UNIVERSITY OF CAMBRIDGE

shelterproject.org

report title

guidelines for the construction of emergency relief infrastructure

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who undertook the work

The research for these guidelines was undertaken by Alison Killing and Allen Rand. The guidelines were compiled by a team of researchers working in a voluntary capacity with **shelterproject**.org

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shelterproject.org is currently funded by the Department For International Development (DFID) Conflict and Humanitarian Affairs Department and is associated with the University of Cambridge in undertaking two projects to develop, with the aid community through a peer review process:

1) the first field guidelines for transitional settlement of displaced populations; and
2) a livelihoods-based assessment tool for transitional settlement

The peer review panel for **shelterproject**.org involves representatives from ECHO, USAID, DFID, JICA, SHA, UNHCR, UNICEF, UNDP, UN/OCHA, UN-Habitat, UNOPS, The Sphere Project, IOM, ICRC, IFRC, MSF, CRS, NRC, and Oxfam GB.

acknowledgements

These guidelines were developed following discussions with MSF Holland and Belgium.

1 executive summary

1.1 introduction

This project was carried out by researchers as a contribution to the work of **shelterproject**.org. These guidelines aim to support the fieldworker in establishing the necessity for and overseeing the construction of multi-purpose buildings to be used in a range of emergency situations.

The buildings are designed to be appropriate for the following uses:

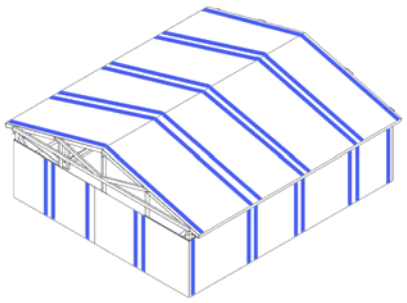
- way stations
- transit centres
- reception centres
- feeding centres
- warehousing

1.2 summary of designs

These guidelines discuss the advantages and disadvantages of various structures that could be used for the multi-purpose building. It goes on to describe two designs in detail.

timber-framed structures

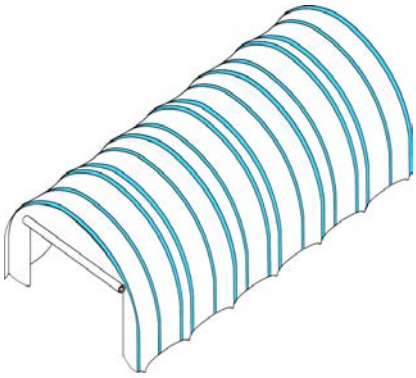
The second structure discussed is a timber column and truss frame. Timber of the size used in this frame is often available locally. Where it is not available, it can usually be procured quickly and economically and transported to site. This frame will also be covered with standard plastic sheeting.



These guidelines will use a frame with a span of 6m and a length of 7m in its examples. However, the structure is modular: additional framing can be added to increase its length in 3.5m increments.

tunnel structures

The first structure discussed is based upon tunnel frames available from agricultural suppliers, which constitutes a new option for emergency relief infrastructure. By using established suppliers a number of frames can be procured quickly. The structure will be built using pre-formed steel framing and standard plastic sheeting for quick construction and ease of relocation.



These guidelines will use a frame with a span of 5.5m and a length of 10m in its examples. However, the structure is modular; additional hoops can be added to increase its length. The frame is also available in a range of spans and in multiple span versions, allowing the fieldworker to adopt a design that fits his or her purpose best.

2 table of contents

	report title
	date published
	who undertook the work
	acknowledgements
1	**executive summary**
1.1	introduction
1.2	summary of designs
2	**table of contents**
3	**current policy and standards**
3.1	site layout
3.2	structure selection
4	**uses and layout**
4.1	possible layout of a way station
4.2	possible layout of a transit centre
4.3	reception centre
4.4	possible layout of a feeding centre
4.5	possible layout of warehousing
5	**project planning for relief infrastructure**
5.1	decision-making flow-chart for the planning and construction process:
5.2	selecting structures
5.3	establishing a team
6	**site preparation**
7	**timber column and truss frame**
7.1	construction procedure
7.2	orthogonal projections of the frame
7.3	materials and tools
8	**tunnel frame**
8.1	construction procedure
8.2	orthogonal projections of the frame
8.3	materials and tools
annex A	**tunnel frame suppliers**
annex B	**alternative materials**
annex C	**glossary of terms**
annex D	**bibliography**

3 current policy and standards

Current policy and standards for the planning of emergency relief infrastructure are given by The Sphere Project standards and by UNHCR in its *Handbook for Emergencies*. MSF also provides detailed information on planning and construction of health buildings such as hospitals and feeding centres in *Temporary and Semi-Permanent Buildings For Health Structures in Refugee Camps*.

3.1 site layout

The Sphere Project standards and UNHCR *Handbook for Emergencies* make a number of recommendations on the layout of transit camps.

- Transit centres should be designed for short stays of 2 to 5 days.
- A drainage gradient across the site of between 2% and 7% should be preferred. If the gradient across the site is not within these bounds then special provision must be made to assist drainage or to prevent erosion. Standing water should be avoided.
- A firebreak of 30m width should be provided for each 300m of built up area.
- At least 7 litres of water per person per day should be provided in addition to water provided for kitchens, cleaning and sanitation. Water should be extracted at least 30m from latrines and soakaways. All accommodation should be within 500m of a water point delivering water at a minimum of 0.125 litres per second.
- One latrine should be provided per 20 people. All accommodation should be within 50m of a latrine. One shower should be provided per 50 people.
- All accommodation should be within 15m of a refuse store or within 100m of a communal refuse pit.
- $100m^2$ of food preparation area should be provided per 500 persons.
- $150\text{-}200m^2$ of storage area should be provided per 1,000 persons.
- Arrival and departure zones that are separate from the accommodation areas should be provided.
- A public address system and lighting should be provided for the camp.

3.2 structure selection

The UNHCR handbook notes that prefabricated building systems and specially developed emergency shelter units have proved ineffective for shelter in large-scale refugee emergencies. Existing buildings or local building materials and methods should be preferred where they are safe and will not harm the surrounding environment.

The Sphere Project standards and UNHCR handbook recommend a floor area of $3.5 – 4.5m^2$ per person for *domestic* shelter in hot or temperate climates. However, these are a benchmark against which standards appropriate to a situation can be agreed. In circumstances where it is certain that accommodation will be for short periods, such as a properly functioning transit centre, floor areas per person may be less than the $3.5m^2$ proposed.

The UNHCR handbook recommends that buildings for administrative and communal services should be of a multipurpose design to facilitate alternative uses in future.

4 uses and layout

Any sizeable settlement, including self-settled and planned camps, will require various forms of communal infrastructure to meet the migrant community's needs. Some structures may be needed on the route to a settlement, such as way stations and transit centres, supplying provisions or offering temporary accommodation.

Larger-scale infrastructure, such as reception and feeding centres may have to be established quickly in a camp, using a modular system of structures and sanitary units. Warehouses and distribution centres (essentially shops) may be set up for the storage and distribution of Food Items (FI) and Non Food Items (NFI).

The diagrams presented in the following pages show how the structures described in these guidelines may be used effectively in a range of relief operations. Options for external site layout as well as internal planning are given.

The following uses are described:

section 4.1 **way station**

section 4.2 **transit centre**

section 4.3 **reception centre**

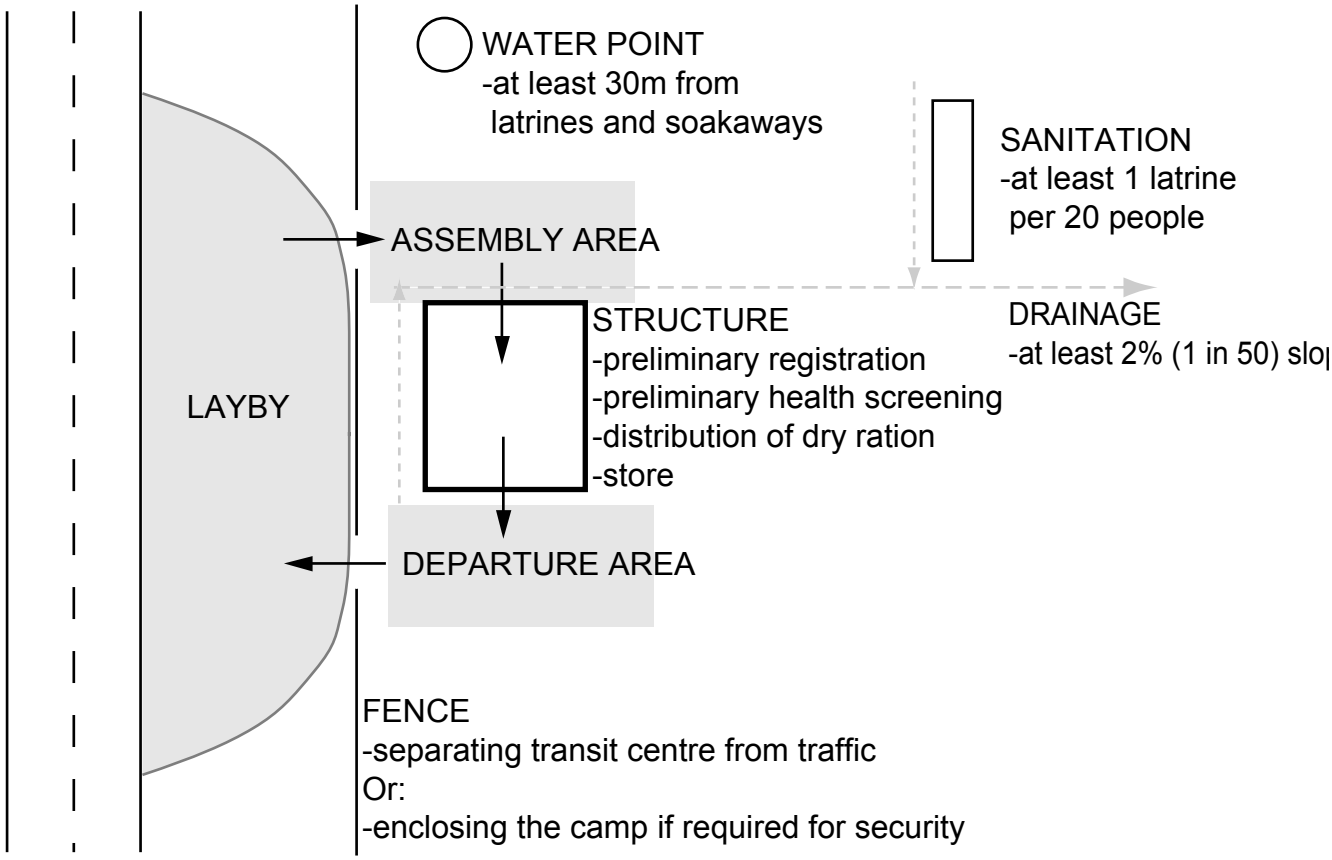
section 4.4 **feeding centre**

section 4.5 **warehouse**

4.1 possible layout of a way station

A way station is an interim stopping point, set up to provide migrants with food and water on the route to a transitional settlement. A way station can also provide an opportunity for health checks and registration of refugees.

The way station will be established off the main track or road, leaving an adequate turning area or lay-by for vehicles. Movement of vehicles and people should be organised into an efficient system of arrival – registration – distribution – sanitation – onward transportation to a camp or settlement.



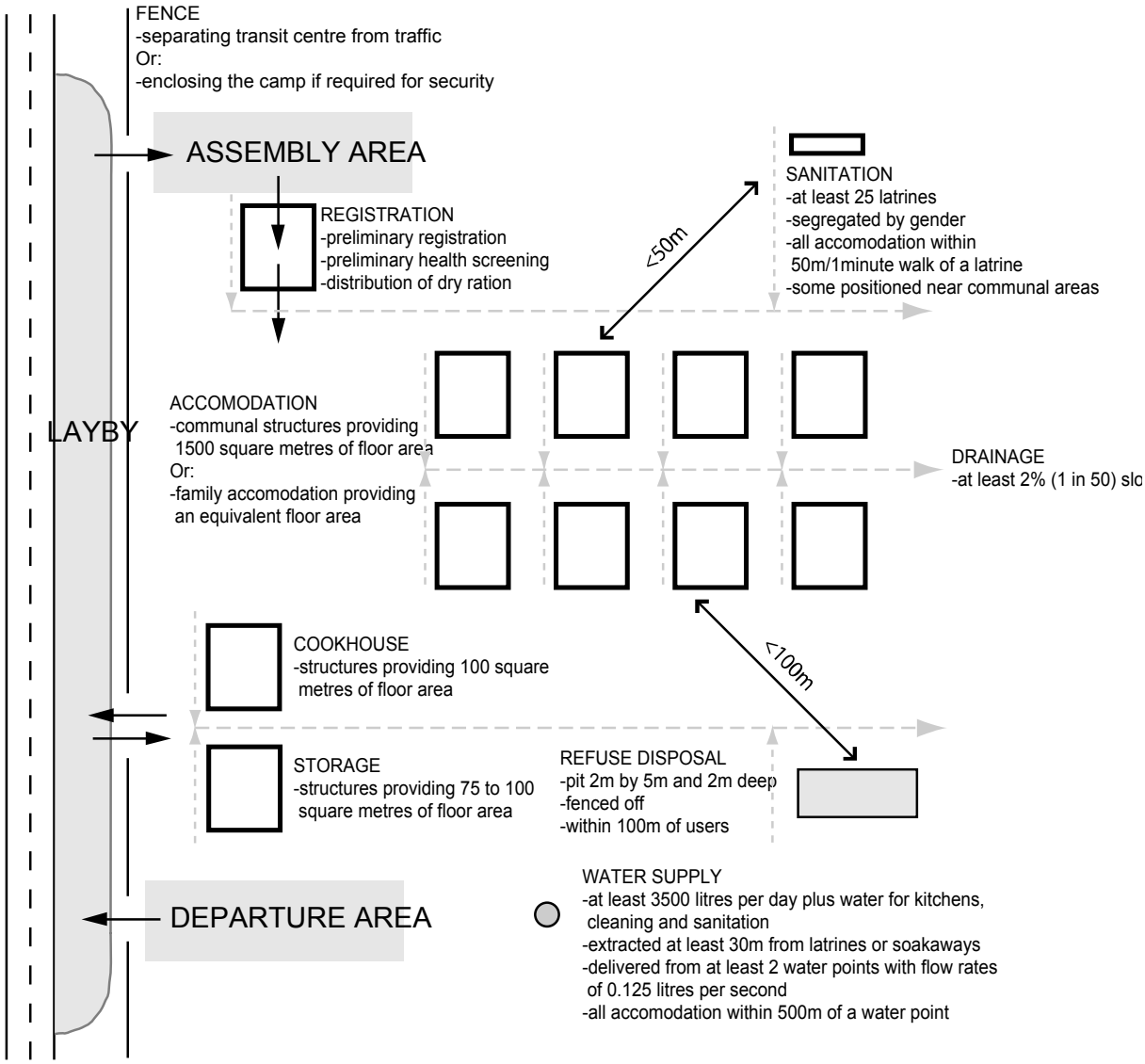
(diagram not to scale)

4.2 possible layout of a transit centre

The transit centre will be set up as one of several en route to a transitional settlement. It provides short-term accommodation for migrants as they travel towards a transitional settlement.

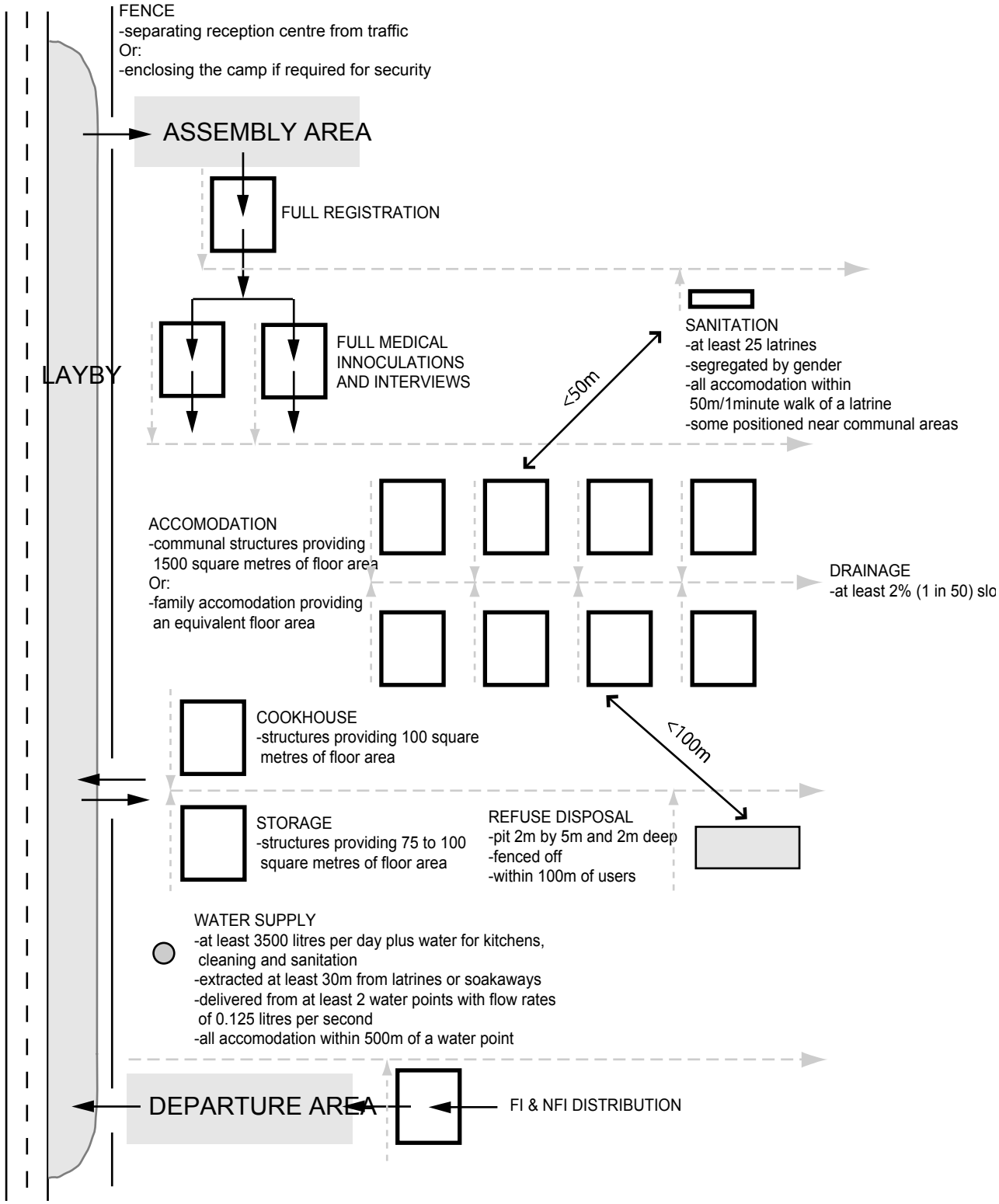
The centre may be fenced or roped, with clearly marked access points. At the arrival point, shown at the top of the diagram, there should be secure registration, health screening, distribution and storage points. Within the boundary, establish large assembly areas around food distribution points and water/sanitation areas.

(Diagram not to scale - Diagram shows a centre providing for 500 migrants, provision should change in proportion to the number of migrants expected.)



4.3 reception centre

Migrants should pass through a reception centre on **arrival** at a camp, since this is the most practical time for registration. Registration facilitates the equal distribution of food items (FIs) and non-food items (NFIs) and enables agencies to identify migrants needing extra assistance. Ration cards and the first package of goods, containing plastic sheeting, cooking equipment etc. can be distributed here, health checks can be carried out and plots for shelters allocated.



(Diagram not to scale - Diagram shows a centre providing for 500 migrants, provision should change in proportion to the number of migrants expected.)

4.4 possible layout of a feeding centre

In a feeding centre, vulnerable members of the refugee population will receive food in order to bring body weight to within a safe limit. Medecins sans Frontières (MSF) divides feeding centres into two types:

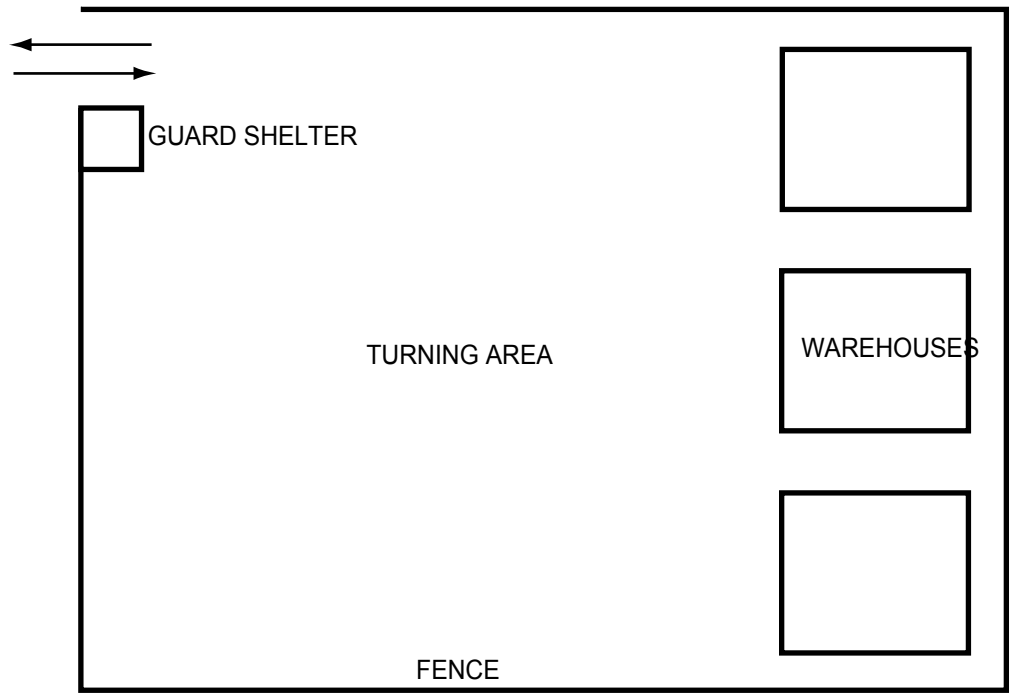
a) **supplementary feeding centres** provide food to supplement the daily diet. A wet feeding centre provides cooked meals that are consumed in the feeding centre before the patient returns home. A health check may also be carried out on the patient;

b) **therapeutic feeding centres** provide 24 hour care to the seriously malnourished and operate on an in-patient system. Medical care and all food is provided. The patient will usually be accompanied by a carer.

Further information on these and other medical centres can be found in the MSF guide “Temporary & semi-permanent buildings for health structures in refugees camps”.

4.5 possible layout of warehousing

Both central camp and ‘satellite’ warehousing may be required. Warehouses are used for the storage of FI and NFI such as grains, pulses, cooking equipment and blankets.



5 project planning for relief infrastructure

5.1 decision-making flow-chart for the planning and construction process:

Before beginning construction, consider the wider context of the project and the function and necessity for the structure. Once a brief and site have been organised it will be possible to plan, quickly and efficiently, the design and construction method. The flow-chart below is a guide to the decisions that will need to be made.

project planning

A project committees

- developed from programme committees, involving all stakeholders at a local level, including users and staff

B project profile

B1 project assessment	▪ refer to existing regional/national/local plans for both ongoing development and contingencies for emergencies
B2 livelihoods assessment	▪ displaced and local populations - natural, physical, financial, human and social capitals at a local level
B3 settlement assessment	▪ depending on the transitional settlement programme; existing infrastructure and housing stock, large buildings or complexes, existing or potential camp sites

C project scenarios

C1 scenario series	▪ based upon the programme scenarios, possibilities for future project scenarios, including: · best and worse cases · livelihoods impacts · durable solutions · indicators of when each scenario deserves consideration
C2 scenario development	▪ based upon the strategic and the programme scenarios selected, development of the project scenario, including indictors for when another scenario should be considered

D objectives+indicators

- aims and objectives are within the strategic and programme aims. indicators are that objectives have been reached, or are no longer relevant

E project design

E1 develop brief	▪ phased functional, social, physical and developmental requirements and specifications
E2 draft project design	▪ a design for the project, including dimensioned plans and a list of materials or 'bill of quantities' that can be put out to tender
E3 schedule of works	▪ developing a schedule of who should complete each job and by when, including appropriate considerations of risks and scenarios
E4 contracting and labour	▪ identifying and initiating the appropriate labour arrangements to undertake the work

F project plan

- an integrated plan summarising the project planning process and decisions made including:
  - · project objectives and indicators
  - · project profile
  - · scenarios and scenario indicators
  - · other projects
  - · phasing and timeframes
  - · budgets

5.2 selecting structures

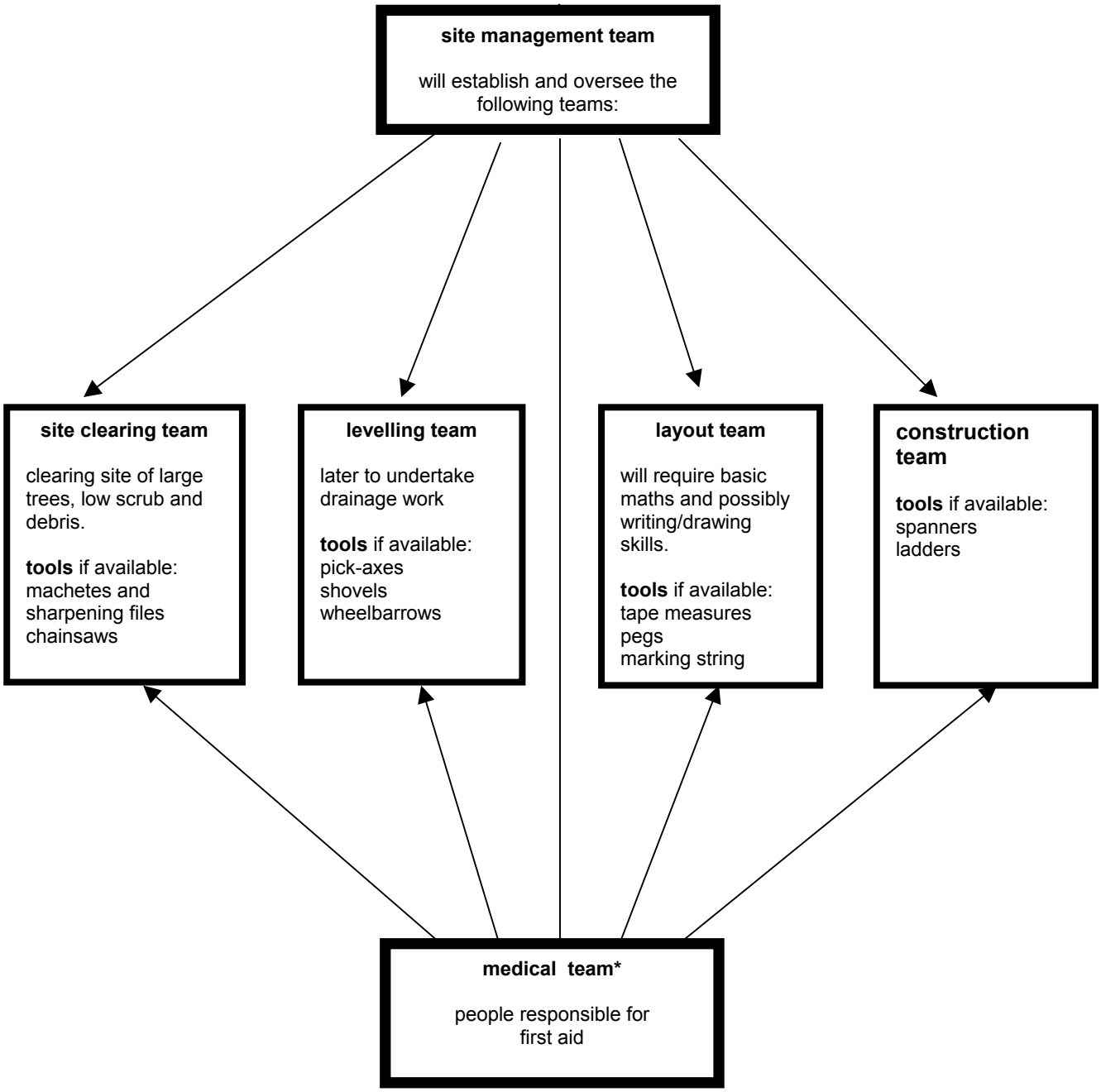
This table describes the advantages and disadvantages of various structures that could be used for emergency relief infrastructure. Humanitarian assistance agency policy, discussed in section 3.2, should be considered when selecting structures.

structure	advantages	disadvantages
existing structures	• cheap and quick to inhabit or adapt (but allow realistic time for modifications) • usually durable, so allow for follow-on use, post emergency	• if in use, may need to consider re-accommodating displaced use • can be deceptive: important to check structurally sound and appropriate to intended use.
tents	• quick and easy to install or move	• high cost and lead time, unless stockpiled tents are readily available • canvas non-durable compared to some other materials • large tents difficult to ventilate
freight containers	• quick and easy to install or move, only need to provide base and cut windows • durable • main advantage is that they are secure.	• expensive and difficult to transport, since each container must be carried on a single truck • susceptible to overheating • may be too small for use as feeding centres
modular metal framed structures eg. *Rubb hall*	• quick to construct • extra UV protection to the PVC cladding can increase durability • modular system can be built to any length - allows flexibility for accommodating a range of uses.	• high cost and lead time, unless stockpiled structures are readily available • heavy and expensive to transport • tendency for heat gain • poor ventilation
pre-stressed modular systems eg. *Conport 'Flospan' structures*	• quick to construct • durable • modular system can be built to any length - allows flexibility for accommodating a range of uses. • secure	• high cost and lead time • heavy • tendency for heat gain • poor ventilation • stacking of stored items is impeded since the walls are inclined at 18^{o}
permanent structures	• relatively low transport costs if materials are locally available • initial investment can be offset by durability and longevity • allow follow-on use	• high cost and lead time • slow to construct, esp. if using concrete (requires 28 days to achieve it optimum strength) • maintenance needed to maintain • may require specialist skills.
prefabs (locally made and transported to site)	• quick to fabricate and erect on site, if made locally	• bulky to transport
tunnel frame	• low cost and lead time • very quick and simple to construct (1-2 days) • modular system	• not easily adaptable
timber column and truss structure	• low cost and lead time • materials often available locally • quick to construct (2-3 days) • flexible, modular system • lifespan (2-3) years can be extended by improving materials	

The table in the previous page is based upon 'Engineering in Emergencies', Lambert and Davis, ITDG/RedR, 2000.

5.3 establishing a team

Organisation of labour and good management of the project is essential to running an efficient and construction process. If the aid organisation plans to oversee construction, rather than employing a contractor, a clear group of teams should be established. Assuming that the construction project is of a sufficient size, each team will be responsible for a different part of the building process. The main groups are outlined below:



* health and safety: ensure that staff are **aware of safe working practices** and that they are **implemented** eg. securing ladders when working at height.

A **first aid kit** and first-aider should be on site and there should be a **health centre** designated for referral in case of a serious accident.

6 site preparation

The steps below illustrate the construction process for a tunnel frame structure, from site clearance to completion.

step A: site clearance

When a suitable site has been chosen clear it of all low scrub. Remove any old or fragile trees. Avoid siting the building close to old trees, which might fall onto and damage the structure. Clear as few healthy trees as possible, in order to provide shade and prevent soil erosion. Termite mounds should be destroyed.

step B: ground preparation and levelling

The site must be levelled and major drainage channels dug. Spoil can be thrown into the centre to raise the floor level.

To level, take a horizontal string across the site, and cut a stick to fit at the lowest point of the ground under the string. Use this as a gauge to level the rest of the site to.

step C: setting out

Mark out the corners first, using pegs with string stretched between. Check that the corners are square, using a 3,4,5 triangle. The interim posts can then be marked out, measuring from the corners. Check the strings regularly to make sure they have not been disturbed by works.

7 timber column and truss frame

Thin sawn timber battens are widely available. By forming trusses and braced columns, these timbers can be used to construct a strong, stiff frame. This section provides instructions on how to produce such a frame. The frame has a number of advantages:

low cost.

- material produced worldwide, allowing short lead times and good availability.
- it can be covered using a variety of materials, including plastic sheeting.
- easily extendable.
- adaptable to a variety of uses.

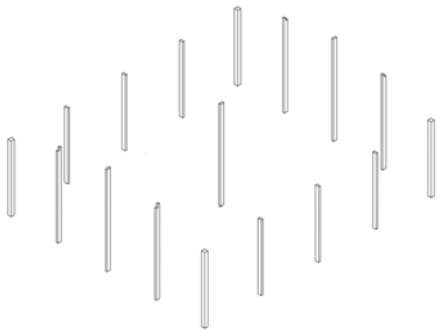
7.1 construction procedure

step 1: foundations for structure

The time available for construction will determine the type of foundation used. Three options are suggested:

- Dig simple post holes (300-500mm deep) and backfill with earth, as illustrated above. This is the quickest method.
- Alternatively, fill holes with concrete and cast a bracket into each, to which the timber can be attached. The concrete will require 28 days to reach optimum strength, though it can bear some load after 5-10 days.
- Lay flagstones, to which the timber structure can be bolted.

step 2: vertical posts



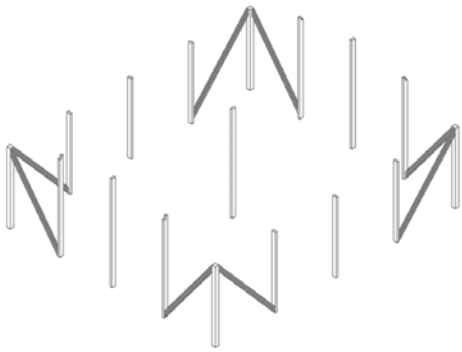
Set out the 100x100mm corner posts first, followed by the 50x100mm intermediate posts. Posts are buried 300-500mm deep. Strong connections to foundations are vital, since this point is most vulnerable to failure, especially in high winds and disasters, such as earthquakes.

Seasoned timber is stronger and less susceptible to insect attack than green timber. For termite protection the wood can be painted with a mixture of creosote and diesel oil and the soil poisoned with insecticide. Avoid contamination of water courses, wells and ponds. Otherwise, posts can be shielded at ground level to prevent the invasion of insects.

step 2: cross bracing

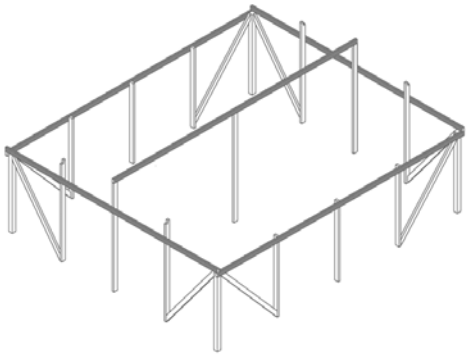
Necessary to strengthen corners. Run diagonals from top of corner post to bottom of next. The ends of the diagonals should be cut to the angle at which they meet the verticals.

Whether building up from the ground piece by piece (as in these guidelines), or constructing pre-fabricated elements, use 2-3 nails per joint. The nails must be the right size to fix the timber, but not so big as to split it (for a 100x50mm frame, 3" nails are recommended). Quantities are given in Section 9.



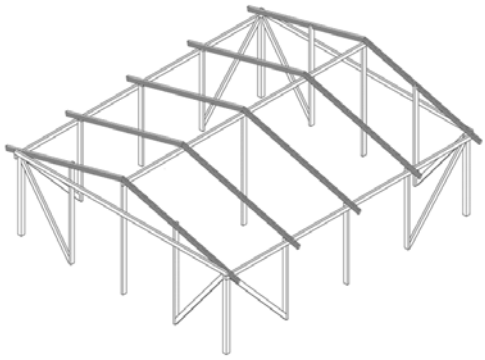
step 3: ring beam and ridge beam

This stage must have been reached by the end of the day.



step 4: rafters

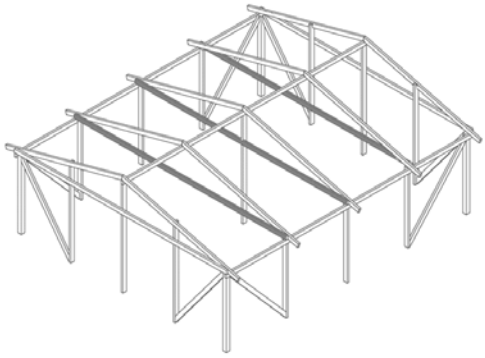
These must be in line with the vertical posts. The roof structure must be very securely attached to the frame, using metal straps or gangnails.

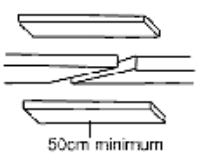


step 5: tie beams

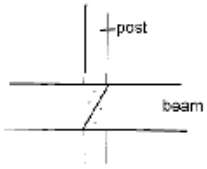
Made from two pieces of wood, 3.1m long. Details of how these are fixed are shown below:

detail 5.1: detail of how to join tie beams, with diagonal cut strengthened with two 50mm minimum length pieces of timber.
detail 5.2**:** view of joined tie beam from the side, showing vertical post behind.





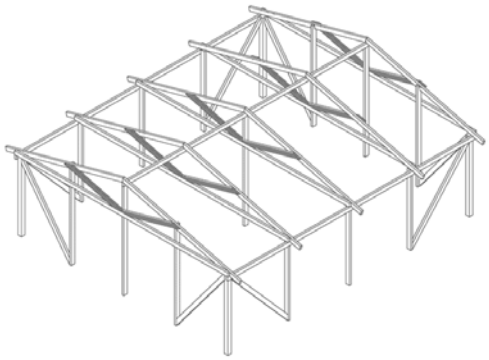
detail 5.1



detail 5.2

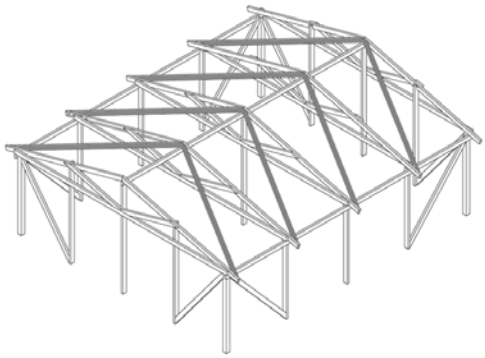
step 6: trusses.

The trusses support the vertical loads from the roof.
Use metal straps to tie the truss to the frame, going from the frame, over the truss and back to the frame. These can be made from distribution cans cut into strips. Gangnails, also made from distribution cans, can be used to join together the pieces of the truss.



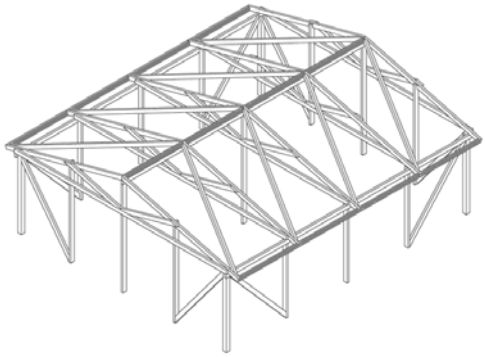
step 7: cross-bracing for roof

Cross-bracing prevents the trussed rafters racking under load. By preventing water pooling, it also allows a lower roof pitch.



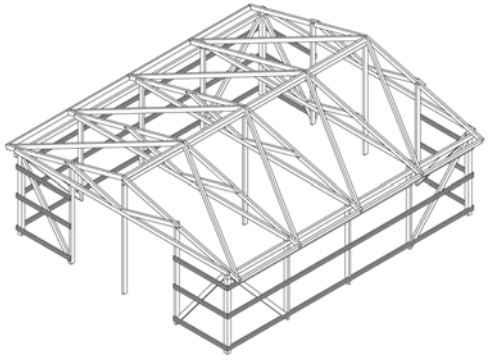
step 8: spacers

Use off-cuts. At the ridge these spread the load of the plastic to stop it tearing and at the eaves they provide a fixing rail for the plastic.



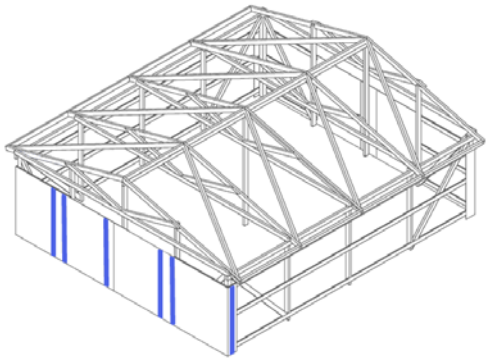
step 9: batons

These can also be made from off-cuts. They are for fixing the plastic to.



step 10: plastic sheet cladding for ends

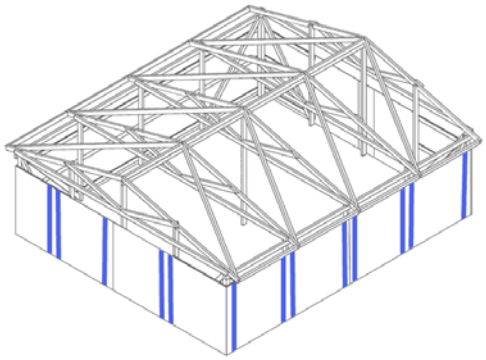
Cladding for the ends is made from two pieces of plastic sheeting, each measuring **3x4m,** with the blue reinforcing strip hung vertically. The pieces should overlap and extend around the corners at the sides. In fixing the sheet, avoid heavy loading at particular points. Contact areas with the structure must be as large as possible to minimise stresses. It is important to tension the plastic sheet prior to fixing it. See fixing details below. Plastic sheeting is widely used in the field. UNHCR and MSF specify standard sheets in rolls of 4x50metres with 4 reinforcing strips running along length, one at either side & two down the centre, allowing it to be cut in half. See bibliography



step 11: cladding for walls

Two pieces of plastic sheeting, each measuring **3x4** are needed for each side wall. They should be hung with the blue reinforcing strip vertical. The sheets should overlap.

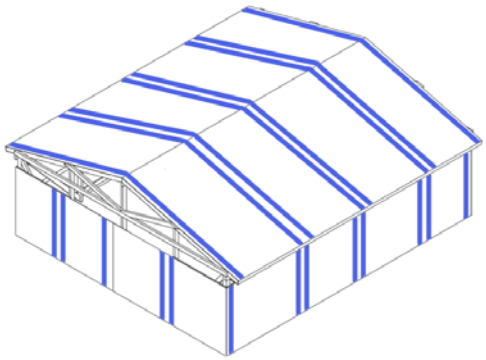
A gap of 300mm needs to be left at the top of the wall, under the eaves, for **ventilation**; the bottom can be buried in the ground.



step 12: cladding for roof

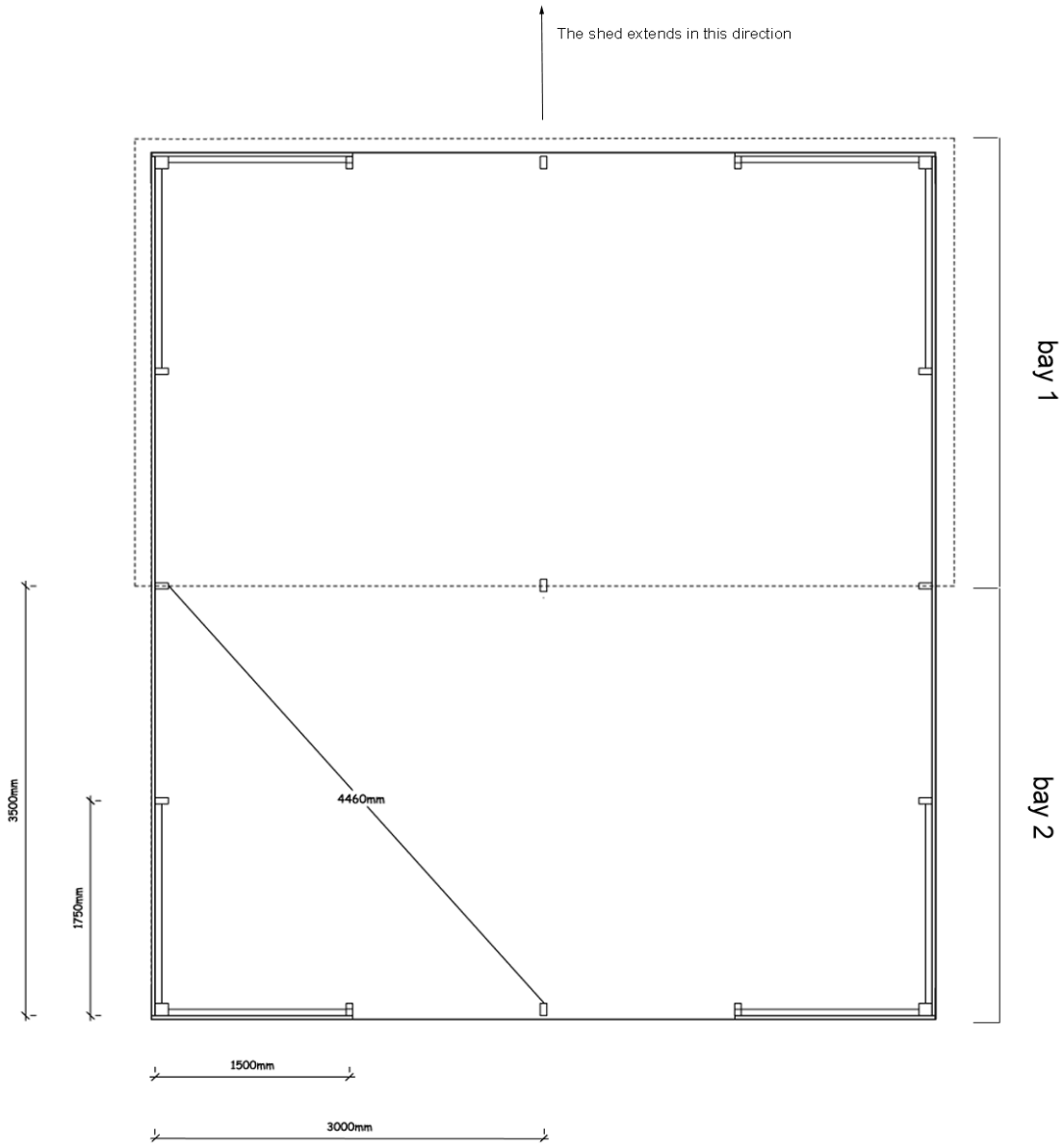
One piece of plastic sheeting, measuring 7x4m is required to cover each bay.
(The shed shown has two bays.)

To extend the life of the plastic as far as possible it should be protected from exposure to sunlight. The building may be shaded by young trees or the roof covered with a thin layer of thatch. This will also provide insulation.

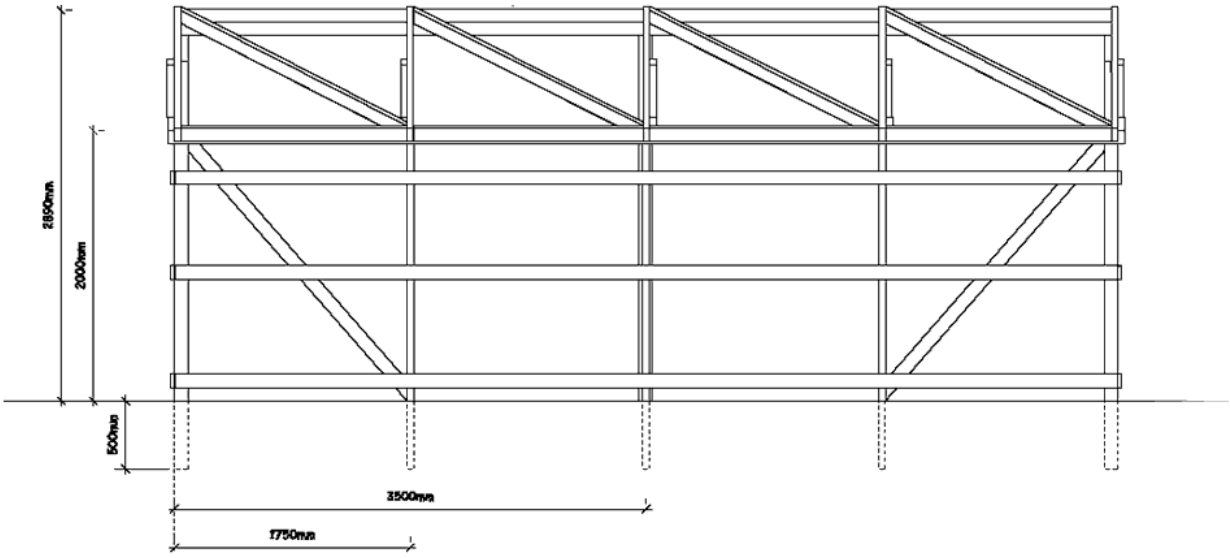


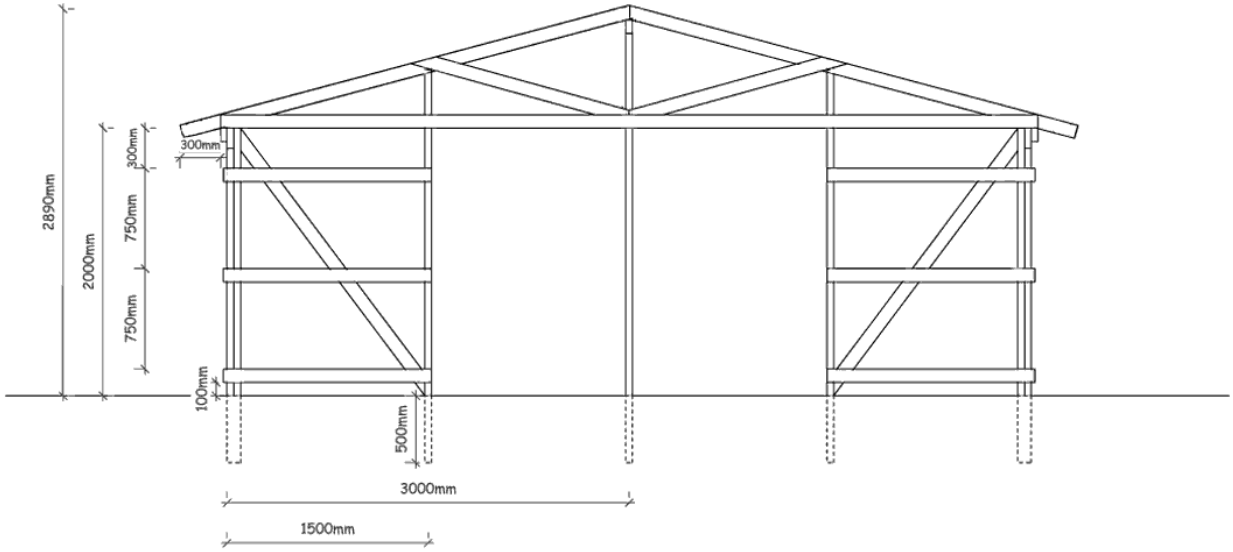
7.2 orthogonal projections of the frame

plan



end elevation





side elevation

7.3 materials and tools

Material specifications: for **one structure 7x6m**, with two closed ends, the following quantities will need to be obtained:

timber
Timber comes in a limited range of sizes. Lengths of 4.5m can be relied upon and sections 50x100mm and 100x100mm. (Note that the lengths for the posts include a post hole 500mm deep)

elements	length of timber members	size of section	quantity of timber members for one shed
3 long uprights to support ridge	3.2m each	50x100mm	**4**
4 corner posts	2.5m each	100x100mm	**4**
uprights for sides	2.5m each	50x100mm	**6**
uprights for ends	3.0m each	50x100mm	**6**
diagonal bracing for ends	2.5m each	50x100mm	**4**
diagonal bracing for sides	2.4m each	50x100mm	**4**
ring beam: sides	3.5m each	50x100mm	**4**
ring beam: ends, 2 made from	3.1m each	50x100mm	**2**
1 ridge beam, made from 2 pieces:	3.5m each	50x100mm	**2**
10 rafters	3.5m each	50x100mm	**10**
3 tie beams, each made from 2 pieces:	3.1m each	50x100mm	**6**
diagonal bracing in truss	1.7m each	50x100mm	**10**
cross bracing between rafters	3.8m each	50x100mm	**8**
spacers	1.7m total	small (off-cuts)	**12**
batons for sides	3.5m total	small (off-cuts)	**12**
batons for ends	1.55m total	small (off-cuts)	**12**

65 lengths of 4.5m will be needed for the above, with the spacers and batons taken from the off-cuts. All the elements referred to are shown in the sequential instructions for construction.

nails
2-3 nails per joint should be used. A 50 x 100 frame should be fixed with steel nails of approx. 70mm (3”). As a general rule, the length of the nail should not be less than 2x the thickness of the timber being secured. Galvanised steel nails must be used if timber is treated with CCA (copper-chromium-arsenic). The structure tabled above requires up to 500 nails in total, usually bought in kilo quantities. Allow for 80 x 70mm steel nails per kilo: a 10 kilo bag will contain approximately 800 x 70mm nails.

plastic sheeting
The plastic sheeting advised is the woven or braided flexible tarpaulin recommended by MSF and UNHCR. Many types of plastic sheeting may be available locally, but often these will not be strong enough to resist wind or UV degradation. MSF offers further advice on plastic sheeting. It has also established an international deal with major manufacturers to lower prices.

plastic sheeting	quantity	size of piece	length of plastic required
sides of shed (2 bays)	4	3m high x 4m long	6x4m
ends of shed (2 pieces per end)	4	3m high x 4m long	12x4m
roof of shed	2	7x4m	14x4m
		total	32x4m

additional bays
For each additional bay:

timber	length of timber	size of section	quantity
Uprights for sides	2500mm	50x100mm	4
long uprights to support ridge	3200mm	50x100mm	1
beams along sides	3500mm	50x100mm	2
ridge beam	3500mm	50x100mm	1
Rafters	3500mm	50x100mm	4
2 tie beams made from	3100mm	50x100mm	4
diagonal bracing for truss	1700mm	50x100mm	4
cross bracing between rafters	3800mm	50x100mm	4
Spacers	1700mm	small (off-cuts)	6
batons for sides	3500mm	small (off-cuts)	6

Approximately 200 70mm long nails are needed.

plastic	quantity	size of piece	length of plastic required
sides	2	3x4m	6x4m
roof	1 (to cover whole of one bay)	7x4m	7x4m
		Total	13x4m

tools
The tools required are: 10 hammers; 2 cross-cut saws; 5 carpentry saws; string for marking out; 2 spirit levels; and tools for ground levelling and digging drainage.

The builders will need basic surveying, marking out and construction knowledge.

8 tunnel frame

Temporary relief infrastructure is currently built from local materials, imported pre-fabricated structures such as RubbHalls, or a mixture of local materials and imported materials such as the timber-framed structures presented in the next section. This section proposes the inclusion of a new pre-fabricated structure, a steel tunnel framed structure. This frame has a number of advantages:

low cost

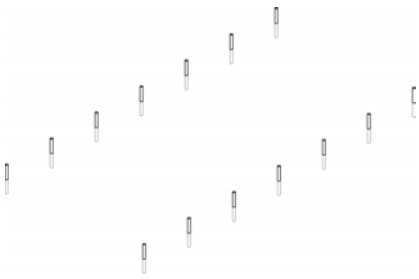
- produced all over the world, allowing short lead times and good availability
- it can be covered using plastic sheeting
- easy to repair
- easily extendable
- adaptable to a variety of uses

8.1 construction procedure

step 1: foundations for the structure

The time and materials available for construction will determine the type of foundation used. Two options are suggested:

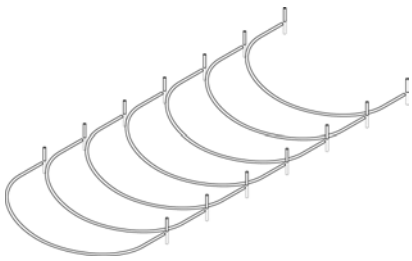
- dig simple post holes (300-500mm deep), place the foundation tubes into the holes and backfill with earth. If this method is used a ground rail should also be installed. This is the quickest method.
- alternatively, fill holes with concrete and cast a foundation tube into each. The concrete will require 28 days to reach optimum strength, though it can bear some load after 5-10 days.



step 2: assemble hoops

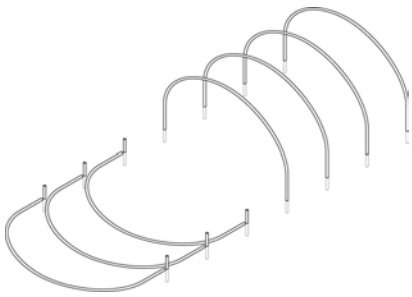
Lay out and assemble the members that make up the hoops. If possible, lay them out close to the foundation tubes that they will rest upon when erected.

Slide any fittings that are required by the design onto the hoops or foundation tubes. Sliding fittings onto the hoops of foundation tubes will be impossible once the hoops are erected.



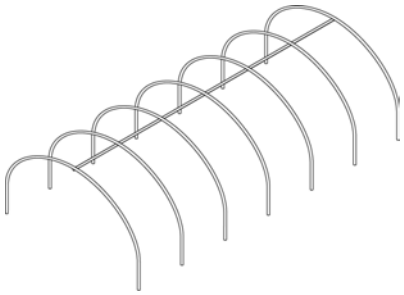
step 3: erect the hoops

Lift the hoops into position on the foundation tubes.



step 4: attach the ridge and rails

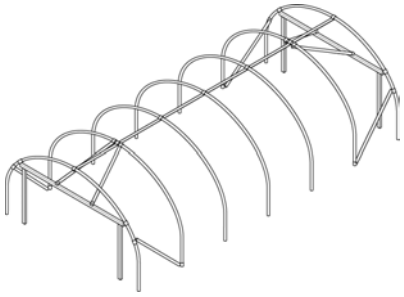
Assemble the ridge and any rails that are included in the design. Lift them into place and secure them using the fittings provided by the manufacturer.



step 5: cross-bracing & end frames

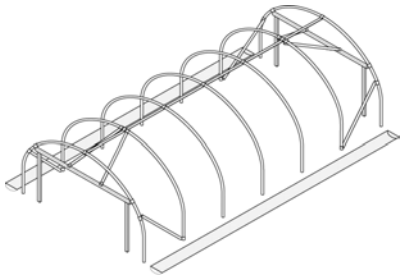
Assemble the end frames and fix them to the tunnel frame

Bracing patterns vary greatly between designs. Follow the instructions provided by the manufacturer.



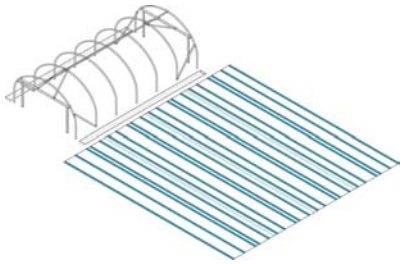
step 6: excavate trenches

Excavate trenches 300mm (12”) wide and 375mm (15”) deep either side of the frame, taking care not to disturb the foundation tubes.



step 7: lay out the cover

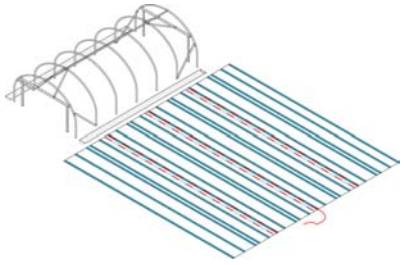
Cut the sheeting off the roll in strips 2.4m (96”) longer than the circumference of a hoop. Lay the strips out, side by side, overlapping each sheet over the next by around 400mm (16”). Lay out enough strips to cover the full length of the frame and leave at least 1m (40”) excess at each end of the tunnel.



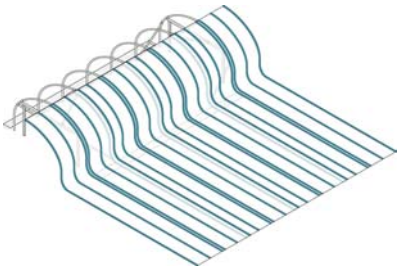
step 8: stitch the sheeting together

Produce a double stitched seam: Perforate through both layers of the overlap at regular intervals along the blue strips. Stitch the sheets together using cord or rope.

Repeat this for all of the sheets to produce a cover at least 2m (80”) longer than the tunnel frame and wide enough to be laid over the frame with around mm excess.

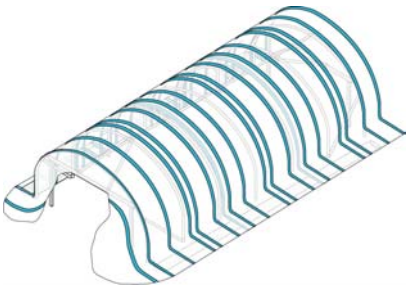


step 9: covering the frame



Pull the sheeting over the frame so that there is an equal amount of excess on each side and equal lengths overhanging each end.

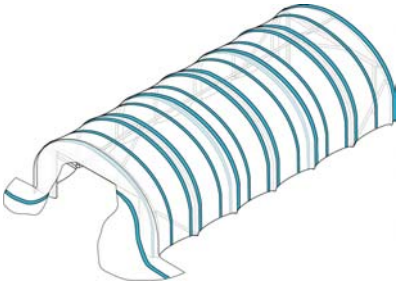
Pull one of the overhangs at the end of the frame down to the level of the lintel of the end frame. Wrap the overhang around the lintel and secure the centre 300mm (12”) to the inside face of the lintel with a wooden batten.



Go to the other end of the frame, pull the cover taut along the length of the tunnel frame and secure this end in a similar way.

Pull the remaining overhang in at the sides of the end frame and secure them to the inside faces of the end frame uprights. Do this at each end of the tunnel frame.

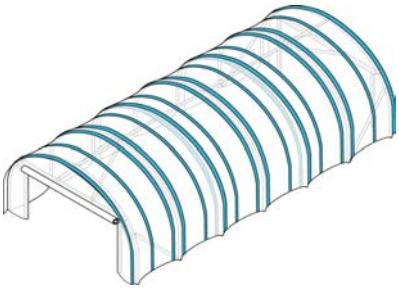
step 10: ballast the cover



If suitable stakes or rebar are available, pin the sheeting in place along the sides of the tunnel frame. Make small perforations in the sheeting where it is lying in the trenches. This should help stop pooling when the sheeting is buried.

Backfill the trenches, covering the sheeting. If the material is available, ballast the sheeting with stone.

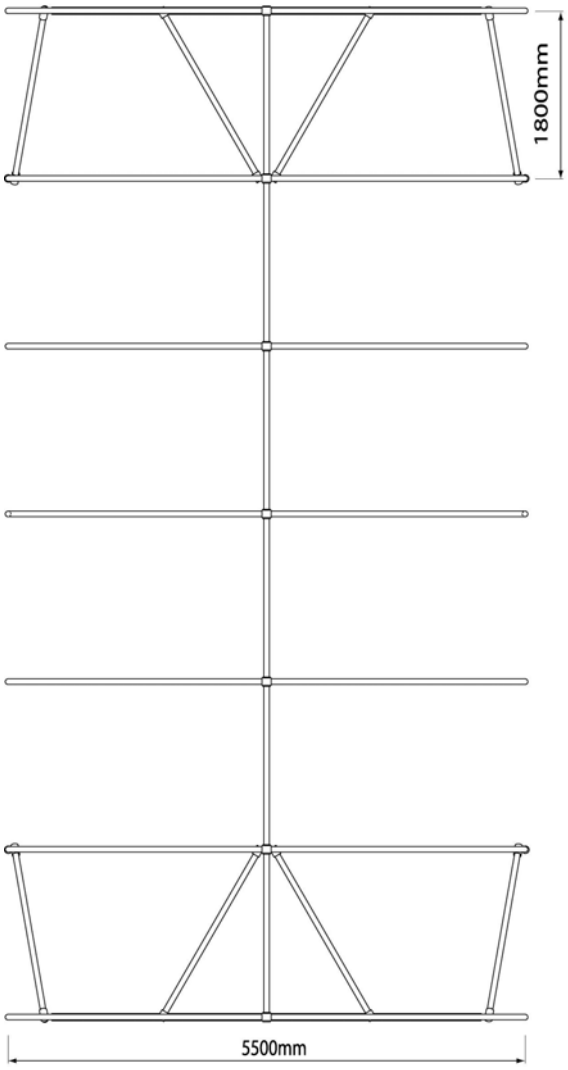
step 11: attach doors



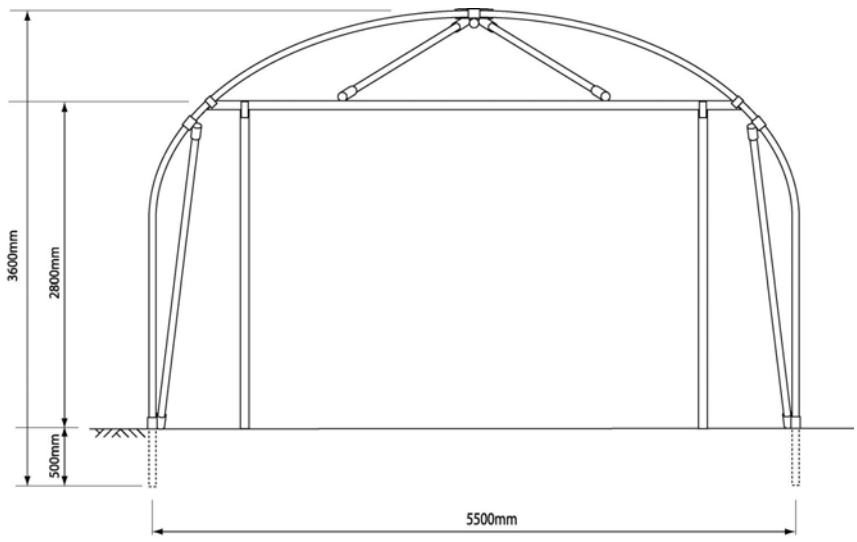
Attach doors or flaps to the end frames.

8.2 orthogonal projections of the frame

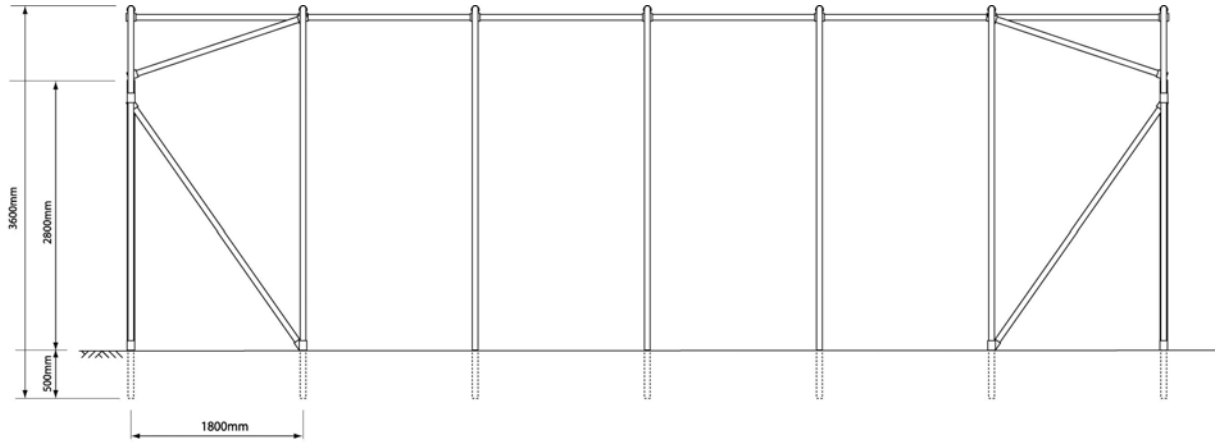
plan



end elevation



side elevation



8.3 materials and tools

steel frame
Preformed steel frames are available from suppliers listed in Appendix A.

plastic sheeting
The plastic sheeting advised is the woven or braided flexible tarpaulin recommended by MSF and UNHCR. Many types of plastic sheeting may be available locally, but often these will not be strong enough to resist wind or UV degradation. MSF offers further advice on plastic sheeting. It has also established an international deal with major manufacturers to lower prices.

Assuming standard 4m wide sheeting is used, the length needed will be given by the formula:

$C \times L / 3.6m$ rounded up. Where C is the circumference of a hoop and L is the length of the frame.

Allowance must be made for covering the end of the frame.

tools
The tools required are: spanner and screwdriver sets; a hammer; string for marking out; a spirit level; and tools for ground levelling and digging foundations and drainage.

The builders will need basic surveying and marking out skills.

annex A tunnel frame suppliers

Company	Website	Location
poly houses	www.polyhouses.com	UK
morris polytunnels	www.morrispolytunnels.co.uk	UK
northern polytunnels	http://www.northernpolytunnels.co.uk/	UK
first tunnels	www.firsttunnels.co.uk	UK
clovis lande	www.clovis.co.uk	UK
conleys	http://www.conleys.com/	USA
jaderloon	www.jaderloon.com	USA
x. s. smith	www.xssmith.com	USA
agroponic	www.agroponic.com	USA
cropking	www.cropking.com	USA
Omni structures international	www.omnicanada.com	Canada
Polyshelters	www.polyshelters.com	USA
Weather Block Shelters	www.weatherblockshelters.com	USA
Atlas Greenhouse Systems	www.atlasgreenhouse.com	USA
Allen Greenhouses	http://www.allengreenhouses.com/	USA
Keeler Glasgow	www.keeler-glasgow.com	USA
Oregon Valley Greenhouses	www.ovg.com	USA
First Quality Industries	www.fqi-greenhouse.com	Canada
Paul Boers Ltd	www.paulboersltd.com	USA
Lombarda Serre	http://www.lombardaserre.it/frameset1.htm	Italy
pontevia	www.pontevia.it	Italy
comagri	www.comagri.it	Italy
umbria serre	www.umbriaserre.it	Italy
serre campioni	www.serrecampioni.it	Italy
puteaux SA	www.puteaux-sa.fr	France
bn serres	www.bnserres.com	France
serres tonneau	www.serres-tonneau.com	France
TPSB Cerizay	www.tpsb-cerizay.com	France
Hummert de Mexico	www.hummertdemexico.com.mx/tunel.htm	Mexico
Filclair	www.filclair.net/en/pageTunnel_ang.php	France

annex B alternative materials

The tables below compare a range of possible materials for structure and cladding.

table 1 structural materials

material	advantages	disadvantages/points to note
timber	• widely available • can be procured locally, cutting cost and lead time	• local timbers may not be stress graded, so advisable to overcompensate on structure • green timber may have to be used, which is susceptible to bending • must be protected from fungal and insect attack* • Timber comes in a limited range of sizes. Lengths of 4.5m can be relied upon and cross-sections 50x100mm & 100x100mm.
bamboo	• cheap and widely available: traditionally used for construction in tropical and semi-tropical regions, where it grows abundantly.	• traditional skills or expert supervision are needed as bamboo cannot be nailed. • must be treated to prevent deterioration (otherwise lifespan of only 2-3 years)
poles	• cheap and widely available • allow the use of trees too thin to be sawn into planks, so can be cheaper than sawn timbers	• variable dimensions • round section can make fixing difficult • tend to split at ends

*In many regions untreated wood will be eaten by termites within **six months**. For protective measures, see **construction guidelines, step 5.**

table 2 cladding materials

material	advantages	disadvantages/points to note
plastic sheet	• cheap • short lead time: readily available and widely used in the field • standard sizings make planning straightforward* • waterproof • durable, although eventually degraded by UV exposure • resistant to insect attack • temperature resistant from –20 to +80 degrees C.	• petrol and lubricating oils can cause swelling, when absorbed • temperature differences where the sheeting comes into contact with a warm surface can cause brittleness locally. • **tearing** is a problem if it is not fixed to the frame properly or if it is in contact with sharp edges or points. • UV degradation causes clear sheeting to become brittle after 6 months of exposure to sunlight. Darker polythenes are more resistant, though with reduced light transmission. The UNHCR specification is for 2 years' UV degradation.
profiled metal sheeting	• readily available and widely used in developing countries • life span of 5 years approx. • allows for fairly shallow pitches of roofs, about 15 degrees	• recommended spacing of timber members to which cladding is fixed may have to be adjusted to match the dimensions of the sheeting.
local materials reeds, grasses etc.	• readily available and often widely used • Thatch a good option for roofing in the second phase of construction, when more time available for construction. • Thatch provides good insulation	• Necessary to harvest large quantities, thereby depleting surrounding supplies • Heavier than plastic sheeting (up to 10kg/m^2 compared to 0.2kg/m^2**)** so more structural support may be needed • Skill needed in construction, but may be available among local/migrant populations

*The standard UNHCR specification is for rolls of 4x50metres with four reinforcing strips running along its length. For further information on plastic sheeting, see Oxfam's *Plastic Sheeting – An Oxfam Technical Guide* and MSF's publications on standards and use of plastic sheeting (See Bibliography)

annex C glossary of terms

camps	displaced populations find accommodation in purpose built sites where a full range of services - for example water, sanitation are provided, usually exclusively for the population of the site. (UNHCR)
community shelter	shelter for families, individuals and communities.
complex emergency	an emergency resulting from human action, rather than natural causes
contingency planning	project planning with responses being in place to deal with many potential outcomes
disaggregation	splitting a total into a series of smaller sections. For example, in the case of "disaggregated spend" we mean a breakdown of the total spend into details such as the total staff time involved in shelter programme management.
disaster	a situation where people's normal means of support for life with dignity have failed as a result of natural or man made catastrophe (SPHERE)
dispersed settlement	displaced people find accommodation within the households of families who already live within the area of the refuge. The displaced people either share exiting accommodation or set up temporary accommodation nearby and share water, sanitation and other services of the pre-existing households (UNCR)
disaster-affected population	all people whose life or health are threatened by disaster, whether displaced or in their home area. (SPHERE)
displaced population	a population which has been displaced from their original place of residence by conflict or natural disaster
emergency	any situation in which the life or well being of individuals will be threatened unless immediate and appropriate action is taken, and which demands an extraordinary response and exceptional measures (UNHCR -adapted beyond just refugees)
groups at risk	people are considered to be exceptionally vulnerable (SPHERE)
guidelines	practical advice, decision-making frameworks tips, examples and good practice for use in the field
host government	government of the country in which humanitarian assistance takes place (SPHERE)
hot climate	a climate where the temperature regularly surpasses 30C. However it may be cold at night.
humanitarian actor	an organisation that supports the provision of humanitarian assistance (SPHERE)
humanitarian assistance	the provision of basic requirements which meet people's needs
IDP	Internally Displaced Person – a person who has been forced to leave their home, but has not left the boundaries of their home country
infrastructure	the basic support network for settlements, such as roads, warehouses e.t.c
land rights	the issues surrounding who is in ownership of the land
local authorities	government or leaders recognised to be in control in the country or region in which the disaster- affected population is located (SPHERE)
local settlement	settlement of displaced populations within the host country
mass shelter	public buildings and communal facilities - where displaced people find accommodation in pre-existing facilities, for example in schools, barracks, hotels, gymnasiums. These are normally in urban areas and are often intended as temporary or transit accommodation (UNHCR)

minimum standard	the minimum level (of service) to be attained in humanitarian assistance (SPHERE)
NFI	Non Food Items – items included in the shelter sector which are not categorised with buildings, nor food, e.g. blankets, mattresses
prefabricated shelters	shelters made in sections prior to delivery on site. Need to be assembled on delivery.
refugee	any person who owing to well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion, is outside the country of his nationality and is unable or, owing to such fear, is unwilling to avail himself of the protection of that country
settlement	a collection of covered living spaces providing a healthy, secure living environment with privacy and dignity to those within them.
shelter	habitable covered living space, providing a healthy, secure living environment with privacy and dignity to those within it.
site selection	the process and the choice for choosing a suitable location for a supported settlement
shelter sector	professionals working in the planning, management and implementation of shelter solutions
SPHERE	the SPHERE project: humanitarian charter and minimum standards in disaster response
STS	supported temporary settlement
support facilities	infrastructure to support the provision of a response
vulnerables	individuals or groups of individuals who are particularly disadvantaged in safeguarding their own well-being
warehouse	a structure for the storage of items.
watsan	water and sanitation

annex D bibliography

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Manfield, P *Emergency Shelter for Humanitarian Relief in Cold Climates: Policy and Praxis.* 2001, Unpublished dissertation for the Department of Architecture, Cambridge University

articles on plastic sheeting

Medecins sans Frontières *Plastic Sheeting: Braided 4 x 50m, transparent, roll.* **MSF code: CSHEPLASR4T**

Howard, J and Spice, R. *Plastic sheeting: Its Use for Emergency Shelter and Other Purposes.* 1989, Oxfam

useful websites

www.sphereproject.org Humanitarian Charter and Minimum Standards in Disaster Response, including guidelines on all sectors including shelter for humanitaran relief workers to aim towards.

www.shelterproject.org information to support the aid community in supporting transitional settlement.