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Foreword to extract

This document is an extract from an unpublished report developed by Australian Water Environments as part of a project for the South Australian Murray-Darling Basin Natural Resources Management Board.

The purposes of the project were to (1) explore different options for devices to return low flows around dams; and (2) trial some of those ideas in the Marne and Saunders catchments. This extract from the project report documents the outcomes from the first part of the project.

This report refers to water management policies in place at the time the report was written, which may have since been superseded or updated in later policy documents such as regional natural resources management plans or water allocation plans.

Please note that Water Data Services, who contributed to the overall project together with Australian Water Environments, owns the intellectual property on the operational elements of the syphonic design shown in this report.
1. Introduction

The impacts of farm dams on water resources has been recognised for many years. The specific impacts were first documented in South Australia in the North Para catchment in the 1980s. A hydrological model of the Marne catchment was developed in the 1990s that first documented the impact of farm dams on the easterly flowing streams of the Mount Lofty Ranges. Our understanding of the impacts of dams has progressed a long way since those two early studies. Whilst the early investigations had a strong resource sharing focus, it is now also recognised that farm dams can have a significant impact on the downstream environment. Of particular concern are the end of season flows, summer freshets, and the start of season flows. Farm dams typically create an early onset of the cease to flow period and a late start to the commencement of flows. Thus the natural environment needs to endure longer periods of no flow than it has naturally evolved to deal with.

Low flow bypass systems are one means by which the duration of flow in a stream can be maintained and help to ensure that harvesting of water in dams occurs when flows are plentiful. Reinstatement of a more natural flow regime should provide downstream benefits for the environment as well as help to ensure that landholders’ riparian rights are also protected. Installing these systems on new dams can be reasonably straight forward but retro-fitting adds another layer of complexity.

It is the aim of this project to build upon previous work undertaken by the South Australian Murray Darling Basin Natural Resource Management Board (SAMDB NRM Board) and others and to explore other practical alternatives to develop and trial a set of designs for low flow bypass mechanisms which can be installed on a wide range of dams at relatively low cost.
2. Concept Development

Previous works undertaken to develop and install low flow bypass mechanisms have produced several interesting and robust concepts that could be installed in new dams and many older dams.

Several of the explored concepts were presented in the brief for this project supplied by the SA MDB NRM Board. These concepts were at various stages of maturity, with several at the general concept sketch stage and only one at a stage where it had been developed to a detailed design and installed at a site. This was done as part of a PhD research project funded by the SA MDB NRM Board.

The bypass mechanisms given in the brief primarily involved mechanical diversion from a point upstream of the dam. These installations can be difficult and costly to retro-fit into existing dams, and in many cases may not be capable of achieving the required low flow bypass volumes, particularly in dams where diffuse runoff from the surrounding catchment is a major source of inflow to the dam meaning there is no single defining inflow point.

Two days of site visits as part of this project to various dams within the Marne and Saunders catchments in the Eastern Mount Lofty Ranges allowed for an assessment of the applicability of each of the concepts to a broad range of different dam types and also provided an opportunity to develop and discuss new concepts which may be more suitable in many of the dams.

Using the designs presented in the project brief and the ideas developed during the field visits, a series of conceptual designs were developed and presented at a workshop held by the SA MDB NRM Board. These concepts are presented in Section 2.1.

2.1 Conceptual Designs

The workshop held by the SA MDB NRM Board saw the presentation of a total of five concepts which were thought to be applicable and relatively easily retro-fitted to a wide range of dams within the Marne and Saunders and Eastern Mount Lofty Ranges catchments.

Two alternative policies are being developed, a single flow rate and a proportional flow diversion policy approach (where the second policy is applicable to some cases in the Marne and Saunders only). Hence, options were developed for achieving appropriate low flow diversion regardless of which diversion policy was applied (be it a requirement for a single flow-rate diversion or a proportional diversion).

The general concept, applicability, and advantages and disadvantages of each concept are discussed in the following sections.
2.1.1 **Adjacent Inflow/Outflow**

Many of the dams in the Marne and Saunders catchments are diversions from a drainage path configured in such a way that the inflow and the outflow of the dam are adjacent.

This essentially means that all flow along the drainage path is captured by the dam until the water level in the dam exceeds the outflow threshold and then all excess water is able to flow downstream.

Figure 2.1 below shows a diagram of the general configuration of a dam with adjacent inflows and outflow and presents the configuration of possible low flow bypass mechanisms.

The nature of a dam with adjacent inflows and outflows means that it is ideally suited to a mechanical diversion at the inflow point, as the distance required to transfer this diverted water to the outflow point is very short.

The diagram in Figure 2.1 shows the installation of a diversion weir which could be modified to divert either a single flow rate, or to divert a proportion of the flow. The general concept of the diversion weir is presented in Figure 2.2.

The inflow diversion mechanism involves using a standard v-shaped weir to allow flow into the dam, and using either a proportionally sized adjacent weir to divert a proportion of flow to the outlet point or a specifically sized orifice plate that would allow for a constant flow-rate diversion.

The nature of the design means that it would be relatively simple to construct, and the majority of the structure could be constructed by the landholder using appropriate materials.

In the case of the concept presented in Figure 2.2, the bulk of the structure could be constructed from sleepers (i.e. a sleeper-drop weir). It is likely however, that the v-notch faceplates of a proportional flow diversion weir, and the orifice for a constant diversion mechanism would have to be made by an appropriate fabricator to ensure that the required accuracy is achieved.

When designing a flow proportioning weir, the point of cease to flow of each weir plate must be at exactly the same level, and the flow area of the diversion weir should always be the required percentage less than the flow area of the larger weir discharging to the dam for all flow heights above the cease to flow. For example, to divert 10% of flows, the area of the smaller diversion weir should be 10% of the area of the larger weir for all water depths above the bottom of the weir. This could be achieved by creating two v-notch face plates of the same height, with the smaller weir having a total width which is 10% of the width of the larger weir. The concept for designing this type of diversion is demonstrated graphically in Figure 2.2 below.
Figure 2.1 – Concept 1a - Adjacent Inflow/Outflow Dam

NOTES:
- INFLOW AND OUTFLOW OCCUR AT SIMILAR LOCATION IN DAM
- POSSIBLE DIFFUSE OVERLAND INFLOW FROM DIRECT CATCHMENT (IF NOT ISOLATED)
- ORIGINAL FLOW PATH WOULD HAVE GONE STRAIGHT PAST DAM
- POSSIBLE LOW FLOW BYPASS VERSUS OF INFLOW POINT

NOT FOR CONSTRUCTION
NOT TO SCALE
Figure 2.2 – Concept 1b - Diversion Weir Concept
When designing a constant flow bypass mechanism using an orifice plate, the orifice should be sized using the formula below.

Equation 2.1 – Orifice Diameter Sizing for Unit Threshold Flow Rate Diversion

\[
D = \sqrt{\frac{4\text{UTFR}.A/1000}{\pi C_D(2gH)^{1/2}}}
\]

Where,

- \( D \) is the diameter of the required orifice in metres (m),
- \( \text{UTFR} \) is the ‘Unit Threshold Flow Rate’ in L/s/km\(^2\) defined by Figure 2.3 and Table 2.1 (or as per current policy in relevant water allocation plan or regional NRM plan),
- \( A \) is the catchment area upstream of the dam in km\(^2\),
- \( C_D \) is the coefficient of discharge for the orifice type (typical values can be seen in Figure 2.4),
- \( g \) is the given by the gravitational acceleration (9.81 m/s\(^2\)), and
- \( H \) is the nominated height between the bottom of the v-notch weir and the centre of the orifice in metres (m).

Table 2.1 – Unit Threshold Flow Rate Index
(as per Catchment water management plan for the River Murray in South Australia 2003)

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Subcatchment Zone</th>
<th>UTFR (L/s/km(^2))</th>
<th>Catchment</th>
<th>Subcatchment Zone</th>
<th>UTFR (L/s/km(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marne River</td>
<td>M1</td>
<td>2</td>
<td>(unnamed creek)</td>
<td>E1</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>M2</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M3</td>
<td>1.5</td>
<td>Finniss River</td>
<td>F1</td>
<td>7.5</td>
</tr>
<tr>
<td>Saunders Creek</td>
<td>S1</td>
<td>1.5</td>
<td></td>
<td>F3</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>S2</td>
<td>1.5</td>
<td></td>
<td>F4</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>S3</td>
<td>1.5</td>
<td></td>
<td>F5</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>S4</td>
<td>1.5</td>
<td></td>
<td>F6</td>
<td>4</td>
</tr>
<tr>
<td>Reedy Creek</td>
<td>K1</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R1</td>
<td>1.5</td>
<td>Tookaverta Creek</td>
<td>T1</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>R2</td>
<td>1.5</td>
<td></td>
<td>T2</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>R3</td>
<td>1.5</td>
<td></td>
<td>T3</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>R4</td>
<td>1.5</td>
<td>Deep Creek</td>
<td>D1</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>R5</td>
<td>1.5</td>
<td>Currency Creek</td>
<td>C1</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>R6</td>
<td>1.5</td>
<td>Bremer River</td>
<td>B1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>R7</td>
<td>1.5</td>
<td></td>
<td>B2</td>
<td>3</td>
</tr>
<tr>
<td>Salt Creek</td>
<td>N1</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preamimma Creek</td>
<td>P1</td>
<td>1.5</td>
<td></td>
<td>B3</td>
<td>3.5</td>
</tr>
<tr>
<td>Rocky Gully Creek</td>
<td>G1</td>
<td>1.5</td>
<td></td>
<td>B4</td>
<td>3</td>
</tr>
<tr>
<td>Angas River</td>
<td>A1</td>
<td>4</td>
<td></td>
<td>B5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>4</td>
<td></td>
<td>B6</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>A3</td>
<td>4</td>
<td></td>
<td>B7</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>A4</td>
<td>4</td>
<td>Long Gully</td>
<td>L1</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>A5</td>
<td>4</td>
<td>Bees Knees</td>
<td>Y1</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Figure 2.3 – Surface water subcatchment zones index (as per Catchment water management plan for the River Murray in South Australia 2003)
Monitoring of a diversion such as this could be done relatively easily by measuring the water level above the crest of the weir(s) and applying a calibrated stage-discharge relationship.

It is important when designing and constructing the diversion structure that adequate erosion control such as rock armouring is installed at the base of the structure where high water powers are likely to be observed.

A table outlining the advantages and disadvantages of this type of installation can be seen below.

**Table 2.2 – Advantages and Disadvantages of Concept 1**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cheap and easily constructed</td>
<td>• Provides a barrier for fish and aquatic biota</td>
</tr>
<tr>
<td>• Could be constructed with minimal engineering supervision/input</td>
<td>• Would require diffusers/erosion control to ensure no stream/structure damage</td>
</tr>
<tr>
<td>• Low maintenance</td>
<td>• Would require larger amounts of trenching/piping if diversion discharge point is not close by.</td>
</tr>
<tr>
<td>• Can be adapted to either policy implementation</td>
<td>• Difficult to tamper with/alter</td>
</tr>
<tr>
<td>• Easily retrofitted to suitable dams</td>
<td>• Easy to assess compliance</td>
</tr>
<tr>
<td>• Easily monitored</td>
<td>• Monitoring/diversion occurs prior to mains/bore inflows</td>
</tr>
<tr>
<td>• Difficult to tamper with/alter</td>
<td>• Can be adapted to multiple inflows (from catchment and flow paths) through modelling</td>
</tr>
<tr>
<td>• Easy to assess compliance</td>
<td>• Easy to alter for policy changes</td>
</tr>
<tr>
<td>• Monitoring/diversion occurs prior to mains/bore inflows</td>
<td></td>
</tr>
<tr>
<td>• Can be adapted to multiple inflows (from catchment and flow paths) through modelling</td>
<td></td>
</tr>
</tbody>
</table>

As this type of diversion weir concept was not adopted for detailed design and construction at any of the trial sites discussed in subsequent sections, some design requirements and construction notes for this type of device are discussed in the following section.
2.1.1.1 Diversion Weir Design and Construction Requirements

When designing a diversion weir to satisfy either of the two implementation options of the policy (if two both options are available), the general theory outlined in Section 2.1.1 should be followed.

In order to achieve a single flow rate diversion, then Equation 2.1 should be used to size an appropriate orifice plate. This orifice plate should always be fabricated by a professional capable of producing a precision orifice. In a single flow rate diversion weir, the v-notch faceplate does not necessarily have to be fabricated by a professional, and may not even be necessary in some cases.

Care should be taken when installing the orifice plate to ensure that it is the exact nominated distance (H in Equation 2.1) below the lowest point of the weir.

The weir faceplates for a flow proportioning weir should be designed in accordance with the methodology discussed in Section 2.1 and the faceplates should be constructed by a professional or an experienced metal worker.

Care should be taken when installing the faceplates so as to ensure that the lowest points of the V-notch weirs are installed at exactly the same level.

The weir structure itself can be constructed from materials such as sleepers, which provide a low-cost alternative to a full concrete structure.

The sleepers should be secured and held together using something similar to an ‘I’ shape bar which should be concreted into the ground.

In order to prevent wash-out and undermining of the structure, the weir structure should be keyed into the bed and banks so that its foot is a minimum of 500mm below the natural surface at all points. Scalable design templates for the two types of diversion weirs is given in Figure 2.5 and Figure 2.6 below.

The downstream sections of the structure should be protected using rock armouring. The rock should have an absolute minimum average diameter of 300mm however in many cases larger rock may be required. The rock should be installed so that has a depth of twice the nominated average diameter (i.e. 300mm rock should be laid to a minimum depth of 600mm).

The rock protection should extend a distance of five times the height of the weir drop. (i.e. if the weir invert is 300mm above the bed of the creek, the rock protection should extend 1.5m downstream).

A water affecting activities permit is required in order to undertake these works, so this should be obtained prior to commencement of construction.

Care should always be taken when designing and constructing a diversion structure such as this, so as to minimise disturbances to the surrounding environment during and after the works are complete.
Figure 2.5 – Single Flow Rate Diversion Weir Design Template
Figure 2.6 – Proportional Flow Diversion Weir Design Template

PROPORTIONAL FLOW BYPASS WEIR

FOR 10% DIVERSION
W₁ = 0.1 W₂

KEY IN 500mm MIN. INTO BANKS

KEY IN 500mm MIN. INTO BED/BANKS

STAINLESS STEEL PLATE

DAM BYPASS

DAM INFLOW

500mm MIN.

W₂

W₁

H

H

500mm MIN.

500mm MIN.

500mm MIN.

500mm MIN.

1/3 W₁

1/3 W₂

1/3 H

1/3 H

1/3 W₁

1/3 W₂

1/3 H

1/3 H

500mm MIN.

500mm MIN.
Existing Drainage Infrastructure

Many dams within the Marne and Saunders catchments contain drainage mechanisms through the dam wall which were installed during construction such as a gravity fed or syphon fed pipe. These can be used to drain the dam in an emergency or for maintenance purposes, release water from the dam to improve water quality in the dam, or to transfer water to subsequent dams in the landholder’s dam network.

This system also provides the opportunity to bypass flows after they have already entered the dam. Measuring inflows upstream or calculating volumetric changes in dam storage from within the dam itself can then be used to automate the operation of the drainage mechanism to release the required bypass volumes of water on a daily or other predetermined timescale.

This type of system could be used to bypass either a proportional or single flow-rate volume and in most cases, could be installed relatively cheaply and easily – particularly if the pre-installed drainage mechanism is simply a gravity-fed pipeline.

The required ‘bypass’ or return volumes can be calculated by using installations such as weirs or velocity meters which measure and record the inflows to the dam at all sources, or by simply measuring the water level in the dam to an adequate accuracy and applying a hypsographic relationship which defines the depth-volume relationship of the dam.

This relationship can be applied to the day’s water level data within a data logger, which would then operate a mechanical valve on the gravity fed pipeline for a calculated period of time to discharge the required ‘bypass’ volume.

It is important that failsafe mechanisms be incorporated into the operation mechanism for the mechanical valve to ensure that it closes at the appropriate time and does not end up in inadvertently emptying the dam.

It is also important that a sensitivity analysis be done on the volume-depth relationship to ensure that the accuracy of the equipment measuring and recording the water level is sufficiently sensitive to low flows.

The general concept of this type of low flow bypass is shown in Figure 2.7.

The advantages and disadvantages of this type of low flow bypass concept are summarised in Table 2.3.
### Table 2.3 – Advantages and Disadvantages of Concept 2

<table>
<thead>
<tr>
<th><strong>Advantages</strong></th>
<th><strong>Disadvantages</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Minimal infrastructure requirements</td>
<td>- Provides a barrier for fish and aquatic biota</td>
</tr>
<tr>
<td>- Easily retrofitted to dams with existing infrastructure</td>
<td>- Only applicable to dams with existing infrastructure</td>
</tr>
<tr>
<td>- Fast installation</td>
<td>- If infrastructure is in place it usually means another dam is downstream (i.e. any diverted inflows would need to be re-diverted at DS dam)</td>
</tr>
<tr>
<td>- Minimal engineering input required</td>
<td>- Measurement of water level to determine inflows would require knowledge of mains/bore water inflows</td>
</tr>
<tr>
<td>- Applicable to both flow-rate or proportional diversion</td>
<td>- Measurement of water level in large dams may not be sufficiently sensitive to measure flows &lt;1L/s</td>
</tr>
<tr>
<td>- Could be easily monitored for operational effectiveness</td>
<td>- Would only require software update to account for policy changes</td>
</tr>
<tr>
<td>- Difficult to tamper with</td>
<td>- Would not need to factor in mains/bore inflows if inflows are measured upstream of dam</td>
</tr>
<tr>
<td>- Would not need to factor in mains/bore inflows if inflows are measured upstream of dam</td>
<td></td>
</tr>
</tbody>
</table>
Figure 2.7 – Concept 2 – Existing Drainage Infrastructure
2.1.3 Contour Drain Diversion

Many dams are configured such that they receive inflows primarily from a single source, however the inflow source is located a long way away from the dam outlet.

The topography of many of these dams however would allow for the construction of a small contour drain or an equivalent pipe which would carry water diverted by a device similar to that presented in Section 2.1.1 to a point where the natural drainage paths would allow for the water to be bypassed downstream of the dam (i.e. to a point outside of the dams’ catchment).

This could be done relatively simply, however the cost of the installation would be governed primarily by the length of the diversion channel/pipe. Due to the length of the required drain in many of the farm dams visited on the site visits and the rocky outcrops present, installation of a contour drain in many instances would be quite costly.

The general concept of contour drain diversion can be seen in Figure 2.8 below.

Similarly, the advantages and disadvantages of such a design are presented in Table 2.4 below.

Table 2.4 – Advantages and Disadvantages of Concept 3

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Diversion mechanism could be constructed from readily available materials</td>
<td>• The total cost is primarily governed by the cost of installing the contour drain</td>
</tr>
<tr>
<td>• Would not need to factor in mains/bore inflows if inflows are measured upstream of dam</td>
<td>• The construction of a weir provides a barrier for fish and aquatic biota</td>
</tr>
<tr>
<td>• Could be easily monitored for operational effectiveness</td>
<td>• Only applicable to dams where the topography/geology is suitable</td>
</tr>
<tr>
<td>• Applicable to both flow-rate or proportional diversion</td>
<td>• Would be easy to breach</td>
</tr>
<tr>
<td>• Could be easily adapted for policy changes</td>
<td>• Reduces the overall catchment of the dam requiring proportioning of bypassed flows</td>
</tr>
<tr>
<td>• Relatively low maintenance</td>
<td></td>
</tr>
</tbody>
</table>
Figure 2.8 – Concept 3 – Contour Drain Diversion.

- Can only be constructed if contours allow for diversion.
- Would be difficult to construct in large dams with rocks at or near surface.
- Flow splitter similar to sketch 1 could be installed upstream.
2.1.4 Pumped Diversion

In many cases, diversion of flows using the previously mentioned concepts may not be possible. In cases such as this, it may be possible to measure the inflows to the dam at a single upstream point and pump the required bypass volume to a point downstream of the dam.

The primary costs associated with a design such as this are in the laying of the pipe, and the pump itself (depending on the required size). The required size of the pump and pipe system is also governed by the policy that has been chosen to be implemented. If a single flow rate bypass is required then the pump and pipe can be sized specifically for this flow rate, however, if a proportional diversion is being applied then the pump and pipe must be sized such that it can transport the nominated percentage for or flow ranges (i.e. if a 10% diversion is required, the pump and pipe system would need to be able to accommodate 10% of the 100 year ARI event at the site).

A general diagram of the concept can be seen in Figure 2.9 below.

The concept presented in Figure 2.9 involves inflow measurement and diversion (pumping) from the same point upstream of the dam, however this could be adapted to measure water levels in the dam to determine the required bypass.

The advantages and disadvantages of such an installation are presented in Table 2.5 below.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Provides a highly adaptable solution</td>
<td>• The total cost is primarily governed by the cost of installing the piping and pump</td>
</tr>
<tr>
<td>• Diversion mechanism and reservoir could be constructed from readily available materials</td>
<td>• Will not always be a cost effective solution</td>
</tr>
<tr>
<td>• Would not need to factor in mains/bore inflows if inflows are measured upstream of dam</td>
<td>• May require solar power</td>
</tr>
<tr>
<td>• Could be easily monitored for operational effectiveness</td>
<td>• Not easily applied to proportional flows without increasing pump capacity</td>
</tr>
<tr>
<td>• Could be easily adapted for policy changes</td>
<td>• Pumping and weirs provide barriers to fish and aquatic biota</td>
</tr>
<tr>
<td>• Relatively low maintenance</td>
<td>• Could be easy to tamper with</td>
</tr>
</tbody>
</table>
Figure 2.9 – Concept 4 – Pumped Diversion

NOTES:
- DIVERSION / PUMPING / MEASUREMENT OCCURS US OF DAM.
- APPLICABLE TO MOST DAMS.
- MAY BE ABLE TO USE LOW COST TUBING RATHER THAN PIPE (DEPENDING ON REQUIRED PUMP SIZE).
- MAY NOT REQUIRE TRENCHING.
- PIPE / TRENCHING GOVERNS MOST OF COST.
2.1.5 Syphonic Diversion

Many of the dams in the Marne and Saunders catchments have complex inflow, outflow and usage schemes which have been adapted to suit the landholders’ requirements. It may often be the case that the previously discussed concepts may either not be applicable, or may be too costly to install.

If the site has a drainage path downstream of it with sufficient fall to create and sustain a syphon, a syphonic diversion system (developed by Water Data Services) may be applicable and less costly.

The syphonic drainage system involves measurement of the water level within the dam and applying a hypsographic depth-volume relationship developed for the dam to activate a syphon which draws water from the dam to a point downstream of the dam.

The advantage of a syphon system is that it is readily applicable and may be the most cost effective solution. It is comparable in applicability to a pumped diversion system, however cost savings can be achieved by reducing the required size of the pump and the operational costs associated with running it as the syphons can be primed using a 12 volt pump in most cases which could be run from solar power.

A syphonic drainage system would work in a very similar way to that of Concept 2, in which the required bypass volumes are calculated and accumulated over 24 hours, however, in place of the data logger activating a mechanical valve on a pre-installed drainage pipe, the logger could activate a syphon system which could be retro-fitted to the dam wall.

This concept was the primary focus of two of the trial sites adopted for Stage 3 of the project.

The general concept of a syphonic drainage system is demonstrated in Figure 2.10 below.

The advantages and disadvantages of this system are summarised in Table 2.6 below.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provides a highly adaptable solution</td>
<td>Would need to factor in and monitor any mains/bore inflows if inflows are measured on the dam itself</td>
</tr>
<tr>
<td>Syphon system can be easily retro-fitted to most dam walls</td>
<td>Will not always be the most cost effective solution</td>
</tr>
<tr>
<td>Could be easily monitored for operational effectiveness</td>
<td>Requires solar power</td>
</tr>
<tr>
<td>Could be relatively easily adapted to proportion flows</td>
<td>May require very complex programming</td>
</tr>
<tr>
<td>Could be easily adapted for policy changes</td>
<td>Would provide barriers to fish and aquatic biota</td>
</tr>
<tr>
<td>Relatively low maintenance</td>
<td>Could be easy to tamper with</td>
</tr>
</tbody>
</table>
Figure 2.10 – Concept 5 – Syphonic Drainage
References