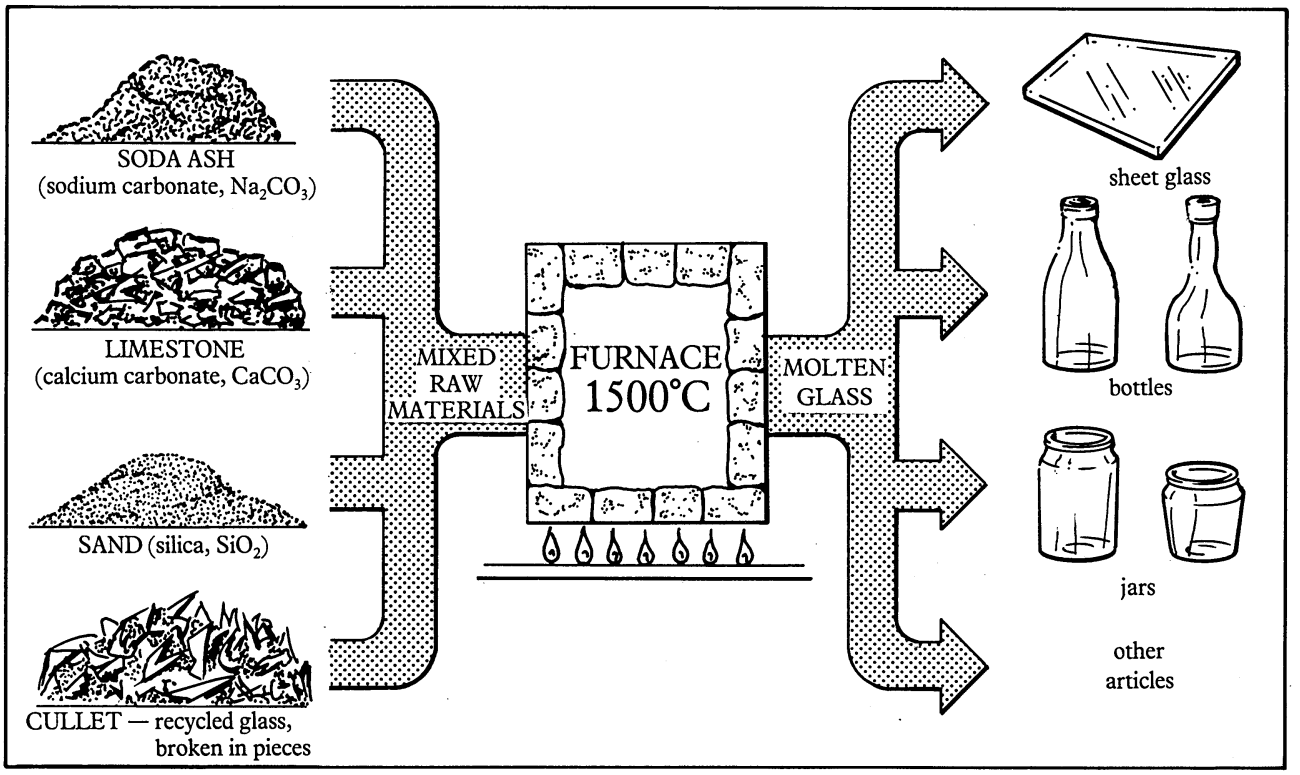



*Figure 2 How soda glass is made*

All the raw materials are cheap, but the process uses a lot of energy to heat the furnace. Other materials such as metal oxides are often added to colour the glass. You may have a chance to make your own sample of glass in the laboratory.

## Recycling glass

There are two ways glass can be recycled (used again).

### 1 Refillable containers

Because glass is strong and hard-wearing, glass containers can be used again and again. Milk bottles are an excellent example. In Britain each milk bottle makes an average of 25 trips to the doorstep and back.

But milk bottles are the exception. In fact, only 3 out of every 20 bottles and jars are designed to be refillable. The main problem is collection. Many people do not want the nuisance of taking bottles and jars back to the shop, and many shops do not want the nuisance of collecting them. As a result about 10 per cent of British household waste is glass — two million tonnes a year!

## 2 Recycling cullet

Cullet is broken glass that is mixed with the ingredients fed into the glass-making furnace. One way of collecting cullet is through Bottle Banks (Figure 3). These are usually situated in public places so people can bring their used bottles for recycling.

*Figure 3 Bottle banks situated on a prominent corner near a shopping area*

One problem is that cullet has fairly low value. This is because the raw materials for making glass are very cheap anyway. The main cost is the energy needed to melt them — and cullet needs melting just the same as the raw materials do.

It turns out that the value of cullet from a Bottle Bank only just pays for the cost of collecting it. But there are good reasons for recycling glass apart from cost. We should save our natural resources, however cheap they are. And by recycling glass we help prevent a serious litter problem.

*Questions*

4 *Why is glass a particularly bad form of litter?*

5 *Does your family recycle glass containers? Do you know where your nearest Bottle Bank is?*

6 *Bottle Banks usually have separate compartments for green, brown and clear glass. Why do you think this is?*

7 *You should always remove metal tops before putting a bottle in a Bank. Why is this? Why do paper labels not matter?*

8 *Why should milk bottles never be put in Bottle Banks?*

9 *Apart from glass, what other household materials can be recycled?*

10 *Suggest a reson why it is difficult to recycle plastic containers.*

# Shaping glass

## Containers

Figure 4 shows one way that containers like bottles and jars can be made from molten glass.

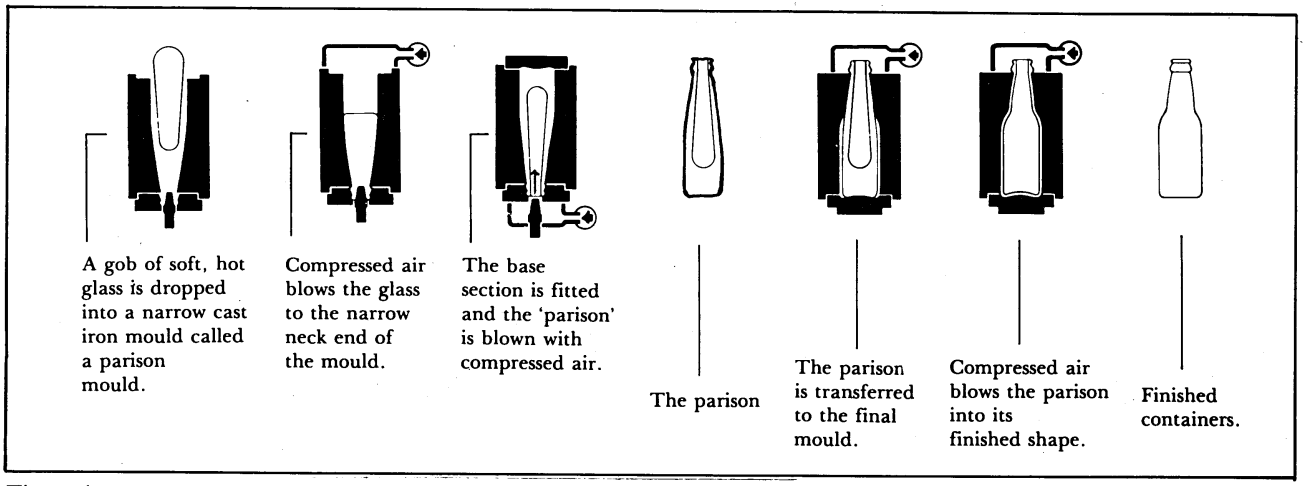



*Figure 4*

### Glass sheets

Glass sheet is mainly used for windows. The important thing is that the sheet should be quite flat, with polished surfaces. One of the most successful ways of making this kind of glass is called the Float Glass Process. It involves floating molten glass on top of a bath of molten tin. The temperature is kept high enough to allow any irregularities in the glass to melt out. This makes the two surfaces completely flat and parallel.

Figure 5 illustrates the process.

*Questions*

*11 In the Float Glass Process, why is the glass floated on* molten *tin, and not on a solid metal?*

*12 Give two reasons why a molten* metal *is used, and not another liquid such as water or oil.*

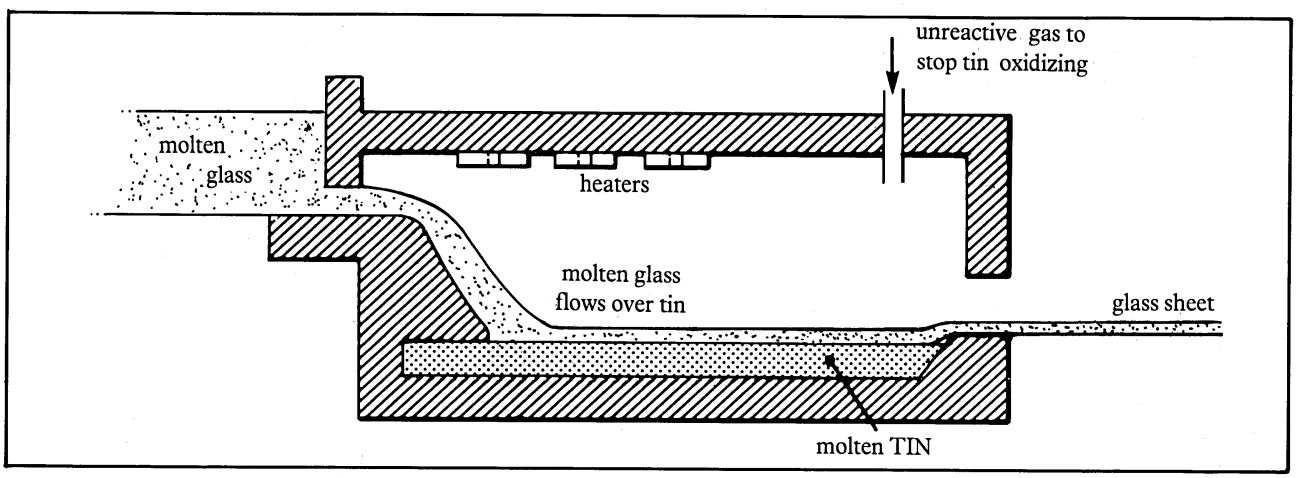



*Figure 5 Making float glass*

## Special kinds of glass

Soda glass is the most common type, but there are many others. Three are given below:

*Heat resistant glass* ('Pyrex' or 'Pyrosil') does not crack when it is heated or cooled quickly. It is very useful for oven dishes and bowls. It is made by replacing some of the silicon in the glass by boron.

*Light sensitive glass* ('Reactolite') contains an additive which darkens in bright light. It is useful for spectacle lenses.

*Slow-dissolving glass* Some types of glass dissolve slowly in water. This is used to help farm animals get the small quantities of trace elements which they need to keep healthy.

The glass contains copper, selenium and cobalt — three elements which cows and sheep need in tiny quantities. The glass is made in the shape of a small cylinder which the animal swallows. The glass cylinder stays in the animal's stomach all year. It slowly dissolves and releases the elements the animal needs.

*Questions*

*13 Why do the windows of some buildings have a gold or silver coating on the outside?*

*14 What is 'glass reinforced plastic'?*

*15 What special types of glass are used in road vehicles?*

# SATIS 4

List of units in this book

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