Abingdon Weir White Water

A feasibility study

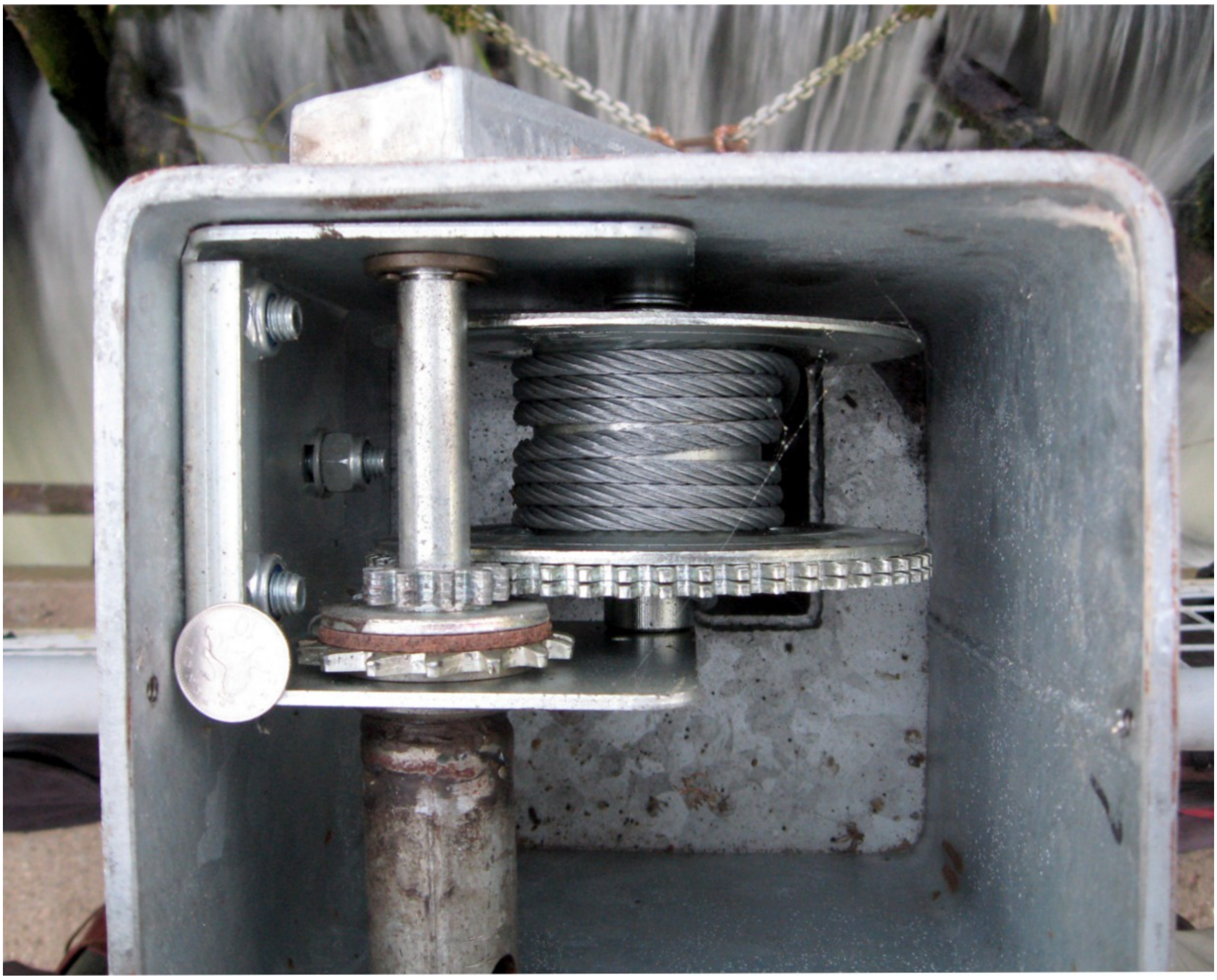
1 Summary

This is a companion report to our joint proposal with the canoe clubs. That proposal sets out the agreement between canoe club representatives and Abingdon Hydro, on generating hydroelectricity, while improving the recreational facilities and without compromising the Environment Agency's ability to control the river.

This report describes two possible technical approaches, hydraulic and electrical. It is intended as a feasibility study, not a full design report.

2 Calculations on the existing winch

Here is a photograph of the mechanism of one of the winches that open the small radial gates:



What weight does it have to lift? We have the 1961 drawings of the gate assembly. It is made of 3/16" thick steel, and the gates are 2' high by 7' wide. There are also the supporting arms. In the drawings the gates have a counterweight, but it was cut off when the manual winches were fitted a few years ago. With the steel frame and wooden base the gates work out at about 180 kg.

Further estimates can be done. The radius of the lifting drum is about 40 mm, so the torque is about 70 Nm. The gear ratio is 4:1, so the handle should need about 20 Nm. Adding a bit extra because of friction, 25 Nm should be adequate. With a handle crank of say 25 cm that would need a force of no more than 10 kg. In practice it seems quite easy to turn so it may be less than that. To lift the gate clear of the water, about 0.6 m, needs about 10 turns of the handle.

By hydraulic standards this weight is very easy to lift. To power it electrically, the best place for a motor is inside the box. That limits its size, and therefore its power, and the speed at which it can lift. A target figure might be that raising or lowering the gate should take no more than 1 minute. For 10 turns of the handle, that means a drive speed of at least 10 rpm.

3 Example of a hydraulic drive

3.1 Method

The winch is in the middle, and the gate must be lifted symmetrically, so two hydraulic cylinders would be needed, one on each side. The diagram on the following page is based on the Environment Agency's drawings. It shows the position of the gate when up and down, relative to the walkway, and how the cylinders are arranged to lift it.

The cable on each side goes from a point on the weir, over the pulley, and down to the gate. The pulley is pushed up by the hydraulic cylinder on each side. The cylinders are on small platforms that clamp onto the side of the weir.

The pump would run for a limited time, set in the control system, with the pressure limited by a safety valve. No position sensor is needed to make it stop when the gate is fully raised, as the safety valve would limit the force. A solenoid valve would then close, to hold the gate up. If the gate were jammed or locked, the hydraulic pump would simply keep pumping until the timeout, but the safety valve would prevent damage.

When it is time for the gate to close, the solenoid valve would open, allowing the gate to fall at a rate that is preset by a bleed valve.

3.2 Design

The positions are chosen so that the force on the cylinder is more or less vertical, because cylinders do not like sideways forces. The cable fixing point on the gate rises about 0.4 m, so the piston needs to move about 0.2 m and the cylinder will be no more than 0.3 m long. The cable is fixed to the gate by a clamp, to avoid the need for welding in difficult conditions.

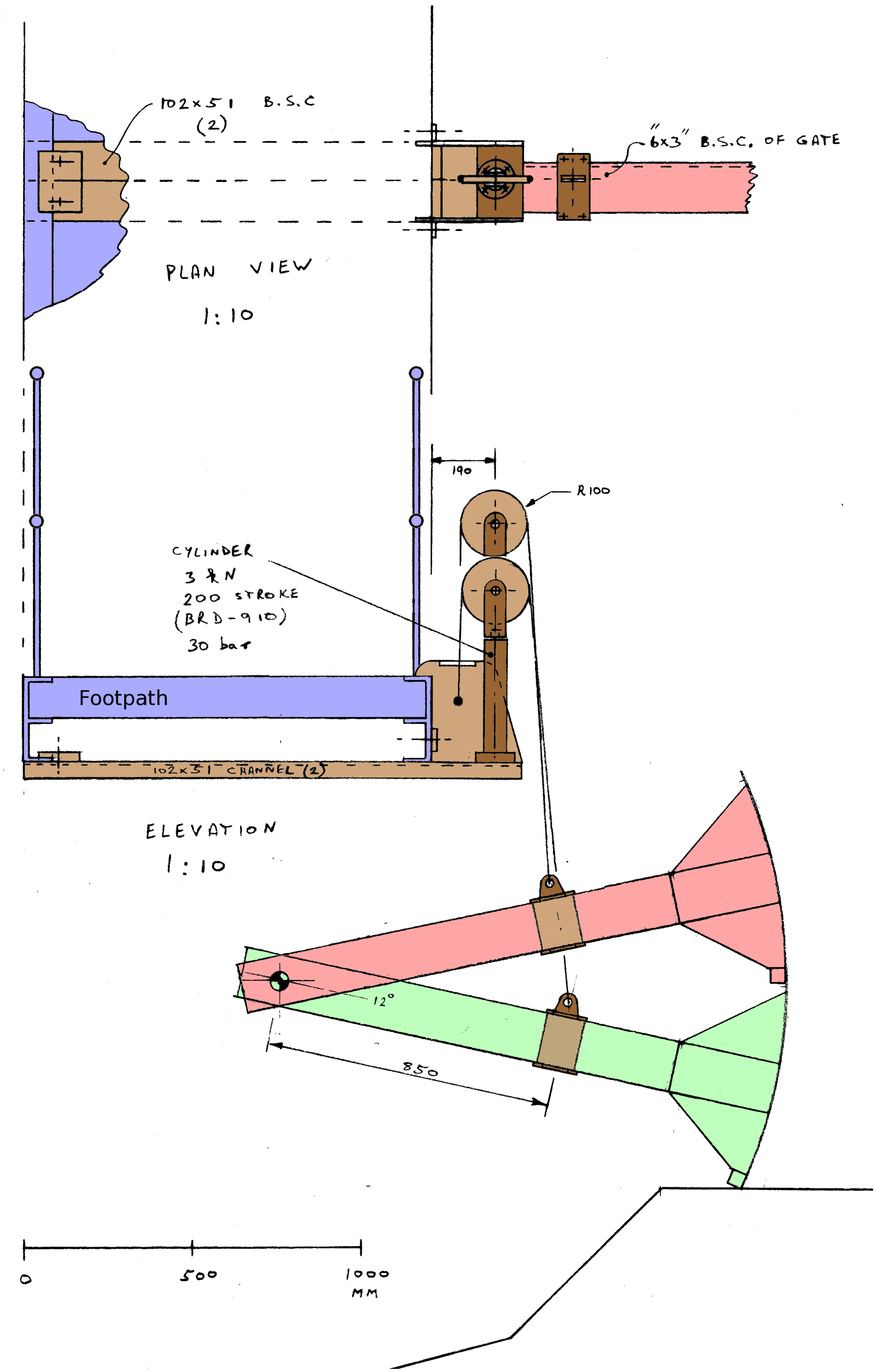
The cylinders can be spring loaded to maintain some tension in the cables, so that they do not go slack when the gate is raised manually. A cover can be added over each cylinder and pulley, for safety and protection from the weather.

The control system and hydraulic pump would be in the generator house, and the only connection to the weir would be the hydraulic pipes. There is a conduit along the side of the weir, to take power to the light at the end.

3.3 Fail safe operation

If power is lost, the solenoid valve will open and the gate will close under its own weight.

The cable fixing at the weir end is a type that can be unhooked. If a cylinder somehow jams, leaving the gate in a raised position, all that is needed is to raise it further using the handle, so the cable goes slack, then the cable can be unhooked and the gate lowered using the handle.


102×51 B.S.C
(2)
6x3" B.S.C. OF GATE
PLAN VIEW
1:10
190
R100
CYLINDER
3 kN
200 STROKE
(BRD-910)
30 bar
Footpath
102×51 CHANNEL (2)
ELEVATION
1:10
12°
850
0
500
1000
MM

4 *Example of an electrical drive*

We do not have engineering drawings of the winch, but the internal dimensions of the box are 188x188 mm and the depth 228 mm. The sketch on the next page shows fairly accurately the position of the major components.

The torque required at the handle was estimated above at 25 Nm, and we want a speed of at least 10 rpm. This corresponds to a power of 25 W. The gearbox ratio is quite large, so allowing for inefficiencies in bearings, gears, etc, 40 W should be adequate.

4.1 Choice of motor/gearbox

Space in the box is limited, and the lid can only be raised about 30 mm because of a handrail above it. The space inside the box to the right and front is about 90 x 120 mm. The connection between the output shaft and the handle sleeve would be simpler if they were parallel, because right angle drives take up more space.

One way to get a high ratio and torque in a small space is a brushless DC motor with a planetary gearbox, but motor/gearbox combinations tend to be rather long. An example is McLennan BM05 motor, 46 W rating: 57 mm square and 55 mm long. With the 2-stage planetary gearhead IP057, output torque 15 Nm, the total length is 162 mm including the output shaft. It would fit across the box at the top right hand side, but it looks a bit awkward.

A promising alternative is a pancake motor. Printed Motor Works GPM9 series is 41 W, 120 mm diameter, and 40 mm thick. Adding a 150:1 gearbox (the GPG9N) gives a torque of 39 Nm and a speed of 23 rpm. That increases the thickness to 81 mm including the output shaft. So it has enough power, and it could fit nicely against the front of the casing, to the right of the handle or underneath it.

4.2 The clutch, and sleeve connection

A clutch is needed so that the motor does not interfere with manual operation. One possibility is a mechanical clutch that disengages the motor when the handle us inserted. If we prefer to keep the existing sleeve, an electromagnetic clutch could be added to the motor output, so that it only engages when power is applied. An example is Techdrives tooth clutch: 546.1 size 13, which is 25 Nm, diameter 67 mm, stator thickness 37 mm, rotor thickness 8 mm.

The output shaft on the printed motor gearbox is offset 30 mm from the centre of the motor. That gives some flexibility in the position. Fitting a clutch directly onto the gearbox still looks difficult, but it is easier to fit if the clutch is mounted beside the motor, driven by gears or more likely a belt. That also gives more flexibility in the choice of ratio. The handle sleeve can then be driven from the clutch by adding a pulley to it and using another belt drive, which widens further the choice of ratio.

The sketch shows the box and a pancake motor drive and clutch, to scale. The entire assembly could be made as a drop in extra, with a minimum of changes to the existing hardware.

4.3 Sensing correct operation

Sensors are needed to tell the motor when to stop. The gates are wet and dirty, and it does not look very practical to sense their position from inside the box. However they have a vertical bar, going up to the side of the weir, that allows them to be locked into position. That offers a convenient sensing point. There could be an analogue readout of position, but limit switches should be enough. It could be done by a tab fixed to the bar, operating sealed switches mounted on the weir, above and below it.

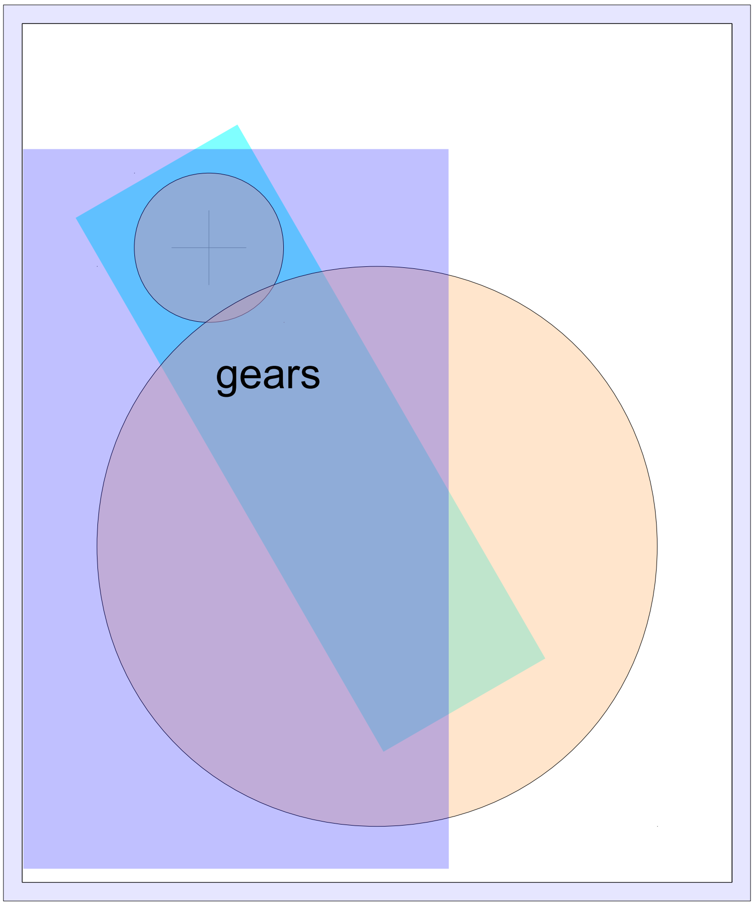
The current through the motor should also be sensed to confirm correct operation, and to provide an overload cutout if the gate is jammed or locked. These signals all feed into the controller, but by the standard of modern PLCs it is all relatively simple.

4.4 Fail safe operation

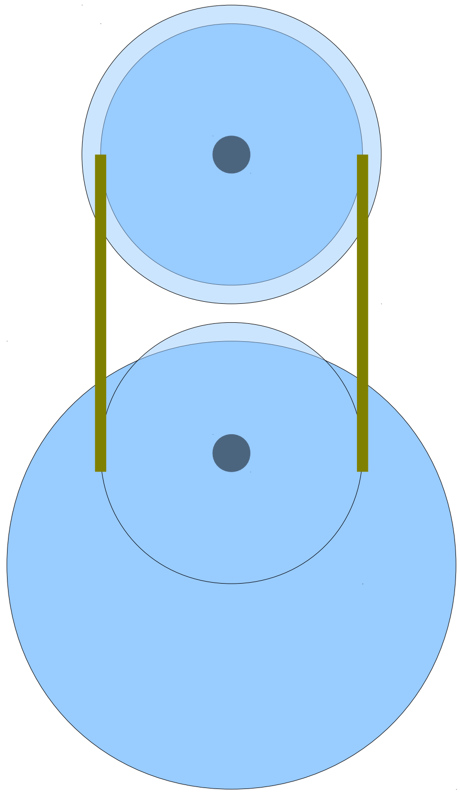
The control system would be in the generator house and would need a backup power supply, to close the gate if power is lost.

If the mechanism somehow jams with the gate open, the motor would be disconnected, by taking the lid off the box (two bolts) and removing the drive belt.

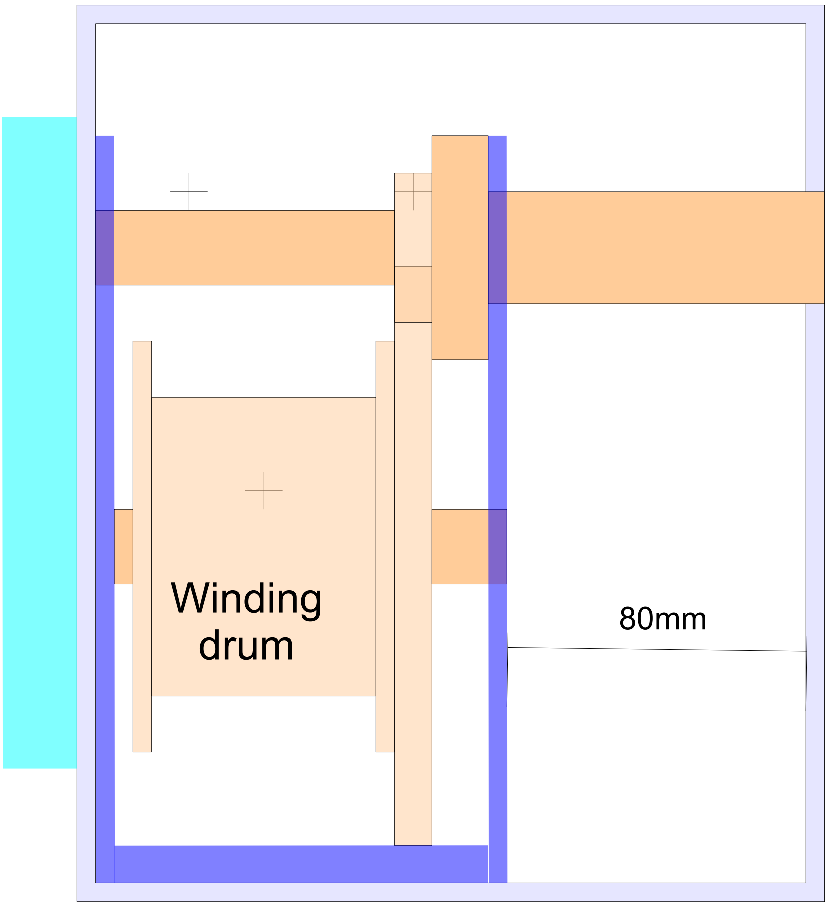
Front view

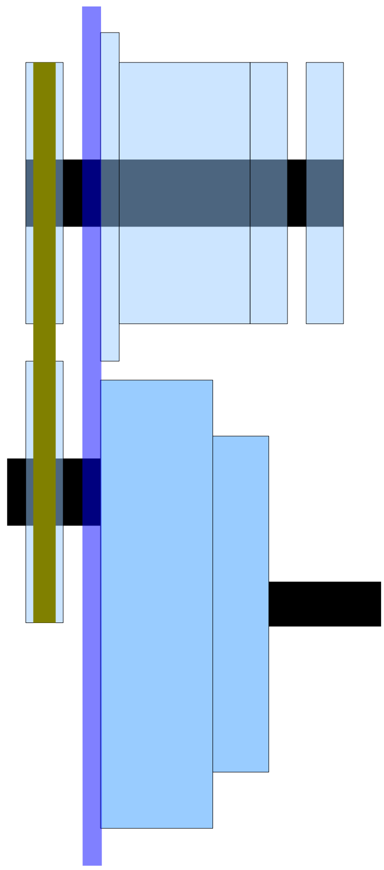


Clutch



Motor+gearbox





Side view

A4 scale 1:2

5 Choice of system

We have not yet decided which method is the better choice. The Environment Agency may have views on this. We have to cost them: components, construction, installation, and commissioning. Labour costs as always are a large part, but as we are a community project someone might come forward and offer to take on some of the work at low cost, instead of needing to subcontract it.

We also have to consider long term reliability and maintenance. Hydraulic components are generally robust and quite generic, therefore easy to replace. Operating conditions for the electrical drive are comfortably within its limits, so it should last a long time. However the weak point of electrical systems tends to be sensors and connectors rather than actuators. That could favour the hydraulic system, as it has no sensors.

6 A comment on water flow

The flow through one gate is about 1.6 cumecs. If it were open for an hour, the volume of water going through it would be nearly 6000 m^3. The area of water between Abingdon and Culham is about 5 km x 50 m, say 250,000 m^2. So if the flow at Culham did not change we could expect the water level to rise by about 1”. However if, like Abingdon, the extra water overflows some of the gates, then it will not rise as much as that. The level would rise a bit and stabilise when the extra flow over the gates reached 1.6 cumecs.

Culham is quite complex, with five weirs, and the lock keeper has a fairly long walk to adjust the gates. Normally when the Abingdon lock keeper changes the gate settings, he makes much bigger changes than a single small radial, which takes less than 1/6 of the flow of a large radial. In any case opening of a small radial for canoeing is temporary. So it seems safe to say that the net effect will be negligible, and the Culham lock keeper would not thank Abingdon for phoning through such a small change.

There is a further point. If the flow is high enough for the screws to run at full power, then opening a small radial will increase the total flow, as above. However if there is not enough flow to run the screws at full power, then the control system will have reduced the intake of the screws, to maintain the upstream level at the limit of SHWL+2”. In that case, when a button is pressed, the control system will further reduce the flow taken by the screws. If it did not, the upstream level would fall below the permitted level and it would have to stop. So in the case of low flow, the net flow downstream would not change at all.

7 Conclusion

The purpose of this report is to show that the white water solution proposed jointly by Abingdon Hydro and the canoe clubs is technically feasible. We invite the Environment Agency's comments. As the work involves some modification of their property, we ask for formal approval, and are happy to co-operate with the EA where necessary to implement it.

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