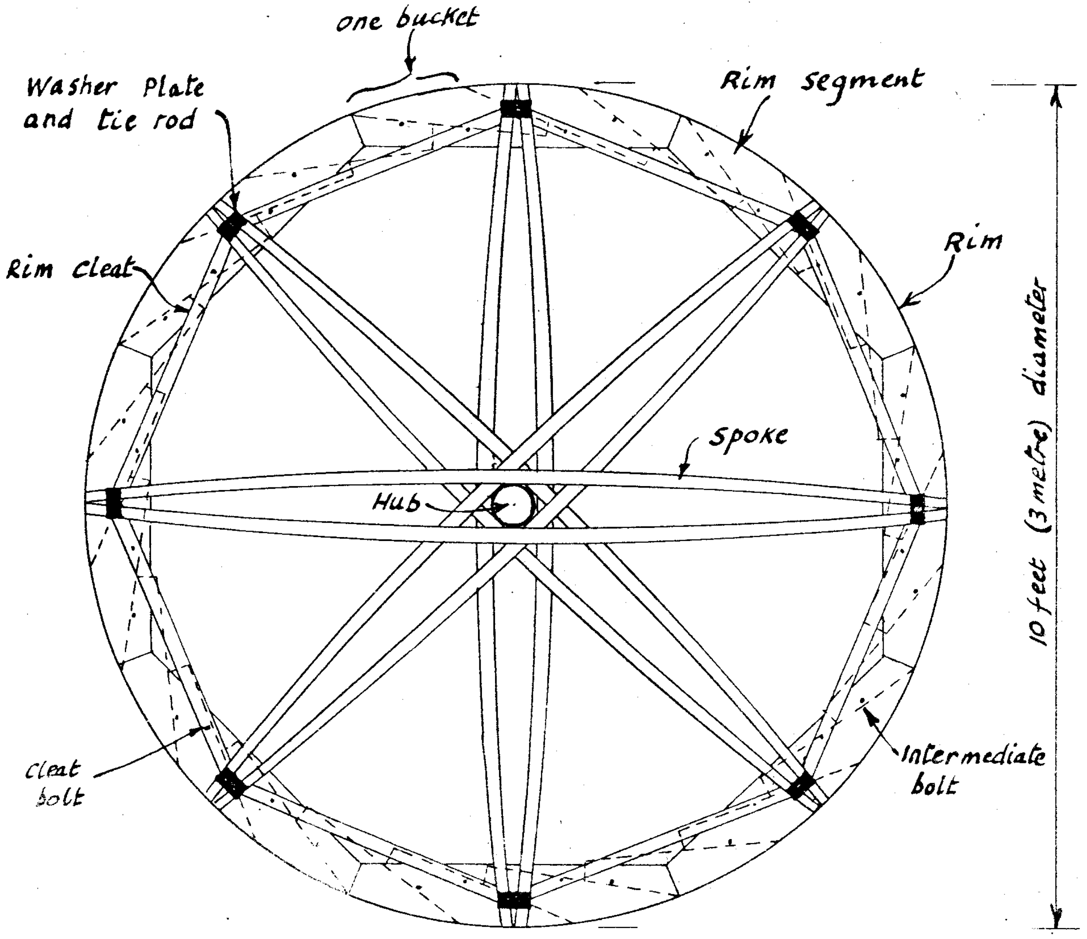
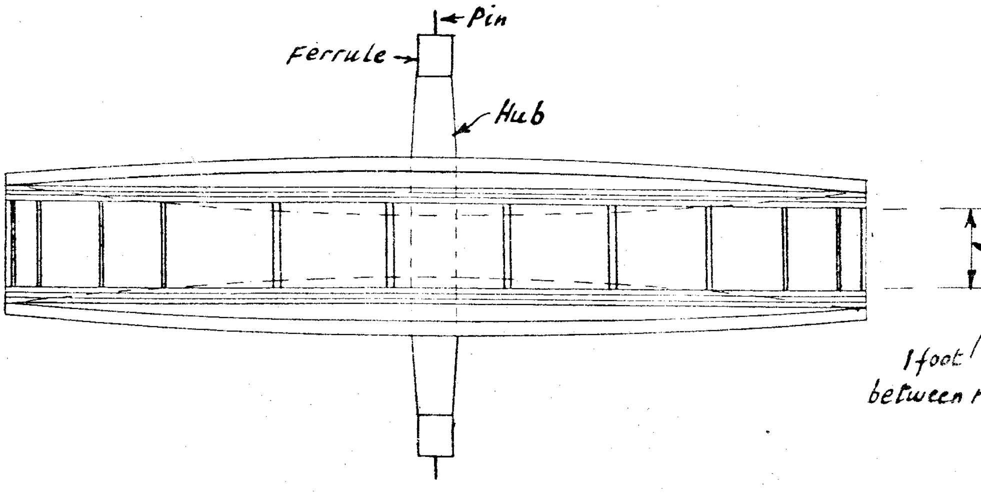
D.I.Y. PLAN 7

TIMBER WATERWHEEL



ELEVATION : scale ½" = 1'



PLAN : scale ½" = 1'

Introduction:

The design and construction of waterwheels reached its topmost quality about 70 years ago; we realised that if our wheel was to be as successful or better than these, we would require cast iron, steel or aluminium, or good quality timber (possibly all of these) combined with the expertise and equipment of the foundry, the steel fabricator (blacksmiths) or the wood machine shop (wheelwright). This would limit construction to professionals only, and take the project out of range of D.I.Y.; the cost would also soar from £10s to £1000s.

We have therefore sacrificed the wheel's performance by reducing the design to simple timber engineering using hand tools on cheap (possibly recycled) materials, assembled anywhere large enough to fit the diameter of the wheel.

In this report we have described in detail the construction and cost of the wheel which we built. However, from our experience we can recommend that this method of construction is applicable to overshot (possibly undershot) wheels of diameter varying from 5ft. to 25ft. and width from 1ft. to 5ft.. Some design guides are given for establishing the size of wheel, and there are recommendations as to member sizes and method of assembly. Final choice of members would have to be found by experiment, or dictated by the availability of materials.

Size of Wheel:

The overshot waterwheel is not an “impulse wheel” - i.e. its movement does not depend on the energy of moving water hitting the wheel, it relies on the weight of the water filling the buckets on one side of the wheel only, causing an out of balance force which rotates the wheel until the water pours out of the buckets at the bottom. Therefore, the more water that can be introduced and held in the buckets and the greater the height of fall from the point of filling to the point of emptying, the more energy will be available from the turning wheel. Hence the design for a given power (or rate of energy) supply for a specific purpose, with a fixed quantity of water available, the wheel diameter can be varied, with the bucket size remaining constant to suit the flow of water. Conversely for a limited head of water the quantity and hence bucket size can be varied and the wheel diameter varied up to a maximum to fit the available space.

The theoretical horse power available is given by H.P.= hQ/530 where 'h' is the wheel outside diameter (ft.) and ‘Q' the flow of water (cubic ft. per minute). However, in practice not all the water flowing remains in the buckets from the top to the bottom of its fall and the efficiency of the wheel could only be about 50%. Hence, as a guide, actual H.P.= hQ/1000. (Note: 1 gallon = 1/6 cu.ft. approx.)

The velocity of the wheel will vary with the load imposed upon it - e.g. no load - fast, maximum load - slow, but for any setting of a sluice gate controlling the flow of water, the water is flowing at a constant rate, and therefore it is impossible to efficiently fill the buckets in every working condition. If the number of buckets is ‘n’ and the wheel is rotating at ‘w’ revs. per minute, then the speed at which the buckets will pass the water supply is wn buckets per minute; hence to fill a bucket from a water flow of Q cu.ft. per minute, the bucket volume must be Q/wn cu.ft..

The velocity of the water supply can be roughly calculated as being the quantity flowing divided by the cross sectional area of the water supply i.e. V= Q/a where 'a' is the area of cross section of the pipe or channel. In practice, for efficient working the peripheral velocity of the wheel should be about 9/10 of this. In a limited space the wheel diameter may have to be reduced allowing for some fall on the feed pipe or channel to increase the velocity of water entering the wheel. The best peripheral velocity of a wheel is roughly 2 x sqrt(diameter) ft./sec..

Having <u>chosen</u> the dimensions of the wheel to suit <u>your</u> purpose, you will need the following timber:

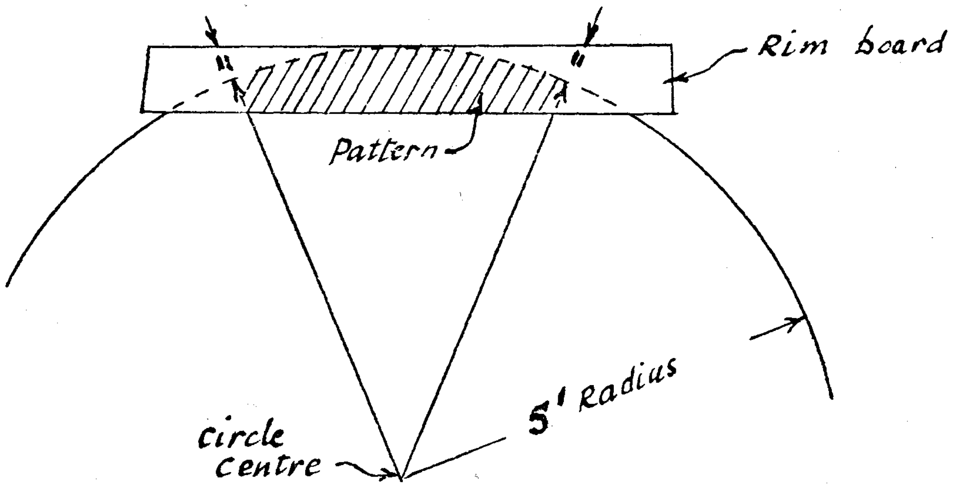
Wide, thin boards, or thick plywood for the rims, thick boards for the buckets, a short piece of straight grained log for the axle and some thin poles for the spokes.

To give a good example of the materials and problems involved in the construction of this type of waterwheel we will describe the wheel that we built for the Centre for Alternative Technology.

<u>Stages in Construction:</u>

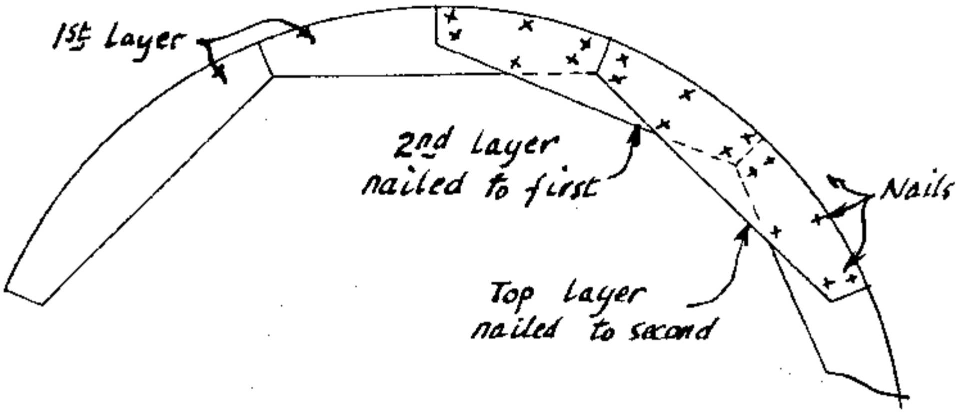
1. <u>Setting out the Wheel</u>: On a flat, smooth, hard surface such as a boarded floor or sheets of plywood laid out on the ground, we drew an accurate 10ft. diameter circle using compasses improvised by lashing a pencil to a batten nailed down at the centre. With a straight edge, we divided the circle into eight equal sections, by first making four quarters, then splitting each quarter into half (a larger wheel may need more divisions, say 12, but there must be an even number).

2. <u>Making the pattern for a rim segment</u>: We laid a 9 inch wide rim board on the outside of a segment, such that its outer edge was equidistant from the centre at each side of the sector. With compasses and straight edge, we reproduced the circle and sector edges on the pattern, and carefully sawed out the pattern leaving the pencil line just visible. (You may need to smooth the edges of this as it has to be drawn round. Hardboard or thin plywood may be more convenient for this.)



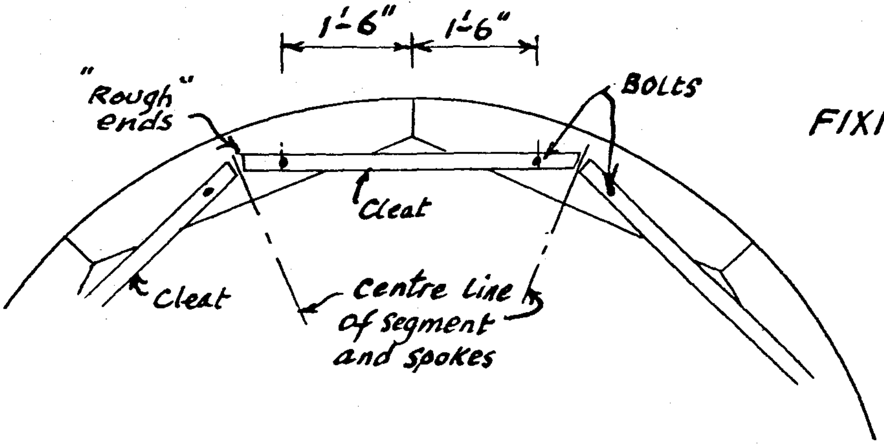
MARKING OUT THE PATTERN FOR RIM SEGMENT ½"=1"

3. Construction of the rim: Each of the two rims consisted of three layers of eight segments, therefore we sawed out forty-eight. Accurate cutting of these is essential; we checked this by fitting the first layer onto the circle. We nailed the second layer onto the first, lapping the joints half way, and the third layer onto the second, in line with the first. 2 inch nails are suitable for this, clenched over afterwards if they protrude.



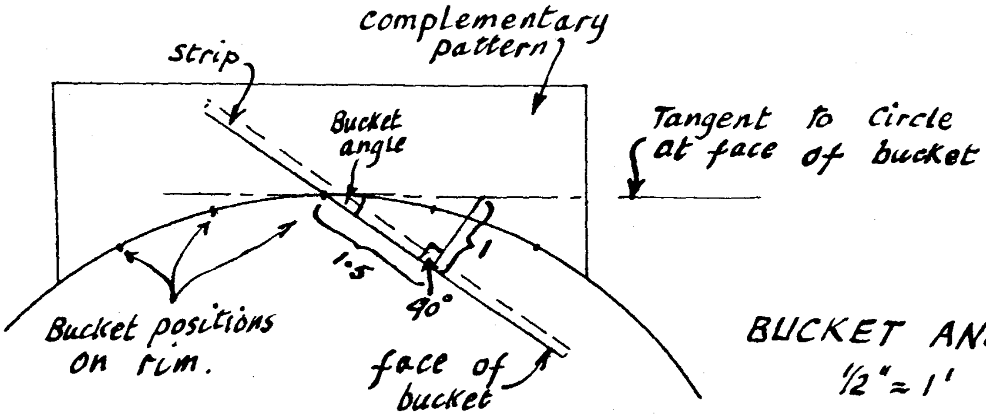
NAILING THE RIMS TOGETHER ½" = 1"

We then bolted 2 inch square by approximately 4 ft. long cleats to the rim, with the ends roughly meeting as shown in the sketch. This procedure was repeated for the second rim.



FIXING THE CLEATS ½" = 1'

4. Marking out the bucket positions: For the 24 buckets required in our wheel, we laid the rims face to face, so that the segments were opposite one another, and divided each segment into three equal lengths round the circle. We cut out a complementary pattern to fit round the rim, and nailed it to a strip, equal to the width of a bucket board in the direction shown:



BUCKET ANGLE : 1 / 1·5
½" = 1'

At this stage, while the rims were together, we drilled the 9/16 inch diameter holes for the main tie rods as shown. Then we laid each rim face up on the ground, fitted the pattern to the circle, and marked along both sides of the strip at each bucket position (note the strip must be nailed on to the opposite hand for the opposite rim). The buckets must not coincide with the main tie holes.

5. Bucket assembly: We laid the rims face to face, spaced apart by the thickness of the 12 inch wide buckets. Having cut the boards to length with a chamfered cut on the outside to match the rim, we nailed the buckets in with three 4 inch nails, through the rim each side, into prebored holes.

6. The spokes: The spokes are fixed in pairs, bent from one side of the wheel, round the hub, to the other fixed at each end by a common tie bolt and two cleats. They are also bent in the other plane because they overlap at the hub (see sketch). It is therefore important that the spokes are sufficiently flexible to allow this amount of bend without splitting, yet be stiff enough to firmly grip the hub and maintain the strength of the wheel. In the case of our wheel, the spokes were 10 ft. long and had to be bent 3 inches at the centre in the plane of the wheel and 1 inch or 3 inches at the centre at right angles to this plane.

Sawn timbers with even the very straightest grain have fibres 'breaking out' of the dawn edges, usually to a considerable extent; a pole, by its nature as a growing tree, has all its fibres 'growing' along its length, and is much more flexible. We used conifer poles forestry thinnings, and tested them by supporting them at their ends and checking whether they would deflect the required amount - i.e. 3 inches each way or 4 1/2 inches total.

We chose 16 suitable poles and roughly tapered them with an adze and saw so that they were about 2 inches square at the centre and 1 3/4 inches square at the ends. Note it was not necessary to make the poles square anywhere except at the ends where they are fastened with a bolt; however a tree is thicker at its base and to curve evenly each side of the axle it may be necessary to reduce the thicker end to roughly the same size as the thinner end.

7. The hub and its bearings: This can be made of any softwood tree trunk about 6 inches diameter and long enough to allow about 4 to 6 inches of bearing length beyond the spokes; additional length must be provided between the spokes and the bearing if a pulley fixing is required.

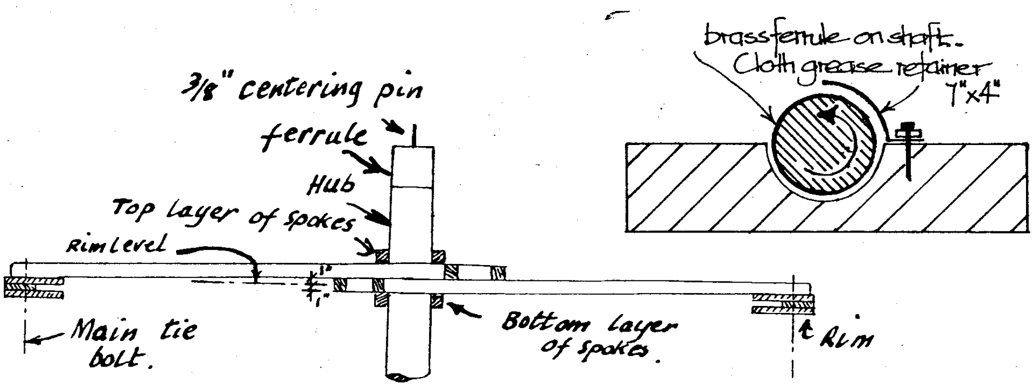
As the wheel is of fairly crude construction the hub need not be turned on a lathe; hand planing is adequate. After rough shaping it is useful to insert a pin (say 3/8 inch diameter) at the centre at each end. The log can then be set up between centres on the bench, and quickly rotated for the final accurate planing.

We drove a 4 inch diameter brass tube (4 inches long) ferrule on each end of our hub. The bearings are half circular open topped, made from yew or similar. We left the centering pins at each end to give frictionless restraint against lateral movement, the other end of the pins bearing against a stone. N.B. These bearings must always be kept well greased. In practice roller bearings may be required.

8. Fixing the spokes: With the wheel horizontally on the ground and the hub propped up in the middle, put the spoke fixing bolts through their holes and put a nut and washer plate on the lower end (nearest the .ground). Lay a pair of spokes with one pair of ends in their correct position on each side of the bolt, mark where to cut the ends of the

cleats so that the spoke ends will fit snugly round the bolt; repeat this for all the other spoke ends, numbering positions to avoid confusion. Saw all the cleat ends off to the correct size (in position). Put one end of the first pair of spokes into position and fit the washer plate and nut tightly, then bend the spokes round the axle and fix the other end. Repeat this for the second pair of spokes at right angles to the first. Note the spokes become increasingly hard to bend as more are fitted; the third and fourth pairs will require two pairs of hands, strong feet and possibly cramps or a Spanish windlass.

Turn the wheel over to the same position the other way up and fit the other set of spokes exactly the same way, except that before each spoke position is marked out on the cleat, the nut and washer plate have to be removed, and this can only be done by cramping the spokes on the opposite side to the far rim so that they don't spring out when the bolt is loosened.



CROSS SECTION THROUGH RIM AND SPOKES

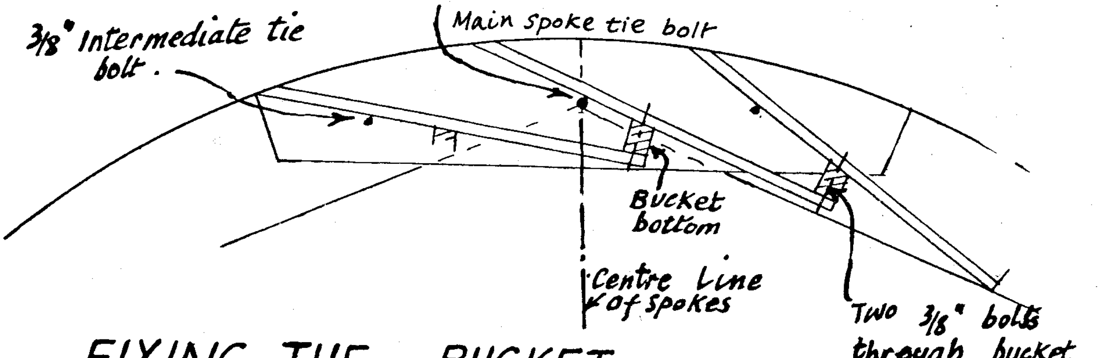
BENDING THE SPOKES ROUND THE HUB 1/2" = 1'

9. Truing the wheel: For this the wheel must be set up in its final bearings or in temporary bearings so that it can be turned. Fix a pointer on an immovable datum so that when the wheel is spun, its movement out of true can be observed. Push the wheel sideways into its correct position; at this stage it should still be sloppy enough to stay where it is pushed, but if it is not, fit temporary pairs of wires in the appropriate direction diagonally across the diameter inside and twist up as a 'Spanish windlass' until the wheel stays in 'shape'.

When the wheel spins reasonably true, fit and insert the plugs of wood which form the bottoms of the buckets and bolt right through from one bucket to the other, with two bolts each.

Insert an additional 3/8 inch diameter intermediate tie rod between the two rims alongside the bucket walls that haven't already a main spoke tie beside them.

Fix each spoke to the hub with a large nail (galvanised) say 4 or 5 inches long. The wheel will now remain tight.



FIXING THE BUCKET BOTTOMS 1/2" = 1'

The following is an ideal specification for the timber in a wheel to be built and used in the British Isles:

1. All timber must be dry (below 22% moisture content), free from dirt and bark.

2. Shape timber to final size.

3. Take all timber to timber merchant to be treated with preservative by vacuum pressure impregnation to 'specification for motorway fencing' (treatment plants in most towns throughout the country, cost per wheel £8 - £10).

   This treatment will permanently protect timber against fungal decay; otherwise it must be brush treated with creosote every 4 to 5 years and only when the wood has been allowed to dry out thoroughly.

4. Allow timber to re-dry after treatment by stacking it carefully so as to allow good air movement, but out of direct sunlight. Separate sawn boards with 1/2 inch thick spacers 2 ft. apart and weight the top board down to avoid distortion.

   Any subsequent cross cut faces to be liberally brush treated with creosote.

5. Suggested species:

Buckets and rims:	Elm, shuttering plywood
Cleats - softwood:	Scots pine, Larch, Douglas fir
Spokes - forest thinnings:	Scots pine, Douglas fir, Larch
Bearing blocks:	Yew, Applewood - all quarter sawn

The Cost of a 10 ft. diameter wheel as at August 1976 (assuming new materials)

3/8″ and 1/2″ nuts and washers	£4.80
32 off ll0mm x 6mm coach bolts and washers	£3.06
32 off 5" x 3/8" coach bolts and washers (should be 5 1/2")	£5.99
2 kg 4" galvanised nails	£2.27
Bolts and bearing sleeve	£9.00
24 tie rods at say 90p each	£21.60
Sawn elm	£44.95
Hub	£0.86
Spokes and cleats	£33.84

£126.37

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This D.I.Y. plan has been prepared for the Centre for Alternative Technology by C.L. Wallis and R.G. King c 1978.

Other D. I.Y. plans, information sheets, and books are available from the "Quarry Bookshop" at the Centre. Please enclose a s.a.e. with all correspondence as we are a charity. Visitors are welcome.

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