natural scotland
SCOTTISH GOVERNMENT

SEPA
Scottish Environment Protection Agency

Guidance for developers of run-of-river hydropower schemes

Draft for public consultation

3 March 2010

Purpose

Developers of hydropower schemes require a water use licence from SEPA[1]. Before granting such a licence, SEPA has to take account of a scheme's likely adverse impacts on the water environment, as well as its potential benefits to renewable energy generation.

Scottish Ministers set out their objectives with respect to striking the right balance between the protection of the water environment and renewable energy generation in a policy statement[2] issued in January 2010.

Part A of this paper:

- outlines how, in determining applications relating to hydropower schemes, SEPA intends to achieve Scottish Ministers' policy objectives;

- provides guidance to developers on identifying sub-100 kilowatt hydropower scheme developments that are likely to be acceptable in the context of the Ministers' policy statement.

Part B of this paper sets out the mitigation SEPA expects to be incorporated into any run-of-river hydropower scheme development.

One of SEPA's prior-authorisation requirements for all hydropower schemes likely to have adverse impacts on the water environment is that all practicable mitigation is taken to minimise those impacts.

All proposed schemes, including sub-100 kilowatt schemes identified as potentially acceptable using the guidance in Part A, will be expected to incorporate the mitigation set out in Part B.

How to respond

Please send your response by email to:

hydro.consultation@sepa.org.uk

Or by mail to:

Hydro consultation
Water Policy Unit
SEPA Corporate Office,
Erskine Court,
Castle Business Park,
Stirling,
FK9 4TR.

Your consultation response should arrive no later than **30 April 2010**. SEPA aims to review the

[1] Under the Water Environment (Controlled Activities) (Scotland) Regulations 2005.
[2] http://www.scotland.gov.uk/Topics/Environment/Water/WFD/DutiesofMinisters/IAStatement/

responses and finalise the guidance in May 2010.

SEPA welcomes comments and suggestions from individuals and organisations on any aspect of the draft. It would also be grateful for your views on the following specific questions:

Consultation questions
Part A criteria – sub-100 kilowatt schemes
1. Taking account of the mitigation described in Part B, do you agree that sub-100 kilowatt schemes identified as provisionally acceptable according to the criteria described in Part A will not cause deterioration of the water environment?
2. Are there other circumstances under which you think sub-100 kilowatt schemes could be developed that will not (cumulatively or individually) pose a risk to the water environment?
3. Do you find the checklist format for setting out the criteria for identifying provisionally acceptable sub-100 kilowatt schemes helpful? Please make any suggestions you may have for how SEPA could make the information clearer to users.
Part A criteria – 100 kilowatt + schemes
4. Do you agree that the draft criteria on the efficiency of schemes of 100 kilowatts or more (in terms of energy output per length of river or stream affected) will help: • deliver Scottish Ministers' objective of optimising the use of the resource; • ensure deterioration of status is not caused where there are significantly better environmental options for generating the same quantity of renewable energy?
Part B mitigation measures
5. Do you agree that the mitigation identified will help achieve Scottish Ministers' objective of minimising the adverse impacts of hydropower scheme developments on the water environment?
6. Do you agree that, in general, the mitigation identified is likely to be practicable? If not, please give your reasons for this view.
7. Do you think that there other practicable measures that you think could be taken to achieve an equivalent or greater level of mitigation? If yes, please describe the mitigation and your reasons for believing that it would be practicable and effective in minimising adverse impacts on the water environment?

Until the guidance is finalised, SEPA will apply this draft when carrying out its regulatory functions under the Water Environment (Controlled Activities) (Scotland) Regulations 2005.

Part A

Putting into practice the principles set out in Scottish Ministers' policy statement on hydropower and water environment protection

1 Sub-100 kilowatt schemes

Scottish Ministers expect SEPA to manage the individual and cumulative impacts of sub-100 kilowatt schemes. SEPA is expected to do this by ensuring that, in general, no deterioration is permitted unless a scheme delivers particularly significant benefits.

> *"Small schemes with a generating capacity of less than 100 kW may provide local economic benefits and, where they can be shown to have no adverse impact on the water environment, such schemes will be welcomed. At this scale of development, particular attention will need to be given to managing both individual and cumulative impacts. Generally no deterioration will be permitted, unless the proposed scheme delivers particularly significant benefits."*

To avoid individual and cumulative adverse impacts on the water environment, sub-100 kilowatt schemes need to be sited and designed appropriately.

Annex A to Part A of the consultation document (p21) provides general guidance to developers on the types of proposals that are likely to be acceptable, subject to consideration of the interests of other users of the water environment.

Schemes not meeting the guidance criteria are unlikely to be acceptable unless they deliver additional and significant social or environmental benefits.

Likely acceptable schemes include those:

- situated in degraded parts of the water environment;
- situated in small, steep streams;
- delivering an overall improvement to the ecological quality of the water environment;
- using only that proportion of flow that can be abstracted from the river or stream without breaching river flow standards.

We recommend developers contact SEPA at an early stage in the planning of potential schemes for help in assessing its likely acceptability.

2 100 kilowatt + schemes

Scottish Ministers have also expressed their wish to optimise the potential for hydropower generation. To this end, they expect that emphasis will be placed on supporting hydropower developments that make a significant contribution to Scotland’s renewables targets whilst minimising any adverse impacts on the water environment.

"In order to optimise the potential for hydropower generation emphasis will be placed on supporting hydropower developments which can make a significant contribution to Scotland's renewables targets whilst minimising any adverse impacts on the water environment."

The efficiency of hydropower developments is important if the potential for hydropower generation is to be optimised. Low efficiency schemes – those that cause extensive lengths of the river or stream to be adversely impacted per unit of energy generated – may reduce the availability of sites for high efficiency schemes. Where the adverse impacts of a scheme would be sufficient to affect the status of a water body, SEPA also has to be able to demonstrate that the scheme's benefits cannot be provided using a significantly better environmental option. The other options include other sites and other relevant technologies for generating renewable energy[3].

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SEPA will normally consider there to be a significantly better environmental option to a scheme likely to have sufficiently extensive adverse impacts as to cause the deterioration of the status of a water body if:

(i) the proposed scheme is ≤ 500 kilowatts[4];

(ii) the output of the scheme compared to the length of river or stream it impacts is equivalent (pro rata) to less than 1.75 gigawatt hours per 500 metres in water bodies at high status and less than1.75 gigawatt hours per 1,500 metres in water bodies at good status;

(iii) the particular importance of the site makes the adverse impacts of the proposal particularly significant. Further details on how SEPA will make this assessment are available on SEPA's website[5].

This will help optimise the potential for hydropower generation and ensure that deterioration of status is not permitted if there are significantly better environmental options for generating the equivalent amount of renewable energy.

Scottish Ministers expect that if schemes of larger than 100 kilowatts are permitted to cause deterioration of the water environment, the deterioration must be justifiable in terms of costs and benefits.

"Ministers accept that in supporting such schemes some deterioration of the water environment may be necessary. However any deterioration must be justifiable in terms of costs and benefits, and therefore considerations such as wider social or economic benefits, or impacts on other users of the water environment, will continue to be important factors in the decision-making process."

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[3] A scheme with an installed capacity of 500 kilowatts typically produces around one third (1.75 gigawatt hours per year) of the output of a modern on-shore wind turbine.

[4] For comparison, the German system of electricity tariffs does not support schemes of less than 500 kilowatts if they would adversely affect the water environment.

[5] See WAT-SG-68: Assessing Significantly Better Environmental Options at http://www.sepa.org.uk/water/water_regulation/guidance/all_regimes.aspx

SEPA will continue to assess whether any adverse impacts caused by schemes of 100 kilowatts or more are justifiable in terms of costs and benefits. It will make these assessments on a case-by-case basis using the regulatory method[6] it has developed for such purposes.

In general, a scheme of 100 kilowatts or more is likely to be acceptable in these terms, subject to consideration of the interests of other users of the water environment, if:

- it meets the acceptability criteria described in Annex A for sub-100 kilowatt schemes; or
- its adverse impacts on the water environment are not out of proportion to its renewable energy benefit.

3 Summary of tiered approach

The principles outlined above are intended to provide a proportionate approach to balancing the protection of the water environment while optimising the contribution hydropower schemes can make to achieving Scotland's renewable energy targets. The tiered approach SEPA will take is summarised in Table 1 below:

Table 1: Tiered approach to the regulation of proposed hydropower scheme developments

Hydropower scheme installed capacity	**Criteria for the provisional acceptability of proposed new hydropower schemes.** (Acceptability is subject to consideration of the significance of any impact on the water environment, including for the interests of other users of the water environment.)
< 100 kilowatts	Do not cause any adverse impacts[7] (including as a result of cumulative effects) on: – waters in good or high condition; – waters not in high or good condition, but determined by SEPA as requiring restoration[8].
≥ 100 kilowatts to 500 kilowatts	Any deterioration caused must not on its own be sufficiently extensive to affect the status of any water body.
> 500 kilowatts	If deterioration of status is caused, the energy produced in comparison to the length of river or stream affected must not be disproportionate, taking account of other options for producing that energy.

[6] See WAT-RM-34: Derogation Determination - Adverse Impacts on the Water Environment: www.sepa.org.uk/water/water_regulation/guidance/all_regimes.aspx

[7] A significant adverse impact is indicated by a breach of one or more environmental standards.

[8] Waters not requiring restoration to good include: (a) those to which SEPA has determined a less stringent objective than good status is applicable; (b) stretches of rivers or stream that are locally not in a good condition but are part of a water body that is in high or good condition overall; (c) coastal burns that are not in high or good condition but are too small to have been identified by SEPA as a water body.

Part B

Draft mitigation SEPA considers likely to be practicable to include in run-of-river hydropower scheme developments

This part of the consultation sets out the mitigation that SEPA expects to be incorporated into all run-of-river hydropower scheme developments, except those where the developer or an interested third party provides evidence that:

- the mitigation measure is unnecessary because of the site characteristics;
- another measure will deliver equivalent mitigation;
- the mitigation measure would be impracticable to incorporate into the development[9] (ie for reasons of unusual technical constraints at the site).

The mitigation described represents SEPA's current view of what constitutes practicable mitigation to reduce the impacts on the water environment of run-of-river hydropower schemes. The list of mitigation measures will be reviewed and updated as scientific knowledge increases and more effective practicable mitigation is identified.

The mitigation is designed to minimise any adverse impacts of hydropower schemes on the water environment and thus contribute to delivering Scottish Ministers' policy objectives:

> *"In order to optimise the potential for hydropower generation emphasis will be placed on supporting hydropower developments which can make a significant contribution to Scotland's renewables targets whilst minimising any adverse impacts on the water environment."*

1 Impact of proposal on river flows

Table 2: Summary of flow impact mitigation

Purpose	Detailed guidance	Mitigation (summarised)
Protection of low flows	Section 1.1	No abstraction of flows at or below a hands-off flow equivalent to Qn90 or Qn95, dependent on site-specific factors detailed in Section 1.1.
Protection of flow variability	Section 1.2	No extended periods during which the flow downstream of intake is at, or below, the hands-off flow: – flow downstream increases in proportion to flow upstream rising to Qn80 when upstream flow would be at Qn30; or – scheme shuts down for a fixed period at an agreed frequency, designed to ensure flow higher than the hands-off flow occurs with

[9] The absence of mitigation for such reasons will be taken into account in assessing significance of the impact of the proposed scheme.

		equivalent frequency.
Protection of high flows	Section 1.3	Maximum abstraction not to exceed 1.3 to 1.5 times the average daily flow depending[10] on the particular characteristics of the scheme (as outlined in Section 1.3).
Protection of flows for upstream movement and spawning of fish	Section 1.4	Good status flows are maintained across the relevant flow range (ie flows up to Qn10) during periods of migration and spawning.

1.1 Protection of low flow level

Purpose
Mitigation should be designed to avoid the development causing:

- the channel to dry;
- the wetted width of the channel to be significantly reduced.

Requirements
When the scheme is operating, a minimum flow must pass over, or through, the weir to the river channel immediately downstream to sustain water-dependent plants and animals. This is known as a hands-off flow. When the flow upstream of the intake is less than the hands-off flow, no abstraction may take place.

Flow through the weir (eg via a pipe) is only appropriate where:

- fish passage upstream is not required (eg because fish are absent);
- alternative provisions for fish passage are included in the proposal.

When flow in the river upstream of the intake drops below the hands-off flow, all the flow in the river upstream of the intake structure must pass over, or through, the weir to the river channel downstream.

In the following circumstances, the hands-off flow must be equivalent to at least the natural low flow that would, on average, be exceeded for all but 36 days in a year (ie Qn90). Sites:

- with populations of salmon or sea trout;
- designated for the conservation of aquatic plants or animals;
- with catchment areas upstream of the tailrace of <10 km^2;
- where the wetted width is significantly reduced at flows below Qn90.

In other circumstances, the hands-off flow must be equivalent to at least the natural low flow that would, on average, be exceeded for all but 18 days a year (ie Qn95).

1.2 Protection of flow variability

[10] Average daily flow is equivalent to around Qn30.

Purpose
Mitigation should avoid extended periods of low flow downstream of the intake – particularly at times of the year when water plants and animals are likely to be sensitive to extended low flow conditions.

Requirements
Periods where the flow exceeds the hands-off flow must be provided by:

- designing the intake structure such that as the flow upstream increases, the proportion of flow (additional to the hands-off flow) passing downstream also increases. When the natural flow upstream would be at Qn30, the flow downstream should be at least equivalent to Qn80: In other words, as flow upstream of the intake increases to the rate that is, on average, exceeded for all but 255 days in a year (ie Qn30), flow downstream should rise to a flow equivalent to that which, on average, would normally be exceeded for all but 73 days a year (Qn80); or

- shutting the scheme down for a fixed period at an agreed frequency – for example not abstracting for six hours every Sunday from midday. The shut-down regime applied must have the effect of avoiding flow downstream of the intake being at or below the hands-off-flow for extended periods.

Providing variable flows through the weir (eg via pipes etc) is only appropriate where:

- fish passage upstream is not required (eg because fish are absent);
- alternative provisions for fish passage are included in the proposal.

1.3 Protection of high flows

Purpose
Mitigation should be designed to ensure that the river between the intake and the tailrace continues to experience high flows and associated high velocities and turbulence necessary to:

- create the disturbance regime that helps maintain the natural composition and abundance of water-dependent plants and animals;
- maintain a range of river habitats dependent on natural sediment erosion, transport and deposition processes.

Requirements
The maximum abstraction rate should be designed to ensure that surplus water during spate flows will spill over the weir into the river downstream.

The maximum abstraction rate should be no more than:

- 1.3 times the average daily flow[11] for sub-100 kilowatt schemes;

[11] Average daily flow is the average of the mean daily flows for a number of whole years taken to represent the long-term condition.

- 1.3 to 1.5 times the average daily flow for > 100 kilowatt schemes, depending on the characteristics of the site.

In certain circumstances, an abstraction of greater than 1.5 times the average flow may be acceptable, subject to discussion with SEPA. For this to apply, the greater abstraction must provide clear benefits in terms of:

- optimising the performance of the scheme; and
- reducing the overall ecological risks by significantly reducing abstraction of lower flows.

As high spate flows are infrequent but very large compared to lower flows, the average daily flow corresponds to the natural flow that is, on average, exceeded for 109 days in a year (ie Qn30).

1.4 Protection of flows for upstream migration and spawning of fish

The mitigation in this section does not apply:

- to schemes located on rivers upstream of natural barriers to upstream fish migration; or
- where the rivers and streams upstream of the tailrace do not provide suitable habitat for fish species that might otherwise migrate upstream to spawn.

Purpose
Mitigation should be designed to provide a flow regime capable of

- triggering migration;
- enabling fish to pass natural and artificial obstacles in the river;
- providing sufficient time at suitable flows for fish to progress upstream.

Requirements
The scheme must be operated so as to provide suitable flows for fish migration and spawning activity during the periods of the year in which that activity would naturally occur. These periods will depend on:

- the fish species and fish populations; and
- the location of the scheme.

In smaller upland tributaries, only a relatively short period in the autumn and winter months may be relevant depending on the species and stocks present. On major rivers in the lower reaches of catchments, fish migration may occur in all months.

During periods in which migration or spawning would be expected to occur, schemes will be expected to operate so that the rate of abstraction is no greater than that permitted by the river flow standards for good[12] across the range of flows providing the flow depths and velocities needed by

[12] The relevant river flow standards are detailed in the Scotland River Basin District (Surface Water Typology, Environmental Standards, Condition Limits and Groundwater Threshold Values) Directions 2009 and the Solway Tweed River Basin District (Surface Water Typology, Environmental Standards, Condition Limits and Groundwater Threshold Values) (Scotland) Directions 2009. These are available on the Scottish Government's website at: www.scotland.gov.uk/Topics/Environment/Water/WFD/RBMPFramework

fish for migration and spawning. In practice, this may be achieved by:

- reducing abstraction rates accordingly;
- ceasing generation during the relevant period of the year;
- operating a much greater hands-off flow.

The most appropriate option for providing the required flows and optimising the electricity output of the scheme will depend on the site-specific circumstances.

The river flow standards for good typically allow abstraction of about 20% of average summer flows rising to about 30% of average winter flows and 40% of spate flows. However, as river flows vary throughout the year and the river flow standards differ slightly according to river type, SEPA should be contacted for detailed advice on calculating the volumes of water that can be abstracted during periods of migration and spawning.

2 Impact of proposal on river continuity for fish

Table 3: Summary of mitigation to minimise risk to fish movements

Purpose	Detailed guidance	Mitigation (summarised)
Protection of downstream fish passage	Section 2.1	Intakes must be appropriately screened unless the scheme uses a 'fish-friendly' Archimedean screw and has no screen on the tailrace. There must be a plunge pool for fish below any drop over the weir.
Protection of upstream passage for fish	Section 2.2A	A fish pass for salmon and trout. This may comprise: • a natural design pass, such as a low-gradient by-pass channel or a rock ramp; or • a proven artificial design fish pass, such as a pool and traverse pass.
	Section 2.2B	An eel pass (suitable for upstream migration of elvers).
	Section 2.2C	A lamprey pass (suitable for upstream migration of lampreys).
	Section 2.2D	Tailrace: • designed and located so as not to attract migratory fish; • screened where necessary (gaps ≤ 20 mm).
Protection of flows for upstream movement and spawning of fish	Section 1.4	See Section 1 summary.

2.1 Provision for downstream passage of fish (all species)

The mitigation in this section does not apply to schemes located on rivers from which fish are absent.

A Intake design and screening

Purpose
Mitigation should be designed to avoid downstream-moving fish from entering the abstraction intake unless:

- the scheme uses a 'fish-friendly' Archimedean screw (ie incorporating appropriate protection of the leading edge[13]and with a blade pitch designed to provide sufficient room for the safe transit of the fish species present); and
- the tailrace is unscreened.

Requirements
The intake must be appropriately designed and screened to avoid downstream-moving fish from entering the intake or becoming trapped against intake screens. To do this:

- a screen with screen gaps of ≤ 10 mm must be fitted to the intake;

- unless coanda or drop screens are used, the intake should abstract water at 90° to the main river flow so that the screen array is continuous with the river bank and the fish pass is located adjacent to the downstream end of the intake screen;

- to ensure that fish are not pinned against, or damaged by, the screen, it must be designed to achieve the approach velocity[14] (also known as 'escape velocity') in Table 4;

- in operation, the screen must be kept clear of debris to avoid flow through the screen becoming concentrated resulting in higher velocities. An allowance must be made for some blocking when sizing the screens, such that the target approach velocity is not exceeded when screen performance is reduced by the accumulation of debris. The inclusion of an automatic screen cleaner will improve performance so that the additional area of screen required can be less. If screens are to be cleared manually, the target approach velocity will need to be maintained with 50% screen blockage. Where automatic screen cleaning is to be used, the target approach velocity will need to be maintained with 10% screen blockage. The use of coanda screens should be used where possible to reduce the impingement of debris and hence cleaning requirements;

- if coanda screens are used, there should be sufficient flow to keep the entire face of the

[13] ie a compressible silicone extrusion.
[14] The approach velocity is defined as the velocity of flow 10 cm upstream of the screen and perpendicular to the screen face.

screen wetted.

Table 4: Maximum acceptable design velocity of approach (metres per second) towards any part of a screen according to fish species present

Salmon and trout	Eel	Lamprey	Shad
0.6	0.5	0.3	0.25

B Weir design

Purpose
Mitigation must be designed to prevent injury to fish moving downstream after passing over the weir (ie by ensuring that fish do not fall directly onto rock or concrete after passing over the weir).

Requirements
A plunge pool of adequate volume must be present on the downstream side of the weir. Where intakes have been built on natural waterfalls, a suitable plunge pool may already be present. Where such a natural feature is not present, a retaining structure must be provided to maintain a pool of sufficient depth.

No part of the weir or plunge pool retaining structure may be constructed of unconsolidated rip-rap or gabion baskets into which fish may be washed and become trapped or injured.

The plunge pool must extend over the entire width of the weir over which water could flow in very high river flows. Its depth must be ≥ 1/3 of the height of the vertical drop.

The plunge pool must be connected with the main flow in the river channel at all times to minimise the risk of fish stranding and to prevent delays to migration.

The weir face and any notch or pipe used to provide downstream flow must be designed to ensure that fish passing over or through the weir are not injured (eg by colliding with protruding structures or sharp and/or abrasive, etc).

2.2 Provision for upstream passage of fish

Disruption or delay to fish migration can have significant adverse impacts on the distribution and/or abundance of fish populations. Run-of-river hydropower schemes can pose significant risks to fish migration and the impacts can extend far beyond the site of the hydropower scheme. Unless such risks can be avoided, authorisation will generally be refused.

Developers are advised to consider:

- sites that are upstream of natural[15] barriers to fish migration;
- sites where fish habitat upstream is only very poor quality, or very limited, and not important for maintaining the distribution or abundance of fish populations;

[15] Rivers and streams upstream of man-made barriers to upstream migration may support local brown trout populations that could be adversely affected by new obstacles to fish movement in those rivers and streams.

- utilising existing weirs that are currently acting as a significant barrier to fish migration. (The development of such sites must aim to improve fish passage.)

SEPA will only consider applications to develop other sites where the developer provides evidence that the fish passage provisions proposed (including the accompanying management regime) will be effective in safeguarding fish migration.

Most fish passes are likely to cause some delay or increase fish stress or energy use. It is not possible to predict the efficiency of any design with 100% confidence. SEPA will take account of this uncertainty in deciding whether or not the benefits of the scheme justify the risk. Even with a well designed fish pass, a development may be unacceptable if located on an important fish migration route or if it would contribute (together with existing obstacles) to a significant cumulative risk to fish migration.

Where there is a significant extent of good fish habitat upstream of a proposed scheme, SEPA is likely to require effective operation of the fish pass to be demonstrated as a condition of continued authorisation. This may involve electric fishing, redd counts or fish pass surveillance using TV or automatic fish counters. For this purpose, camera systems, light boxes and counter housings may need to be incorporated into the initial design of the fish pass.

The most appropriate fish pass design to use will depend on a range of factors including:

- the fish species present (eg Atlantic salmon, sea trout/brown trout; eel; lamprey, shad, sparling, etc);
- the characteristics of the intake structure, including the head difference;
- the characteristics of the river or stream;
- the type of management regime it is feasible to put in place to ensure the fish pass is maintained in working order.

The fish pass need only operate during the period of the year used for migration by the fish species and populations that are present. Early discussions with SEPA are recommended.

A Fish pass design – salmon and trout

The mitigation in this section does not apply to schemes located on rivers lacking populations of salmon and trout (eg schemes located above the upstream limit to migratory fish in steeply sloping channels through which upstream movement of brown trout is unlikely).

Purpose
Mitigation should be designed to ensure that salmon and trout are provided with a means of ascending past the weir at times during which they would naturally move upstream.

Requirements
Passage must be provided by one of the following fish passes outlined below. In all cases, there must be an appropriate flow attracting fish to the pass entrance. To achieve this, the fish pass discharge must be able to out-compete other flows in its attraction to fish. Where a turbine is on a weir, the turbine outflow should be adjacent to the fish pass so that it augments attraction rather than competing with it:

Natural design passes

- **Low-gradient, by-pass channels:** These can accommodate all fish species and also provide additional fish habitat.

- **Rock-ramps:** These are built into the river channel and lead up to the weir crest. They must be engineered with strategically placed rocks (boulders) designed to provide natural refuge pools and reduced water velocities. They must also be able to withstand flood flows. The appropriate gradients and boulders for a rock ramp depend on the fish species that are present. Table 5 provides indicative design criteria for ramps suitable for salmon and trout. Adjustments may need to be made (eg to boulder placements etc) to optimise the performance of the rock-ramp;

Artificial design passes

- **Pool and traverse passes:** These break-down the head-difference at the main weir into a series of small steps that can be ascended by fish. The pass should be designed to ensure that:

  - the drop in water levels between adjacent pools does not exceed 30 centimetres if trout are present or 45 centimetres if only salmon are present;
  - the pools have minimum dimensions of 3 metres long, 2 metres wide and 1.2 metres deep;
  - the downstream edge of the notch and traverse is curved so as to reduce turbulence and ensure water flows down the face of the wall rather than forming a free-spurting jet;
  - the majority of the Qn95 flow passes through the fish pass;
  - the pass is positioned at the most upstream section below the weir where fish naturally accumulate;
  - the pass is still effective at Qn10 flows (energy dissipation 150 to 200W/m^3);
  - a means of preventing blockage by debris (eg an upstream debris boom) must be included into the design and operation of the pass;

- **Pool and traverse passes using pre-weirs (sometimes called 'easements'):** These operate on similar principles to the conventional pool and traverse pass but have the effect of raising tailwater levels. The pre-weirs span the width of the river about 10 metres downstream of the main weir. The same traverse design criteria as for pool and traverse passes apply. The principal difference is that pre-weirs take the full flow of the water passing over the main weir;

- **Baffled fish passes:** These consist of rectangular channels/troughs containing various shaped, closely-spaced baffles set at an angle to the axis of the channel. The baffles form secondary channels whilst leaving a proportion of the channel/trough to take the main flow. The gradient and length (between resting pools) of baffled fish passes must be designed to suit the swim speeds and endurance of the fish present. Baffled passes can be constructed off-site and bolted together *in situ*, or the baffles inserted into a pre-formed channel. Examples of baffled passes include:

– the Alaskan ‘A’ baffled pass. This can operate at steeper gradients than other baffled passes. A maximum slope of 25% and maximum length of 12 metres (ie a 3 metre head difference) can be used for salmon. A less steep gradient and shorter length is required for smaller fish. These passes operate with relatively low flows, give the most lift before requiring a resting pool, and accommodate about a 1 metre change in upstream water level. Their complicated baffle geometry and narrow free gap makes them very prone to blockage by debris. An effective means of preventing blockage by debris (eg an upstream debris boom) must be incorporated into the design and operation of the pass;

– the plane baffle or Denil fish pass. This uses a less complicated baffle design than the Alaskan A and can operate up to a maximum slope of 20% and maximum length of 12 metres (ie a 2.4 metre head difference) before a resting pool is required. An effective means of preventing blockage by debris (eg an upstream debris boom) must be incorporated into the design and operation of the pass;

– Larinier Superactive baffled pass. This consists of 10 to 15 cm high chevron baffles that span the bottom of the fish pass channel and (unlike in the Alaskan A and Denil) do not extend up the sides. Channel widths can be very wide to accommodate large flows provided longitudinal webs are used to separate each set of chevron baffles. The design can achieve very low water velocities and so enable passage of small salmonids and large coarse fish. They are not as prone to blockage by debris as other baffled passes and so require less maintenance. The Larinier pass operates at a maximum gradient of 15% and a maximum length is 12m for large salmonids before a resting pool is required (ie a 1.8 metre head difference). This type of pass is less tolerant than other designs of large upstream head fluctuations. The maximum head over the top baffle is limited to about 0.7 metres;

- one or more notches in the crest and apron of the weir with associated take-off pools beneath them. The depth of a take-off pool must be 1.25 times the height of the drop. This type of fish pass may only be used where:
  – the maximum head difference across the weir (at the fish pass notch) is less than the relevant head difference in Table 6; and
  – the downstream face of the weir is vertical or close to vertical.

Table 5: Guide design characteristics for rock-ramp fish passes[16]

Fish species present	Salmon only	Trout only	Salmon & trout
Average water velocity on ramp during periods of	< 2 m/s	< 2 m/s	< 2 m/s

[16] Adapted from *SNIFFER research project (in progress), WFD111 Development of a screening tool for assessing the porosity of barriers to fish passage: Phase 2a: Draft project report; January 2010; SNIFFER, Edinburgh. The Table will be updated, where necessary, to take account of any revisions made in the finalised project report.*

upstream migration			
Depth of flow on ramp	> 15 cm	> 10 cm	> 15 cm
Slope of ramp	< 15 %	< 15 %	< 15 %
Length (diagonal slope) of ramp between resting pools	< 10 metres	< 10 metres	< 10 metres

Table 6: Maximum head difference across the weir

Fish species present	Salmon only	Trout only	Salmon and trout
Vertical height (centimetres)	80	50	50

B Fish pass design – eels

The mitigation in this section does not apply to schemes located on rivers upstream of natural barriers to upstream eel (elver) migration or upstream of permanent man-made barriers to eel migration, such as large impoundments where there are no plans to improve the situation.

Purpose
Mitigation should be designed to ensure that eel are provided with a means of ascending the river.

Requirements
An eel pass must be provided that:

- does not involve vertical drops that eel would have to leap in order to ascend the river;
- provides a permanently wetted and non-smooth surface up which eels can move

Weirs devoid of a suitable climbing substrate (ie wetted surfaces covered in algae, moss or other growth) will require an eel pass. This must consist of a trough containing a suitable bristle substrate with an irrigation and attraction flow. Staged holding/release tanks must be included for weirs with high head differences[17].

A proportion of the eel population may attempt to ascend the turbine channel. This may require both the turbine channel and the depleted river channel to have an eel pass.

C Fish pass design – lampreys

The mitigation in this section does not apply to schemes located on rivers or streams from which lampreys are absent. Lampreys are unlikely to be present in steep streams and reaches upstream

[17] Eel pass designs should reflect recommendations in: *Solomon D J and Beach M H. 2004. Fish Pass Design for Eel and Elver (Anguilla Anguilla). R&D Technical Report W2-070/TR1. ISBN 184432267X. 92pp*

of waterfalls or large impoundments. Schemes using existing weirs and dams are unlikely to further compromise lamprey migration.

Purpose
Mitigation should be designed to ensure that lampreys are provided with a means of ascending the river.

Requirements
Lampreys have a very poor swimming ability and could not negotiate the artificial-type fish passes discussed in Sections 2.2A and 2.2B above. A natural-type fish pass (such as a low-gradient, by-pass channel) may be used if the pass can be designed to provide sufficiently low flow velocities (eg < 0.5 metres per second).

Lampreys can negotiate relatively steep gradients, even vertical, if sufficiently smooth to employ a sucker, swim, and re-engagement technique. It may be possible to design a fish pass with a sidewall section that is sufficiently smooth to enable the fish to use this technique. However, the effectiveness of such a design has not yet been tested.

D Tailrace design

Purpose
Mitigation should be designed to ensure that migrating fish are not diverted from upstream migration by the presence of competing tailrace flows.

Migrating fish are attracted to the areas of high flow. They can therefore be attracted to high tailrace flows, particularly when turbines are operating at high capacity, and flows in the depleted reach are low.

Requirements
The tailrace must be designed so as not to attract upstream migrants. This may be achieved by:

- designing the tailrace so that the exit velocity of water from the tailrace is significantly lower at all flows than the main flow leading upstream; or
- locating the tailrace so that it does not compete with the main river flow leading upstream to the fish pass (eg co-locating the tailrace in line with the main flow).

If there is potential for fish to enter the tailrace, it must be screened with 20 mm or smaller screens. These should normally be located at the confluence with the receiving stream. It may be possible to avoid the need for screening if fish-friendly Archimedean screws are being used and sufficiently low tailrace exit velocities can be achieved to avoid attracting upstream migrants.

3 Provision for sediment transport

Table 7: Summary of sediment transport mitigation

Purpose	Detailed guidance	Mitigation (summarised)
Protection of	Section 3.1	Removal and return downstream (at appropriate

downstream transport of sediment		times and locations) of sediment accumulation upstream of intake structure.
Protection of river banks and bed from erosion	Section 3.2	Appropriate design of engineering structures and tailrace to ensure that erosion rates of the bed and banks is not increased.

3.1 Management of sediment accumulating upstream of weir

Purpose
Mitigation should be designed to aim to avoid significant disruption of sediment supply to river reaches downstream of the weir by re-supplying those reaches with sediment that accumulates upstream of the intake structure.

Requirements
The natural erosion and downstream migration of sediments are essential for the creation and maintenance of natural river habitats. Therefore, natural sediments should be reintroduced to a suitable location that is as close downstream of the intake as possible.

Accumulations of sediment in the ponded reach upstream of the intake structure must normally be returned (eg by operating scour valves or excavating, transporting and reintroducing):

(a) within 10 metres downstream of the weir if suitable sites are available and it is practicable to use them or as close to this downstream as possible;
(b) during periods of high flow conditions;
(c) at locations that will not create an accumulation of sediment likely to impede the free passage of migratory fish;
(d) during periods other than those during which fish are likely to be spawning and the period between spawning and emergence of the juvenile fish.

Where the proposal is to use a pre-existing weir and the sediment in the ponded reach may include sediment that has accumulated behind the weir over many years, steps should be agreed with SEPA that will avoid potentially contaminated sediments from being excavated and returned to the downstream reach.

These requirements apply on the assumption that the scheme is designed to ensure the river downstream of the intake structure continues to experience high spate flows (Section 1.3).

3.2 Management of erosion risks

Purpose
Mitigation should be designed to avoid the scheme increasing bed and bank erosion rates.

Requirements
The tailrace should be designed and located such that the water exiting the tailrace does not cause erosion of the bed and banks.

Engineering structures must be designed so as not to concentrate high flows onto parts of the bed or banks that are vulnerable to erosion.

Annex A

Part A guidance on identifying provisionally acceptable sub-100 kilowatt schemes

The checklists below are intended to help developers identify potential sub-100 kilowatt schemes that are likely to be acceptable. They will form the basis of pre-application discussions with SEPA.

1 Proposals identified as provisionally acceptable

Confirmation of acceptability will require case-by-case assessment by SEPA to ensure:

- the criteria are met;
- all relevant practicable mitigation measures will be taken (see Part B);
- the interests of other users of the water environment (including recreational and amenity interests) are taken into account.

2 Proposals identified as provisionally unacceptable

Proposals identified as provisionally unacceptable may be considered for authorisation if they provide other significant social or environmental benefits. Such cases are expected to be rare.

Checklist A: Proposals sited in degraded parts of the water environment

Questions		**Instructions**	
1	Is the river or stream between the intake and the tailrace: • part of a heavily modified water body (information from SEPA)? • surrounded by land used for commercial forestry or agriculture (other than rough grazing)? • urbanised?	**If yes, go to 2**	**If no, go to checklist B**
2	Is the river or stream between the intake and the tailrace already significantly impacted? For example, the condition of the bed and banks is poor or bad because of: (i) extensive stands of conifers or invasive non-native plant species on the banks; (ii) extensive engineering modifications, including channel straightening, bank revetment, dredging, culverting, etc.	**If yes, go to 3**	**If no, go to checklist B**
3	Is the stretch of river or stream planned to be improved (including by re-establishing access to migratory fish) to achieve the objectives of a river	**If no, proposal provisionally acceptable (see**	**If yes, go to checklist C**

	basin management plan (information available from SEPA)?	**note 1)**	

Note 1

The provisional acceptability assumes that one or more of the following applies:

- the rivers or streams upstream of the intake do not contain any significant areas of good fish habitat;
- the tailrace is located above, or immediately downstream of, a natural barrier to the upstream movement of fish species, or a man-made barrier to such movement that is not planned to be removed to achieve the objectives of a river basin management plan; or
- risks to fish passage can be avoided through appropriate mitigation (developers should seek advice from SEPA).

Checklist B: Proposals sited in small, steep rivers and streams

Questions		Instructions	
1	Is the area of the catchment upstream of the proposed tailrace < 10 km^2	**If yes, go to 2**	**If no, go to checklist C**
2	Is the channel slope[18] between the intake and the tailrace ≥ 0.1	**If yes, proposal provisionally acceptable**	**If no, go to 3**
3	Is the channel slope between the intake and the tailrace > 0.06?	**If yes, go to 4**	**If no, go to checklist C**
4	Is the affected stretch part of a coastal burn with a catchment area of < 10 km^2 that has <u>not</u> been identified by SEPA as a water body?	**If yes, go to 6**	**If no, go to 5**
5	Is the distance between the intake and the tailrace together with any reaches impacted by other activities < 500 metres if the water body is at high status and < 1,500 metres in all other cases?	**If yes, go to 6**	**If no, go to checklist C**
6	Does the river or stream between the intake and the tailrace lack any significant area of good habitat for fish[19]?	**If yes, proposal provisionally acceptable (note 1)**	**If no, go to checklist C**

[18] 'Channel slope' is the drop in elevation between two points, divided by the stream length between those two points. A gradient of 0.1 is equivalent to a 10 metre drop in 100 metres. As a guide, on Ordnance Survey 1:50,000 maps, this means that, where the 10 metre contours cross the river or stream, they are 2 millimetres apart as measured along the centre line of the river channel. A gradient of 0.06 is equivalent to a 6 metre drop in 100 metres. As a guide, on Ordnance Survey 1:50,000 maps, this means that, where the 10 metre contours cross the river or stream, they are 3.3 millimetres apart as measured along the centre line of the river channel.

[19] These are generally areas where there is a reduction in gradient and the bed of the river channel contains extensive areas of gravels and/or cobbles. Such areas are important if they provide the main spawning areas for fish populations in the stream. If there are two or more such stretches, each of 50 metres or more. Developers should seek further advice from SEPA on whether the stream contains a significant area of good habitat for fish.

Note 1

The provisional acceptability assumes that, for the majority of its length, the river or stream between the intake and the tailrace is an entrenched[20], confined and low sinuosity[21] (eg < 1.2) stream with cascading reaches and frequently spaced, deep pools in a step/pool bed morphology[22]. One or more of the following also applies:

- the rivers and streams upstream of the intake do not contain any significant areas of good fish habitat;
- there is a natural barrier to the upstream movement of fish to fish habitat upstream of the intake;
- there is already a man-made barrier to the upstream movement of fish to fish habitat upstream of the intake and this barrier is not planned to be removed to achieve the objectives of a river basin management plan; or
- risks to fish passage can be avoided through appropriate mitigation (developers should seek advice from SEPA).

Checklist C: Proposals delivering net benefits to the ecological quality of the water environment

Questions		Instructions	
1	Will the proposal significantly improve fish access to upstream or downstream fish habitat (ie by improving fish passage at a man-made obstacle to migration such as a dam or weir)?	**If yes, go to 2**	**If no, go to 3**
2	Is the length of fish habitat to which access would be improved significantly longer than the length of river or stream between the intake and the tailrace?	**If yes, go to 4**	**If no, go to 3**
3	Will the proposal provide other significant net benefits to the ecological quality of the water environment (eg remedying low flow impacts, etc)?	**If yes, go to 4**	**If no, go to checklist D**
4	Is the length of river or stream between the intake and the tailrace < 1,500 metres?	**If yes, proposal provisionally acceptable**	**If no, go to checklist D**

Checklist D: All other proposals

Questions		Instructions	
1	Will the scheme be powered by the flow of water through an existing weir or dam (ie without	**If yes, proposal provisionally**	**If no, go to 2**

[20] 'Entrenched' means that the river is incised into the valley floor, making the flood-prone area very narrow such that in floods, river depth increases much faster than river width.
[21] 'Sinuosity' is the ratio of channel length to valley length.
[22] 'Confined valley' is a valley whose narrowness is such as to prevent all, or nearly all, lateral movement of the river channel.

	removing water from the river channel)?	**acceptable (see note 1)**	
2	Will the scheme be powered by water flow from an existing outfall?	**If yes, proposal provisionally acceptable**	**If no, go to 3**
3	Will the scheme be powered by water that is abstracted from immediately above a drop (eg a waterfall or weir) and returned immediately[23] below that drop?	**If yes, proposal provisionally acceptable (see note 1)**	**If no, go to 4**
4	Will the scheme use only the proportion of the flow in the river or stream at any one point in time that can be abstracted without causing a breach of the river flow standards for good (note 2)?	**If yes, proposal provisionally acceptable (see note 1)**	**If no, proposal provisionally unacceptable**

Note 1

The provisional acceptability assumes that one or more of the following applies:

- The rivers and streams upstream of the intake do not contain any important areas of good fish habitat.
- The tailrace is located above, or immediately downstream of, a natural barrier to the upstream movement of fish species, or a man-made barrier to such movement that is not planned to be removed to achieve the objectives of a river basin management plan.
- Risks to fish passage can be avoided through appropriate mitigation (developers should seek advice from SEPA).

Note 2

The river flow standards for good quality water bodies typically allow abstraction of about 20% of average summer flows, rising to about 30% of average winter flows, and 40% of spate flows. However, as river flows vary throughout the year and the river flow standards differ slightly according to river type, it is worth contacting SEPA for detailed advice on calculating the volumes of water that can be abstracted.

3 Background rationale to criteria for proposals sited in small, steep streams

In SEPA's view, the balance of risk is that run-of-river hydropower schemes will not normally significantly adversely affect the ecological quality of small, steep streams, provided appropriate mitigation is incorporated into the design and operation of those schemes.

The characteristics of such streams – their steepness and the rapidity of the rise and fall of their flows in response to rainfall – naturally make them a very high disturbance environment. They also tend to be incised into their valleys with low width to depth ratios. These characteristics mean that the wetted width typically changes little between low flows (which would be retained) and the mid-range flows that would be utilised by hydropower schemes. Hydropower schemes with the appropriate mitigation would not impact the high disturbance characteristics of these streams to which the stream's water plants and animals are adapted.

[23] That is, as close to the base of the falls as practicable and at most no further than 10 metres downstream.

Some streams at the lower end of range of streams defined as ‘steep’ for the purposes of this guidance may include stretches containing river habitats that may be more sensitive to the effects of hydropower schemes on river flows. These may support populations of trout that are important for the maintenance of the trout populations within the river/stream or may even be used by salmon. Sub-100 kilowatt schemes may cause deterioration of such important habitats and should therefore not be situated on stretches containing them.