# TECHNICAL NOTE 07/07

## Department of Water, Land and Biodiversity Conservation

# SUSTAINABLE EXTRACTION LIMITS FOR FARM DAMS

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Technical Note prepared in conjunction with the South Australian Murray-Darling Basin Natural Resources Management Board, with significant input from Mardi van der Wielen



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# CONTENTS



**List of Tables**

# AIM

This technical note describes a methodology used to derive sustainable[1] extraction limits[2] for on-stream farm dams. The methodology was developed as part of the technical investigations undertaken to develop a Water Allocation Plan (WAP) for the Marne–Saunders Catchment area. It could be applied to other catchments by incorporating local catchment parameters and corresponding environmental water requirements, in the model used.

# BACKGROUND

Farm dam development limits have been devised and used in the state on different geographical scales, a few of which are listed below:

- State Water Plan — 50% of median adjusted annual flow (flow with impact of farm dams removed).
- River Murray Catchment Water Management Board (RMCWMB) — 30% of long-term average runoff for the period May to November.
- Clare WAP — sub-catchment-based dam development limits.
- Barossa WAP — the combined capacity of all dams in a catchment should not exceed 50% of the annual runoff of that catchment.

The limits set in the plans vary due to the variable catchment conditions and level of water used in those areas. The limits defined in this note are for local condition of the Marne–Saunders Catchment.

The Marne–Saunders Catchment is an unregulated system that is part of the Murray–Darling system in South Australia. The catchment's water resources are vital for the local domestic, stock, irrigation and environmental needs. In recent years, increasing development, of farm dams in particular has put pressure on the availability of water resources. In response to this pressure, the South Australian Government 'prescribed' the surface water, watercourse and groundwater resources in the catchment in March 2003.

The South Australian Murray–Darling Basin Natural Resources Management Board is currently preparing a WAP for the area. The plan is being prepared in consultation with the Marne–Saunders Water Resources Planning Committee, with technical advice from DWLBC and PIRSA.

# INTRODUCTION

The RMCWMB (2003a) plan sets the farm dam development limit at 30% of long-term average May to November (winter) runoff. This limit was set for the whole of the Eastern Mount Lofty Ranges and was based on preliminary estimates of dam development and corresponding stress levels from a wide range of catchments across Australia. However, the need to develop catchment-specific limits on diversion, capture and use was identified during the WAP process. Hence, this work attempts to arrive at catchment-specific sustainable extraction limits for farm dams in the Marne–Saunders Prescribed Area.

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[1] The term 'sustainable', in this report, refers to 'agreed environmental water provisions', as explained in page 3.

[2] The term 'extraction limits', in this report, refers to 'limits on diversion, capture and use', as explained in page 2.

The current estimated dam capacity in the Marne Catchment is 3200 ML (irrigation 1650 ML; stock and domestic 1550 ML). This has exceeded the allowable dam capacity (2400 ML) set in the RMCWMB plan by ~800 ML. Hence, any new development would be possible only as a result of transfer(s) of allocation from existing dam(s) with corresponding reduction of dam capacity, the rules for which would be outlined in the WAP.

The limits defined in this note would be applicable only to new on-stream dams, as diversion and use limits for existing irrigation dams will be separately defined as part of the Marne–Saunders existing user allocation process.

# METHODOLOGY

## DEFINITION OF TERMS

The methodology involved in arriving at sustainable limits for extraction involves firstly defining the terms 'sustainable' and 'extraction limits' as used in this note.

'Sustainable' refers to agreed[3] environmental water provisions.

'Extraction limits' refers to limits on:

- Diversion — flows that can be diverted to the dam. In this case, flows below the threshold flow level to be diverted around the dam.
- Capture — dam capacity, as percentage of winter runoff from its catchment area.
- Use — volume of water that can be used from the dam during the irrigation season, which in the model is apportioned during the months from October to March.

## UNIT CATCHMENT MODEL

A catchment model for the Upper Marne Catchment has been constructed and calibrated (Savadamuthu 2002), with various diversion and management scenarios. The results were used by the committee in determining limits on 'diversion to dams' and 'use from dams' for existing irrigation dams.

Limits on capture (dam capacity) for existing dams was not endorsed by the committee, as reducing the capacity of existing dams was seen to be the least socially acceptable option for managing water allocation. However, limits on capture needed to be defined for new dams as agreed by the committee. To determine sustainable use limits from new dams with respect to agreed 'environmental water provisions', multiple scenarios involving varying combinations of diversion, capture and use were modelled.

A unit catchment model is a representation of an actual catchment model for a unit area, 1 $km^2$ in this case. A 'unit catchment model', as opposed to the model for the entire catchment, was considered appropriate for this purpose due to the ease of running multiple scenarios. The study recognises the limitation of parameter lumping in the unit model methodology. However, the catchment parameters used in the unit model were derived from the calibration of a partially distributed catchment model of the entire catchment.

The steps involved in its construction for the Upper Marne Catchment are explained below.

[3]Agreed to by the Marne–Saunders Water Resources Planning Committee, on the basis of MREFTP (2003).

## Unit catchment model setup

1. Construct a catchment node of 1 $km^2$ area.
2. Use the catchment characteristic parameters derived from calibrating the entire Upper Marne Catchment.
3. Use average rainfall and evaporation data for the Upper Marne Catchment.
4. Drain the catchment to a dam.

## Scenario modelling

The following scenarios were modelled for 30 years (1974–2003) of daily rainfall data:

- Variable capture — dam capacities of 100%, 90%, …, 30% of winter runoff.
- Variable use — for each dam capacity scenario, use rates of 100%, 90%, …, 0% of dam capacity were modelled.
- Variable diversion — for each capture and use scenario, two diversion scenarios (with low flow bypass[4] (LFB)' and 'without LFB') were modelled.

## Agreed environmental water provisions

The RMCWMB carried out a study on the environmental water requirements of the Marne Catchment (MREFTP 2003), employing the 'Seasonal Flow Deviation Analysis (SFDA)' methodology. The methodology identifies four flow seasons (low, high, two transitions) and a series of key flow statistics during those seasons. These statistics are then used as surrogate measures of key environmental flow requirements, a few of which are listed in Table 1.

**Table 1. Examples of flow components used in seasonal flow deviation analysis methodology**

| Flow season | Flow statistic (component) | Rationale |
|---|---|---|
| Low flow season | Zero flows — frequency and duration of spells of daily flows of 0.1 ML and lower | A measure of how often and for how long pools become isolated |
| Transition season | Freshes — frequency and duration of spells above median daily flow | Surrogate measure of longitudinal connectivity, breeding triggers and sediment flushing |
| High flow season | High flows — frequency and duration of spells of daily flows over the 10th percentile exceedance flow | Surrogate measure for bankfull and overbank flows relating to lateral connectivity and disturbance flows |

A full list of the flow statistics used in the seasonal flow deviation analysis methodology is attached in Appendix A.

For each key flow component in each season, a comparison is made between the natural flows (no dams scenario) and the flows generated under different scenarios. The percentage change between the natural flows and flows under each scenario for each component is transformed into a rating between 0 and 3 as shown in Table 2. The higher the rating, the higher the environmental stress.

[4] LFB flows below the threshold flow level of 2 $L/s/km^2$ were bypassed around the dam.

The committee agreed during the WAP process that a component rating of 2 (up to 50% reduction of natural flow components) for all flow seasons would be adopted as an acceptable maximum level of environmental stress for developments in the Marne–Saunders Prescribed Area. This level represents a balance between social, economic and environmental needs for water within the area. The water resources of the Marne–Saunders Prescribed Area are under high demand, with many flow statistics currently at a rating of 3 (high stress). The committee considered that bringing the stress level back to 2 (medium stress) provided a good short-term benefit, with a longer-term aspirational target level of 1 (low stress).

**Table 2. Rating system used for reduction and increases in key flow parameters (MREFTP 2003)**

| Percentage of natural flow | | Component rating |
|---|---|---|
| **Decrease** (%) | **Increase** (%) | |
| 90–100 | 100–149 | **0** |
| 70–89 | 150–199 | **1** |
| 50–69 | 200–399 | **2** |
| <50 | ≥400 | **3** |

### Components' ratings — single scenario

Daily flows from each modelled scenario were compared with natural (no dams scenario) daily flows to determine the rating for the flow components during the four flow seasons. The component rating calculations are illustrated with an example in Appendix B. The values highlighted in the example indicate the stress rating for mean daily flows during the first transitional flow season is 2 for the scenario: capture — 80%; use — 20% of dam capacity; diversion — low flows bypassed.

### Components' ratings — multiple scenarios

The methodology illustrated in Appendix B was used to calculate the components' ratings for various diversions (with and without LFB), capture and use rates scenarios. An example of one capture rate and variable use rates is illustrated in Appendix C. The values highlighted in the example indicate that for transitional season (June-July), when low flows are bypassed and when the dam capacity is 80% of winter runoff, then the maximum use rate to achieve the desirable stress rating of 2 is 20% of dam capacity.

### Maximum use rate for capture rates

The maximum use rates to achieve the desirable stress rating of 2 for each capture rate are shown in Appendix D.

# RESULTS AND DISCUSSION

## *IMPACTS ON FLOW REGIME*

The impacts of variable diversion, capture and use on the different flow components during different seasons are shown in Appendix D and summarised below.

## Low flow season (January–May)

The Marne River and Saunders Creek are ephemeral systems where flows during summer are rare and minimal. Hence, during this season, the flow statistics 'median daily flow' and '80th percentile flow' are 0, and the 'mean flows' are very low, even under 'natural' conditions. Changes to dam capacity, use and diversion do not have an impact on these statistics during this season. Hence, these statistics were not included in the analysis. However, bypassing low flows around the dam restores other flow statistics (frequency and duration of freshes) to those of natural conditions (App. D). Freshes during this season, although infrequent, are likely to be important in maintaining the presence and quality of water in pools over this season.

If low flows are not bypassed, the dams have to fill and spill before the freshes can occur. This means the dams have to be full at the beginning of the flow season. This rarely occurs, as water would be lost to evaporation even if it were not used during the irrigation season.

Since, the Marne River and Saunders Creek are ephemeral systems with rare and/or minimal flows during summer, it is considered that management actions need to focus more on improving flows during the two transition periods ('break-of-season' and 'late baseflow season'), rather than improving flows during the low flow season.

## Transitional flow seasons (June–July and November–December)

Bypassing low flows around the dam improves the ratings of most of the flow statistics during these seasons, except for the mean daily flow during the months of June and July. However, the rating of this statistic is sensitive to capture and use from the dam. Hence, the rating of this statistic was used to determine the maximum allowable capture and use for the transitional seasons.

If low flows are not bypassed, no water can be used from the dam to achieve the desired stress ratings for two of the parameters (median and frequency of flushes).

## High flow season (August–October)

Capture and use have a higher impact on the flow statistics during this season than the impacts of bypassing low flows. Unlike the transitional season, water (to a certain extent) can still be used during the season to achieve the desired environmental stress ratings without bypassing low flows. Since dams in the catchment have progressively filled during the transitional season, they start spilling during this season. Hence, bypassing low flows appear to have a lesser impact on the flows in comparison to the 'low flow' and 'transitional flow' seasons.

The results indicate that when low flows are bypassed, 'overbank flows — frequency of flows greater than the 10th percentile flow' is the parameter that is most sensitive to capture and use. Bypassing low flows around the dam delays the dam filling and spilling process and, hence, reduces the peaks of the hydrographs. Thus, if low flows are bypassed, and if high dam capacities are maintained, use from the dam has to be reduced a great deal for the frequency of high flows to be maintained.

The summary of the results discussed above is:

- Capturing low flows increases the stress rating of many of the environmentally relevant flow components to their highest levels during all four seasons.

OR

Bypassing low flows returns most of the environmentally relevant low flow components to natural (‘no dams’) conditions.

- Mean daily flows during the transitional season (June, July) and overbank flows during high flow season are the only two parameters that are more sensitive to capture and use than to low flows being bypassed. Hence, with low flows being bypassed, the maximum water that can be extracted before the stress rating rises above the acceptable level of 2 is tabulated for each capture rate in Table 3.

**Table 3. Maximum use rates[c] for variable capture rates, with low flows bypassed**

| Season | Diversion | **Capture** (dam capacity as percentage of winter runoff) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **100** | **90** | **80** | **70** | **60** | **50** | **40** | **30** |
| Transitional flow[a] | With LFB | <10 | 10 | 20 | 30 | 50 | 100 | 100 | 100 |
| High flow[b] | With LFB | 0 | <10 | <10 | 10 | 20 | 50 | 100 | 100 |
| Minimum of the above | | 0 | <10 | <10 | 10 | 20 | 50 | 100 | 100 |

[a]Transitional flow — mean daily flows during June and July

[b]High flow — frequency of overbank flows (flows above 10th percentile)

[c]Use rates — expressed as a percentage of dam capacity

The results tabulated in Appendix D and summarised in Table 3 are explained with an example below.

<u>Example highlighted in Appendix D</u>

Capture: 80% of winter runoff

Diversion: low flows bypassed

1. Transitional Flow Season (June, July)

By comparing the use rates for the five flow statistics during this season, the lowest use rate corresponds to the statistic ‘mean daily flow’. Hence, this use rate (20% of dam capacity) was selected as the limiting factor for that season. Use limits for other seasons were selected on this basis.

2. High Flow Season

By comparing the use rates for the five flow statistics during this season, the lowest use rate corresponds to the statistic ‘frequency of overbank flows’. Hence, this use rate (<10% of dam capacity) was selected as the limiting factor for that season.

As explained in the example above, the maximum use rates for different capture rates were compiled for the two flow seasons; these are presented in Table 3. The last row in Table 3 (and Appendix D) indicates the minimum of the two flow seasons, which is then the annual use limit for a particular capture rate.

The results presented in Table 3 indicate that, when:

- capture rates are lower than 40% of mean annual winter runoff, and
- low flows are bypassed around the dam,

all the water captured in the dam during winter could be used during the irrigation season and the desired environmental stress rating of 2 could still be achieved during both flow seasons. However, if capture rates are above 40%, and if the stress rating of 2 is to be maintained, then the maximum use rates start decreasing with increasing capture rates.

Since flows during both seasons are ecologically important, the lower of the use rates from the two seasons was considered as the sustainable use rate for each capture rate (last row in Table 3).

The study recognises that the flow statistics used in the seasonal flow deviation analysis methodology are only surrogate measures for environmental water requirements. Hence, they need to be verified with data collected from actual sites in the catchment. This requires a monitoring network to be established in the Marne–Saunders Prescribed Area to measure the relevant environmental parameters.

# CONCLUSIONS AND RECOMMENDATIONS

The impacts of variable diversion, capture and use from farm dams on environmental water requirements are:

- Diversion — Bypassing low flows is estimated to provide for most of the environmental flow requirements during the transitional and low flow seasons. However, bypassing low flows delays the dam filling and spilling process, resulting in reduction of flow peaks. The implications could be reduction in frequency and delay of overbank flow events, which is an important environmental flow component during the high flow season.
- Capture — Level of capture controls the timing of the filling and spilling process of the dams and, hence, has the highest impact on the 'overbank flow' environmental component during the high flow season.
- Use — Use from the dams also controls the timing of the filling and spilling process of the dams.

The results indicate that to achieve the desired levels of environmental stress ratings, low flows have to be bypassed, irrespective of the level of capture and use. However, with low flows being bypassed, limits still have to be set on use rates for various capture rates to ensure that the desired environmental stress levels are not exceeded. The use limits for different capture rates, with low flows being bypassed, for the Marne–Saunders Prescribed Area are listed in Table 4.

**Table 4. Use limits for variable capture rates, with low flows bypassed.**

| | **Capture and use rates[a] (%)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Dam capacity[a]** | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 |
| **Use limit[a] — with LFB** | 0 | 2[b] | 4[b] | 7 | 12 | 25 | 40 | 30 |

[a]Capture and use rates are expressed as a percentage of mean annual winter runoff

[b]The actual calculated values were <10%. Hence, values shown in the table were interpolated

The results in Table 4 are the recommended range of capture and corresponding use rates for new on-stream farm dams for the Marne-Saunders Prescribed Area. Similar limits could be derived for other catchments by incorporating local catchment characteristics and corresponding environmental water provisions to:

- define sustainable extraction limits from existing on-stream farm dams.
- provide a range of capture and corresponding use rates for new on-stream farm dams.

# APPENDICES

## A. SEASONAL FLOW DEVIATION ANALYSIS: KEY FLOW COMPONENTS (MREFTP 2003)

### Low flow season (January–May)

| Key flow components | Rationale |
|---|---|
| Average daily flow | A measure of total seasonal volume |
| Median daily flow | A surrogate measure of low flows |
| 80th percentile flow | A surrogate measure of low flows |
| Zero flows — number of spells per 100 years | A measure of how often pools become isolated. A measure of 0.1 ML/d is used as effectively zero flow |
| Zero flows — median duration of individual spell events | A measure of how long pools are isolated. Increases in zero flow durations increase stress on the system |
| Freshes — number of spells per 100 years | A measure of refreshing pools and flushing sediment. A surrogate measure for freshes has been defined as flows over the median daily flow in low flow season |
| Freshes — median duration of individual spell events | |

### Transitional season (June–July and November–December)

| Key flow components | Rationale |
|---|---|
| Average daily flow | A measure of total seasonal volume. Also a surrogate measure of seasonal increase or decrease in baseflow |
| Median daily flow | A surrogate measure of seasonal increase or decrease in baseflow |
| Zero flows — number of spells per 100 years | A measure of changes in low flows and how often pools become isolated. Increases in zero flow durations increase stress on the system |
| Zero flows — median duration of individual spell events | A measure of how long pools are isolated. Increases in zero flow durations increase stress on the system |
| Freshes — number of spells per 100 years | Surrogate measure of longitudinal connectivity, breeding triggers and sediment flushing. A surrogate measure for freshes has been defined as flows over the median daily flows in the transitional flow season |
| Freshes — median duration of individual spell events | |

### High flow season (August–October)

| Key flow components | Rationale |
|---|---|
| Average daily flow | A measure of total seasonal volume |
| Median daily flow | A surrogate measure of water persistence and longitudinal connectivity |
| Coefficient of variation (Cv) | A measure of flow variability |
| Freshes — number of spells per 100 years | Surrogate measures of longitudinal connectivity and low level disturbance. A surrogate measure for freshes has been defined as flows over the median daily flow in the high flow season |
| Freshes — median duration of individual spell events | |
| High flows — number of spells per 100 years | Surrogate measures for bankfull and overbank flows relating to lateral connectivity and disturbance flows. A surrogate measure is defined as the frequency and duration of flows over the 10th percentile exceedance flows |
| High flows — median duration of individual spell events | |

## *B. FLOW COMPONENT RATINGS — AN EXAMPLE*

| | | | |
|---|---|---|---|
| Scenario: | Capture: | dam capacity = 80% of mean annual winter runoff | |
| | Use: | 20% of dam capacity (16% of mean annual winter runoff) | |
| | Diversion: | low flows bypassed | |
| Data highlighted (in red): | | | |
| Season: | | transitional (June–July) | |
| Mean daily flow: | | natural (no dams scenario): | 0.26 ML |
| | | current scenario: | 0.13 ML |
| Change in flow: | | 0.51 (51%) — flow under this scenario is equivalent to 51% of flow under natural conditions. | |
| **Rating:** | | **2** (as shown in Table 2 in the main text) | |

| | | | | | | Rating | Weighting | Score |
|---|---|---|---|---|---|---|---|---|
| | | | Natural | Scenario | Change | | | |
| **Low Flow** | Jan-May | | | | | | | |
| | Zero flows | f | 119.9 | 119.9 | 1 | **0** | 0.15 | 0 |
| | | mean(d) | 116.5 | 116.5 | 1 | **0** | 0.1 | 0 |
| | Flushes | f(>median) | 59.9 | 59.9 | 1 | **0** | 0.2 | 0 |
| | | mean (d) | 19.1 | 19.1 | 1 | **0** | 0.1 | 0 |
| | | | | | | | 3 | 0.43 |
| | | | | | | | | |
| **Transitional** | June-July | | | | | | | |
| | | Mean | 0.26 | 0.13 | 0.509141 | **2** | 0.05 | 0.1 |
| | | Median | 0.07 | 0.07 | 1 | **0** | 0.35 | 0 |
| | | Cv | 2.10 | 2.58 | 1.227923 | **0** | 0.05 | 0 |
| | Flushes | f(>median) | 239.76 | 239.76 | 1 | **0** | 0.3 | 0 |
| | | mean(d) | 12.63 | 12.63 | 1 | **0** | 0.25 | 0 |
| | | | | | | | 3 | 0.03 |
| | | | | | | | | |
| **High Flow** | Aug-Oct | | | | | | | |
| | | Mean | 0.34 | 0.25 | 0.73 | **1** | 0.1 | 0.1 |
| | | Median | 0.06 | 0.06 | 1.00 | **0** | 0.35 | 0 |
| | | Cv | 2.79 | 3.45 | 1.24 | **0** | 0.1 | 0 |
| | Overbank | f(>10%ile) | 280.50 | 119.88 | 0.43 | **3** | 0.25 | 0.75 |
| | | mean(d) | 3.24 | 4.67 | 1.44 | **0** | 0.2 | 0 |
| | | | | | | | 3 | 0.28 |
| | | | | | | | | |
| **Transitional** | Nov, Dec, Jan | | | | | | | |
| | | Mean | 0.03 | 0.03 | 0.83 | **1** | 0.05 | 0.05 |
| | Flushes | f(>median) | 39.96 | 39.96 | 1.00 | **0** | 0.3 | 0 |
| | | m(d) | 21.58 | 21.58 | 1.00 | **0** | 0.25 | 0 |
| | | | | | | | 3 | 0.37 |

## *C. MAXIUMUM USE RATES FOR VARIOUS CAPTURE RATES — AN EXAMPLE*

Scenario: **Capture**: dam capacity = 80% of mean annual winter runoff. **Use**: 100%, 90%, …, 0% of dam capacity. **Diversion**: low flows bypassed.

Data highlighted (in red):

Season: transitional (June–July)

Flow component: mean daily flow

**Maximum use rate for a stress rating of 2: 20% of dam capacity or 16% of mean annual winter runoff** (20% of 80% = 16%)

### Seasonal Flow Deviation Analysis - Upper Marne Catchment

**Dam Capacity:** 80%_of_WinterQ_LFB

| | | | Scenario | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 100%Use | 90%Use | 80%Use | 70%Use | 60%Use | 50%Use | 40%Use | 30%Use | 20%Use | 10%Use | 0%Use |
| *Low Flow* | Jan-May | | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating | Rating |
| | Zero flows | f | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | m(d) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Flushes | f(>median) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | m(d) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | SCORE | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 |
| *Transitional* | June-July | | | | | | | | | | | | |
| | | Mean | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 |
| | | Median | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Cv | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Flushes | f(>median) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | m(d) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | SCORE | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.03 | 0.03 | 0.03 |
| *High Flow* | Aug-Oct | | | | | | | | | | | | |
| | | Mean | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | Median | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Cv | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Overbank | f(>10%ile) | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 |
| | | m(d) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| | | SCORE | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.35 | 0.35 | 0.35 | 0.28 | 0.28 | 0.20 |
| *Transitional* | Nov, Dec, Jan | | | | | | | | | | | | |
| | | Mean | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Flushes | f(>median) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | m(d) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 0.38 | 0.38 | 0.38 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 |

## D. USE LIMITS FOR VARIABLE CAPTURE RATES

Maximum Use Rates[2] for Variable Capture Rates[1] for a maximum Stress Rating of 2

[1] - Dam Capacity = % of winter runoff (**100%, 90%, ...50%**)
[2] - Use from Dam = % of Dam Capacity (100%, 90%,…,0% or No Use)

**ex:** If dam capacity is equivalent to **80%** of winter runoff from catchment above the dam (with low flows bypassed "With LFB"), then the use has to be 20% (or lower) of that capacity for the stress rating of daily "**mean**" flows during the transition season (June-July) to be 2 or less. Use above that results in a score of 3.

**Refer Appendix C for the actual stress ratings for "80% capture - with Low Flow Bypass" and variable use rates .**

| | | | Variable Capture (Dam Capacity = % | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | With LFB | | | | | | | | | NO LFB | | | | | | | |
| Low Flow | Jan-May | | 100% | 90% | 80% | 70% | 60% | 50% | 40% | 30% | | 100% | 90% | 80% | 70% | 60% | 50% | 40% | 30% |
| | Zero flows | f | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | m(d) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | Flushes | f(>median) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | NO Use | NO Use | NO Use | NO Use | NO Use | NO Use | NO Use | NO Use |
| | | m(d) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | **30%** | **30%** | **40%** | **50%** | **70%** | **90%** | **100%** | **100%** |
| Transitional | June-July | | | | | | | | | | | | | | | | | | |
| | | **Mean** | **<10%** | **10%** | **20%** | **30%** | **50%** | **100%** | **100%** | **100%** | | **NO Use** | **NO Use** | **NO Use** | **<10%** | **10%** | **20%** | **40%** | **70%** |
| | | Median | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | NO Use | NO Use | NO Use | NO Use | NO Use | NO Use | NO Use | NO Use |
| | | Cv | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | 100% | 100% | 100% | 100% | 100% | 0% | 100% | 100% |
| | Flushes | f(>median) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | NO Use | NO Use | NO Use | NO Use | NO Use | NO Use | NO Use | NO Use |
| | | m(d) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| High Flow | Aug-Oct | | | | | | | | | | | | | | | | | | |
| | | Mean | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | 80% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | Median | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | NO Use | NO Use | NO Use | NO Use | NO Use | NO Use | NO Use | NO Use |
| | | Cv | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | **Overbank** | **f(>10%ile)** | **NO Use** | **<10%** | **<10%** | **10%** | **20%** | **50%** | **100%** | **100%** | | **30%** | **30%** | **50%** | **70%** | **100%** | **100%** | **100%** | **100%** |
| | | m(d) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Transi-tional | Nov, Dec, Jan | | | | | | | | | | | | | | | | | | |
| | | Mean | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | 50% | 60% | 70% | 90% | 100% | 100% | 100% | 100% |
| | Flushes | f(>median) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | 10% | 20% | 20% | 30% | 30% | 60% | 20% | 40% |
| | | m(d) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | | **<10%** | **<10%** | **10%** | **10%** | **20%** | **40%** | **90%** | **90%** |
| **Min of the 2 Factors:** | | | **0%** | **<10%** | **<10%** | **10%** | **20%** | **50%** | **100%** | **100%** | | **0%** | **0%** | **0%** | **<10%** | **10%** | **20%** | **40%** | **70%** |

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