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TROUT CREEK
HYDROLOGY AND OPERATIONS REVIEW

June 2003

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INTERIM REPORT

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Operations Review
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1 INTRODUCTION

1.1 Background

The District of Summerland supplies water to domestic, commercial and agricultural users. There are approximately 4,100 single family, 269 commercial and 1,151 irrigation connections. The Trout Creek watershed supplies about 90% of the District water supply. There are 8 reservoirs in the headwaters of the Trout Creek watershed, which are currently operated by the District to provide flow regulation. The reservoirs that are currently operated are Thirsk, Crescent, Whitehead, Isintok and the four Headwaters Reservoirs. Water is released from the reservoirs as required to provide sufficient flow at the diversion structure on Trout Creek.

The diversion structure supplies water to a balancing reservoir located on glacial outwash deposits of sand and gravel. Losses from the balancing reservoir have been estimated by the District. The District meters flow at the chlorination chamber downstream of the balancing reservoir. There are currently no other meters on the system.

The District of Summerland releases flow from the diversion structure on Trout Creek to provide downstream flow for fisheries. The Ministry of Water, Land and Air Protection (MWLAP) has recently commissioned studies to review the habitat and fish flow needs of Trout Creek. An increase in fish flows has been requested.

This study addresses three key questions:

- To what extent can the existing water supply system provide the requested increased fish flows?
- What reservoir operation policies should be put in place to trigger water restrictions based on reservoir storage levels?
- What is the best strategy for providing increased reliable flow on Trout Creek to meet future demands?

This Interim Report addresses the first two questions. The Final Report will include the water supply strategy for Trout Creek watershed to meet future demands.

1.2 Scope of Work

The Scope of Work included the following:

- Development of a hydrology model of the Trout Creek watershed
- Development of reservoir operations model to simulate operations of the water supply system
- Analysis of existing and future water demands including estimates of water savings with water restrictions in place
- Development of a reservoir system operations policy and guidelines to trigger water restrictions based on storage levels
- Assessment of future storage requirements with increased demands
- Comparison of options including water metering and lining of the balancing reservoir based on a life cycle cost analysis
- Recommendations for a water supply strategy.

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2 TROUT CREEK HYDROLOGY

2.1 Previous Studies

The hydrology of Trout Creek has been studied by the Provincial Government; Reksten (1973), Weiss (1981), and Letvak (1989). The Letvak report essentially updated the previous two studies.

The Letvak report estimated the mean annual runoff in Trout Creek watershed to be 65,499 acre-feet based on observed flow data for the period 1970 to 1982, data from the Summerland diversion and an estimate of the Brenda Mines diversion. The runoff model developed by Letvak estimated the mean annual natural runoff to be 60,480 acre-feet; which is 77% of the runoff estimated from data available.

The Letvak report used a mean monthly distribution for monthly runoff. This is a significant limitation on the analysis as the distribution of runoff varies from year to year.

Northwest Hydraulic Consultants (2001) carried out an assessment of the hydrology of the Okanagan Lake Basin as part of a fish flow assessment. The mean annual natural runoff for Trout Creek watershed for an area of 759 km^2 was estimated to be 110 mm. This corresponds to a mean annual flow of 2.65 m^3/s or 68,000 acre-feet per year.

See p. 7.62

2.2 Watershed Model Inflows

2.2.1 Introduction

The modelling strategy used for this study was to first develop a watershed model for the unregulated recorded flows on Camp Creek, a subcatchment of the Trout Creek watershed. Once the model was calibrated for Camp Creek, it was expanded to natural flows for the entire Trout Creek watershed making adjustments for elevation differences and catchment areas.

The model used for this study was the WMC Watershed Model, which was originally developed for simulating runoff in semi-arid climates. The Trout Creek watershed was divided into subcatchments to facilitate calibration to monitoring locations and provide inflows to the reservoirs. The subcatchments are illustrated on Figure 2.1 and listed on Table 2.1.

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Table 2.1 Subcatchments of Trout Creek Watershed

		Total Area (m^2)							
Area		Below 600 m	600 m to 900 m	900 m to 1200 m	1200 m to 1500 m	1500 m to 1800 m	Above 1800 m	Total	Contributing Area
1	Headwaters Lakes	0	0	0	14,227,323	1,147,216	3,802,959	19,177,498	19,177,498
2	Crescent Lake	0	0	0	4,136,750	9,050,419	2,204,286	15,391,455	15,391,455
3	Whitehead Lake	0	0	0	6,710,492	0	0	6,710,492	6,710,492
4	Thirsk Reservoir	0	0	15,359,978	99,655,404	74,522,979	5,904,898	195,443,259	236,722,704
5	Camp Creek	0	0	7,747,184	15,454,731	12,776,611	1,361,975	37,340,501	37,340,501
6	Isintok Lake	0	0	0	0	10,422,940	5,882,346	16,305,286	16,305,286
7	Trout Creek at Intake	0	33,696,047	85,059,026	115,842,136	103,262,124	8,338,341	346,197,674	636,566,165
8	Trout Creek at Mouth	12,589,737	24,235,567	8,463,669	235,912	0	0	45,524,885	682,091,050
9	Darke Creek	0	20,833,954	26,647,730	18,257,298	10,937,920	0	76,676,902	758,767,952

Total 758,700,000 m^2

Meadow Valley Irrigation District operates Darke Lake. Finley Creek and Lapsley Creek are diverted into Darke Lake. To account for the Meadow Valley operations it would be necessary to model the operations of this system, which was outside the scope of the current study. According to local information, there is very little flow in Darke Creek downstream of the Meadow Valley system. Therefore, the subcatchment of Darke Creek was excluded from the total Trout Creek watershed for the purposes of the current study.

The total watershed area of Trout Creek was determined from a GIS analysis to be 759 km^2. Excluding Darke Creek, the watershed area of Trout Creek is 682 km^2. The watershed area at the Summerland intake is 637 km^2.

2.2.2 Temperature and Precipitation

Temperature and precipitation data was available for a number of nearby sites including Summerland, Penticton, Osprey Lake and Brenda Mines. The last two stations although not active, provide an assessment of the impact of elevation and location within the catchment. Snow course data was available from Summerland (near Headwaters Lake), Isintok Lake and Trout Creek.

The temperature and precipitation data for Summerland is relatively continuous for the period 1916 to present with the few missing data points infilled with data for Penticton. Based on the available information, a correlation was derived for the upper reaches of the catchment and the Summerland data.

The temperature correlation used was:

$$T = T_s - \frac{(E-E_s)7.5}{1065} \qquad \text{for } T_s > 0 \quad \text{and}$$

$$T = T_s\left(1 - \frac{(E-E_s)0.27}{1065}\right) - \frac{(E-E_s)7.5}{1065} \quad \text{for } T_s < 0$$

where T = required temperature
T_s = temperature at Summerland
E = elevation of calculation point
E_s = elevation at Summerland

The precipitation correlation used was:

$$P = P_s(1+(E-E_s)/644) \qquad \text{for winter months and}$$

$$P = P_s(1+(E-E_s)0.42/644) \qquad \text{for summer months}$$

where P = required precipitation
T_s = precipitation at Summerland
E = elevation of calculation point
E_s = elevation at Summerland

The distribution of precipitation to snow and rainfall assumed that all precipitation fell as rain if the average monthly temperature was greater than 2°C and all as snow if the average monthly temperature was below -2°C. In between the ratio of precipitation as snow was varied linearly with the temperature between -2°C and 2°C.

Calculations were carried out in 300 m bands beginning at below 600 m and going up to above 1800 m. The linear variation was calculated from data for Summerland and the midpoint of each elevation band.

2.2.3 Sublimation

Sublimation is complex and requires tabulation of a number of variables for a rigorous determination. In this analysis, we have assumed that maximum sublimation is 0.3 mm/day. This was modified where necessary to meet site water balance requirements. Sublimation was allowed in the months November through April. Although sublimation rates may be high during snowmelt, the sublimation is often offset by night-time condensation into the snowpack. Sublimation therefore was not considered for May.

2.2.4 Adjustment for Snowpack Measurements

Snowpack was calculated based on the calculated precipitation and temperature distributions as described above. However, winter precipitation measurements are difficult to measure reliably. For this reason, the winter snowpack was adjusted using the measured snowpack on April 1st at the Summerland site (Headwater Lakes). The calculated snowpacks for each elevation band were multiplied by a snowpack factor and the ratio of the measured and calculated snowpack at the Summerland station. The snowpack factor allows for input of a correction factor to account for the relationship between the point measurement and the whole basin.

2.2.5 Snowmelt

Snowmelt is responsible for much of the available water in this region. Although snowmelt can be estimated, the required meteorological parameters are not available for this site. The snowmelt was estimated using a temperature index method. A first order estimate of the apparent losses were:

$$\text{Snowmelt (mm)} = 90(T-5).$$

Where T is the average monthly temperature.

This equation was used to estimate the potential snowmelt for each month. The actual snowmelt was up to the potential after considering the available snow after sublimation. The factors, (90 and 5) were determined by fit to available streamflow data. The water available each month was calculated as the sum of snowmelt and rainfall.

2.2.6 Evapotranspiration

Evapotranspiration was calculated with a methodology described by Thornthwaite (1948). First, the potential evapotranspiration (PET) was estimated based on the ~~average~~ monthly temperature and modified by the site latitude and the number of days in the month. The monthly water balance was calculated assuming the soil profile could retain some moisture from month to month. A maximum soil moisture retention was defined. The balance considered losses and gains to soil moisture, rainfall and snowmelt, evapotranspiration and surplus water (available for infiltration and runoff). Evapotranspiration was limited by the soil moisture condition. Below the soil moisture capacity of the soil, the PET was reduced linearly with soil moisture. This calculation was completed for each elevation band.

During snowmelt, the ground may be frozen, preventing contribution of snowmelt to soil moisture, and thereby contributing more water to runoff. This is particularly noticeable in low snowpack years. This was addressed by preventing any contribution to soil moisture below a set temperature and ramping the water available to soil moisture up linearly to a second temperature.

Open water is assumed to evaporate at the full PET.

2.2.7 Infiltration

Infiltration was modelled at an adjustable rate that is dependent on surface conditions, soil permeability and available storage capacity. The infiltration rate was adjusted with a single parameter per unit area to account for variations between subcatchments. The infiltration was accumulated within the groundwater compartment and released at a rate determined by the product of the volume of water in storage and a discharge factor. In this way, month-to-month storage was allowed within each subcatchment, allowing an increasing discharge rate with increasing storage.

2.2.8 Groundwater Discharge

Water is infiltrated into storage in each subcatchment. The water is discharged from storage as a product of a discharge factor and the total storage. Corrections are included to prevent negative storage. Lower factors result in larger accumulated storage with the same recharge. The effect of decreasing the factor is to cause a more uniform discharge rate.

2.2.9 Calibration to Camp Creek

Camp Creek flows have been measured since 1965. The model parameters were adjusted to achieve a best fit to measured flows in Camp Creek. The results for 1995 to 2001 are illustrated on Figure 2.2.

2.2.10 Calibration to Upper Reservoir Base Flows

The infiltration and groundwater storage discharge factors were adjusted for the Upper Reservoirs to match measured reservoir level increases over recent winters. The calibration was achieved primarily by adjusting the allowed infiltration rate and the groundwater discharge factor.

2.2.11 Calibration to Flows at the Mouth of Trout Creek

There are a few limited times when sufficient information is available to fit calculated to measured flows at the mouth of Trout Creek. This was true in the fall and winter of 2001, when all reservoir storage values were well known. Table 2.2 is a listing of data and calculated flows for these times.

Table 2.2 Comparison of measured and calculated flows at the mouth of Trout Creek

Measured Flow		Calculated Flow	
Date	Flow (L/s)	1/4 month ending date	Flow (L/s)
Sept 26, 2001	197	Sept 30, 2001	296
Oct 19, 2001	466	Oct 23, 2001	445
Oct 25, 2001	278	Oct 31, 2001	253
Dec 3, 2001	372	Nov 30, 2001	377

2.2.12 Summary

The model was calibrated by varying calibration parameters to achieve a best fit to Camp Creek flows and minor modifications to match base flows into the upper reservoirs and the fall and early winter flows at the mouth of Trout Creek. ~~The~~ mean annual runoff for the period from 1938 to 2002 determined from the model was 2.58 m^3/s for a catchment area of 682 km^2 (excluding Darke Creek). This corresponds to an annual runoff of 123 mm, about 10% higher than the estimate by Northwest Hydraulics (2001).

Based on the above calibration, an output of natural monthly flows was generated for each of the eight subcatchments that contribute to Trout Creek flows. These flows were used in a routing study through the reservoirs, described in Section 4.

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3 WATER DEMANDS

3.1 Disaggregation of Demands

The flow into the Summerland distribution system is measured with a flow meter at the chlorination house immediately downstream of the balancing reservoir. The water is used for agricultural irrigation, residential indoor and outdoor consumption, urban commercial use and unaccounted for losses. A plot of the recorded flows, presented as Figure 3.1 illustrates the annual variability of the demand, driven mostly by agricultural irrigation. Also illustrated on Figure 3.1 is an estimate of the residential/urban commercial indoor use, based on the winter flows. Residential outdoor use and agricultural irrigation are illustrated as the remainder of the flows. The trend in residential/urban consumption is increasing probably due to urban development and residential construction. There is a notable decline in irrigation consumption.

According to Denise Neilsen of the Pacific Agri-Food Research Centre in Summerland, (Neilsen, 2003) the decline in irrigation consumption is likely due to improvements in irrigation technology and more intensive agriculture. About a third of the growers in the Summerland area are now using micro-irrigation techniques, which are better suited to intensification of production. Despite higher temperatures over the past 10 years, irrigation demands have dropped because of improved management practices which were introduced to increase fruit tree production.

∴ * MIG × 4546 = m^3/day

For the model, the residential indoor component (includes urban commercial) was estimated by examining the Summerland winter demand. The winter demand for 2001/2002 used in this analysis was 1.24 mig/day (5,600 m^3/day).

Based on studies reported by Water Management Consultants (2001) for the Vancouver area, the residential outdoor demand was estimated as a multiple of the indoor demand on a month-by-month basis. However, the evapotranspiration values for turf grass supplied by the BC Ministry of Agriculture (2002) are 75% higher in Summerland than in Vancouver. In addition, studies completed by Water Management Consultants (2001) noted that when lawn sprinkling was banned in Surrey in 1997, the residential outdoor use declined by 50%, indicating that lawn watering in Surrey in the summer accounted for 50% of the summer residential outdoor use. To account for the drier climate, the residential outdoor demand was therefore increased by a factor 1.375. The outdoor demand was also increased in early spring, to account for increased water use measured in Summerland at that time.

The water demand was based on the 2002 water use. The irrigation demand for that year was calculated by subtracting the residential indoor and outdoor water used derived as noted above from the total water used per month. As apparent from Figure 3.1, the water use in 2002 was above average for recent years (2772 mig or 12.6 million m^3). The design demand values used are presented on Table 3.1.

Table 3.1 Monthly design demand in thousands of m^3 based on 2002 use

	Residential indoor	Residential outdoor	Irrigation	Full Demand
Jan	174	0	0	174
Feb	159	0	0	159
Mar	174	10	0	185
Apr	168	12	319	500
May	174	54	1012	1241
June	168	64	1915	2147
July	174	117	2627	2918
Aug	174	121	2287	2583
Sept	168	69	1417	1655
Oct	174	21	505	701
Nov	168	4	0	172
Dec	174	0	0	174
Annual	2051	473	10083	12608

3.2 Fish Flows

Proposed fish flows were provided by Phil Epp of the Ministry of Water, Land and Air Protection based on a draft report by Northwest Hydraulics. The "normal" proposed fish flows for an average year are shown in Table 3.2. The proposed fish flows for a "drought" year are also shown. It should be noted that the flows in April, May and June are the peak required flows and not the average monthly flows.

Table 3.2 Proposed Fish Flows in m^3/s

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Normal	0.55	0.55	0.55	2.74	5.47	2.74	1.09	0.82	0.68	0.55	0.55	0.55
Drought	0.25	0.25	0.25	1.25	2.50	1.25	0.50	0.37	0.31	0.25	0.25	0.25
DROUGHT AF	17.5	17.5	17.6	87.5	175	87.5	35.0	25.9	21.7	17.5	17.5	17.5

$m^3/sec \times 69.993 = AF/day$.

eg = $0.37 \times 69.993 = 25.9$ AF/day

3.3 Future Water Demands

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$0.25 \times 69.993 = 17.5$ AF/day.

4 RESERVOIR OPERATION MODELLING

4.1 Model Structure and Operating Rules

The Reservoir Operation Model was set up within a spreadsheet format, with inflows generated into each of the subcatchments input from the hydrology model. The subcatchment boundaries are illustrated on Figure 2.1. The model was operated over the period from 1937 to 2002, the period when both local climate and snowpack data were available. The headwaters reservoirs were combined into one operating reservoir.

The reservoirs cannot be drawn down to the intake levels because of likely water quality degradation, particularly silt from eroding deposits in the floor of the reservoir. There would also be environmental impacts if reservoirs were drawn down completely. For this study we adopted the standard currently in use by the Greater Vancouver Water District, which is to set the minimum reservoir levels 2 m above the intake (Water Management Consultants, 2001). Therefore the reservoirs were operated to allow live storage between 6 feet above the intake to the spillway crest. All additional water was spilled downstream.

The model operates by accumulating inflows and discharges over quarter-month periods. Quarter-month time steps were required for effective modelling of the relatively small reservoirs. Based on the volume of water in the reservoir in the preceding month, the reservoir area was determined and the evaporation losses calculated. Seepage losses were neglected, as seepage would continue downstream towards the intake from most reservoirs.

The reservoir operating rules incorporated in the model were based on the rules set out in Associated Engineering (1997) modified to account for current operation practices.

Water spilled from Crescent Lake or released from Crescent Lake was routed to Headwaters Lakes. Release from Crescent Lake was required in the model as soon as Headwaters Lakes fell below full volume. Water spilled from Headwaters Lakes or released from Headwaters Lakes was routed to Thirsk Lake. The first release from Headwaters lake effectively removed water from storage in Crescent Lake and the inflows in the same time period. The second release from Headwaters Lakes removed the water that could be refilled relatively reliably. The third release was the remaining live storage.

Water spilled from Whitehead Lake or released from Whitehead Lake was routed to Thirsk Lake. The first release from Whitehead Lake was water that would be refilled relatively reliably. The final release from Whitehead Lake was the remaining live storage.

Water spilled or released from Thirsk Reservoir was routed to the intake. When 80% of the storage was depleted, makeup releases were requested in a specified order from the upstream reservoirs and Isintok Reservoir. Releases from upstream were routed through Thirsk Reservoir whereas Isintok Reservoir releases reported to the intake.

Water spilled or released from Isintok Reservoir was routed to the intake.

The operating rules for the mouth of Trout Creek were as follows:

- Release makeup water from the reservoirs to meet water supply demand, losses and fisheries requirements; and
- Adjust demand according to volume of water in storage.

The operating rules for release from the reservoirs were in the following order:

1. Withdraw water from storage in Thirsk to a water level 6 feet above the intake. Begin releasing makeup water from other reservoirs when 80% of the Thirsk storage capacity has been depleted.
2. Withdraw water available from Crescent Lake first. In the model, this water was routed through Headwaters Lakes. This lake was drawn down to 6 feet above the intake. Until demand dropped, Crescent was held at 6 feet above the intake.
3. Withdraw 432 ML of water from Whitehead Lake and hold at that level until the next drawdown of this lake or the demand was not required.
4. Withdraw 2339 ML from Headwaters Lakes and hold at that level until the next drawdown or the demand was not required.
5. Drawdown Isintok Lake to 6 feet above the intake and pass any additional inflow until the demand is not required.
6. Draw down the remainder of Headwaters Lakes to 6 feet above the intakes and pass any additional inflow until the demand is not required.
7. Drawdown the remainder of Whitehead Lake to 6 feet above the intake and pass any additional inflow until the demand is not required.

A summary of the operating drawdowns is presented on Table 4.1.

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Table 4.1 Summary of operating reservoir drawdowns in m^3

Reservoir	Full Reservoir	First Drawdown		Final Drawdown	
	Volume	Feet remaining	Volume remaining	Feet remaining	Volume remaining
Thirsk	3,404,460	6	8,042	6	8,042
Crescent	769,704	6	284,939	6	284,939
Whitehead	1,248,302	8.81	816,688	6	519,304
Headwaters	4,472,671	8.9	2,133,790	6	1,326,383
Isintok	1,372,886	6	49,340	6	49,340
Total	11,268,023				2,188,007

By leaving 6 feet of water over the intake, the amount left in storage and not used is 2.2 million cubic metres. This is about 19% of the total storage above the intakes in all reservoirs. The effective total live storage, leaving 6 feet of water over the intake, is 9.1 million m^3.

The balancing reservoir is constructed in gravelly material. Losses in the balancing reservoir included both seepage and evaporation and were estimate to be about 4000 m^3/day (0.88 mig/day). These losses were added to the demand removed from the Trout Creek at the intake.

4.2 Comparison with Operation Data

For 2001 and 2002, there is an excellent record of reservoir levels, and therefore knowledge of the volume of water in storage. Figure 4.2 is a presentation of measured and calculated total volume of water in storage, assuming that fish flow releases as specified in 1997 were met. The agreement between the modelled reservoir operations and observed data provides a verification of the reservoir operation model.

5 OPERATIONS POLICY

5.1 Proposed Water Restrictions

For the available water supply to meet demand under all conditions, water restrictions will be required. Table 5.1 presents the proposed restrictions.

Table 5.1 Proposed Water Restrictions

	Residential Outdoor	Fish Flows	Agricultural Irrigation
Stage 1	Watering twice a week	Fish flows at drought year levels	No Alteration
Stage 2	Watering once a week	Fish flows at minimum levels ($0.25\ m^3/s$)	Late and early irrigation restrictions
Stage 3	No outdoor use	No fish flows	Late and early irrigation restrictions
Stage 4	No outdoor use	No fish flows	No irrigation

Based on the analysis in Water Management Consultants (2001), the residential outdoor use was reduced by 16% in Stage 1 and by 50% in Stage 2. Agricultural irrigation was reduced in Stage 2 and Stage 3 by eliminating irrigation in the months of April and October.

The fish flow volume required in June was based on providing a peak flow as specified in Table 3.2 for 10 days and then applying the July flow for the remainder of the month (Ptolemy, 2003)

Based on the above, the following Table 5.2 was constructed to define demand for the five possible operating conditions.

Table 5.2 Demand used in model in millions of m^3

	Full Demand	Stage 1	Stage 2	Stage 3	Stage 4
Jan	1.6	0.8	0.8	0.2	0.2
Feb	1.5	0.8	0.8	0.2	0.2
Mar	1.7	0.9	0.8	0.2	0.2
Apr	7.6	3.7	0.8	0.2	0.2
May	15.9	7.9	1.9	1.2	0.2
June	6.4	4.1	2.8	2.1	0.2
July	5.8	4.2	3.5	2.8	0.2
Aug	4.8	3.6	3.2	2.5	0.2
Sept	3.4	2.4	2.3	1.6	0.2
Oct	2.2	1.4	0.9	0.2	0.2
Nov	1.6	0.8	0.8	0.2	0.2
Dec	1.6	0.8	0.8	0.2	0.2
Annual	54.1	31.5	19.4	11.3	2.1

$m^3 \times 219.97$
$= \text{Imp.Gal}$

5.2 Annual Demands and Available Flows

Table 5.3 is a summary of the total annual volume demands in an average year together with the available flow volumes. The Summerland consumption does not include losses from the Balancing Reservoir (about 1.5 million m^3 an annual basis). The fish flows correspond to the flows in Table 3.2 for average year and drought year.

Table 5.3 Annual flow volumes and demands

	Average year		Drought year (Stage 1)	
	millions of m^3	thousands of acre-feet	millions of m^3	thousands of acre-feet
Res/commercial	2.5	2.0	2.4	2.0
Irrigation	10.1	8.2	10.1	8.2
Summerland total	12.6	10.2	12.5	10.1
Fish flows	41.5	33.6	19.0	15.4
Total demands	54.1	43.9	31.5	25.5
Trout Creek total flows	84.1	68.2	30.3	24.5
Reservoir inflows	36.2	29.3	13.0	10.6

As shown in Table 5.3, the total demands in an average year are much less than the reservoir inflows. Thus, a considerable portion of the demand has to be met by unregulated flows. In a drought year (36% of mean annual runoff) the reservoir inflows are slightly greater than the Summerland total consumption which indicates that the Summerland consumption can be met from the reservoir inflows if no fish flows are provided. The usable total reservoir capacity is about 9 million m^3, slightly less than the Summerland total drought year demand of 10 million m^3. In a drought year, fish flows would have to be provided from the unregulated portion of the Trout Creek watershed.

In a drought year the total demands, including fish flows are greater than the total volume of flow in Trout Creek. Thus even if Trout Creek was totally regulated, it would not be possible to meet the Summerland and fish flow demands in a drought year. The monthly distribution of flows and demands in a drought year are illustrated on Figure 5.1.

Table 5.3 does not include other licences on Trout Creek which total about 330 ML per year (400 acre-feet). If these licences are being used to the full licensed extent the additional demand would be less than 1% of the total demand including fish flows.

5.3 Proposed Operations Policy

The Operations Policy was developed based on the design criteria of three consecutive drought years. The water restrictions described in Section 5.1 were implemented in the model based on the total available water in storage in a given month. Figure 5.2 shows the total storage level for each month when the restrictions would have to be implemented to avoid Stage 4 when irrigation water would not be available. The analysis for the three years of design drought included an additional 10% of the total demand to account for losses in dry conditions and increased demands.

At Stage 3 there would be no fish flows released. This would be required through the second half of the first year of drought and throughout the second and third years.

To determine the frequency with which Stage 3 would be required, the reservoir system was modelled over the 65-year period from 1938 to 2002. It was found that there were periods in the record that were more severe than the defined drought year. This occurred when there was a low snowpack and early runoff with very low runoff in May. Therefore snowpack conditions were incorporated in the operating rules as follows:

If the snowpack water equivalent at Headwaters Reservoir is less than 130 mm on April 1, the minimum water restriction level must be Stage 2 from April through August for that year.

Over the 65-year period, it was found that Stage 3 would be required in nine years, 1939, 1947, 1955, 1958, 1970, 1971, 1973, 1982 and 1987. This was based on using a minimum fish flow of 0.25 m^3/s (18 acre-feet per day). If the minimum fish flow was reduced to 0.1 m^3/s (7 acre-feet per day), the frequency of Stage 3 restrictions reduced to six occurrences.

Thus if 0.25 m^3/s is used for the minimum fish flow there would be no fish releases for a month or more about once every seven years. If the minimum fish flow is reduced to 0.1 m^3/s, there would be no fish releases about once every 11 years.

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6 FUTURE STORAGE REQUIREMENTS

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7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

1. The WMC Watershed Model provided an estimate of natural Trout Creek flows over the period from 1938 to 2002. The model was verified by comparing to available recorded flows.

2. The mean annual natural flow in Trout Creek was estimated to be [redacted] period from 1938 to 2002. This corresponds to an annual runoff of 123 mm, about [redacted] than previously estimated by Northwest Hydraulics.

   = 180.58 AF/da
   = 65,912 AF/year.
   ?

3. The reservoir operations model developed for the Trout Creek water supply system was verified using reservoir operational data from 2001 and 2002.

4. The ~~total demands~~ (water supply and fish flows) ~~in an average year are much greater~~ [redacted]. Therefore much of the demand in an average year has to be provided by unregulated flows.

5. In a drought year, (with water restrictions and reduced fish flows to drought year levels) the total annual demand is greater than the total volume of natural flows from the entire Trout Creek Watershed. It is therefore not feasible, in a drought year, to supply the Summerland water supply demand and drought-year fish flows. *

6. In a drought year the reservoir inflows are about equal to the Summerland demand so fish flows would have to be provided from the remaining unregulated portion of the Trout Creek catchment.

7. A Reservoir Operations Policy was developed that will ensure that [redacted]

8. The Operations Policy will result [redacted]

7.2 Recommendations

To come

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REFERENCES

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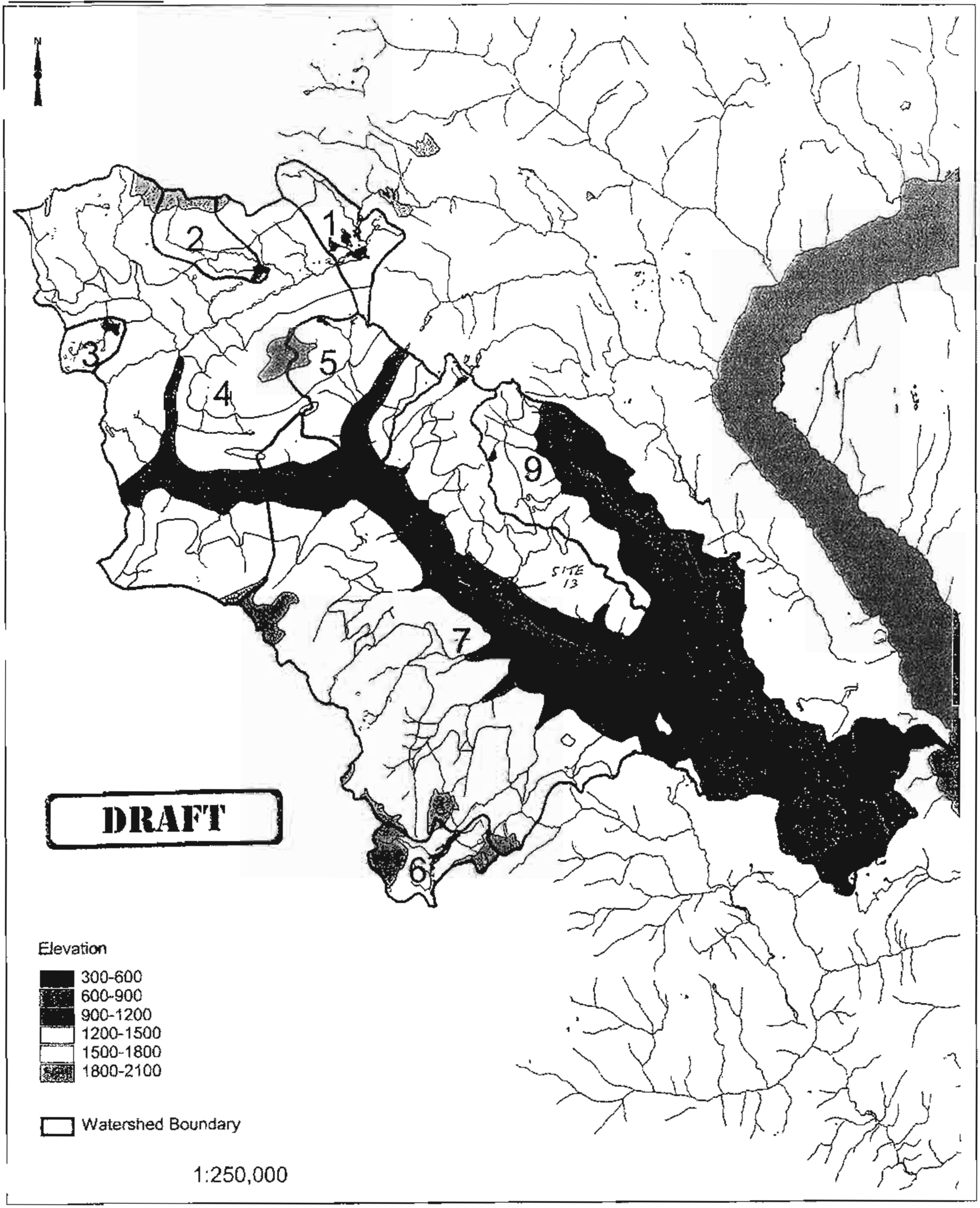
Figure 2.1 - Trout Creek Watershed



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FIGURES

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Figure 2.2 Camp Creek Measured and Calculated Monthly Flows

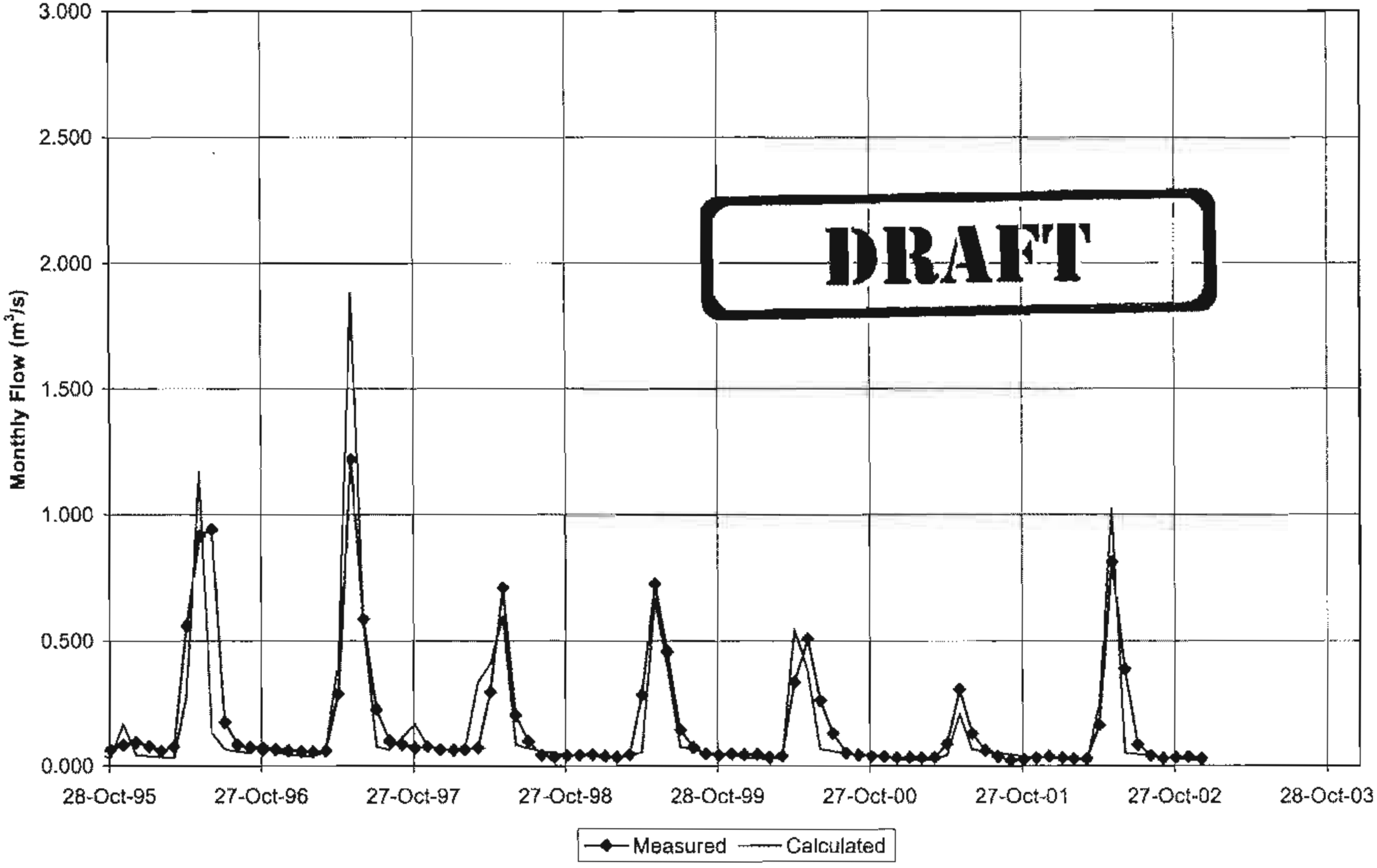

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Figure 3.1: Summerland water consumption
Annual water use

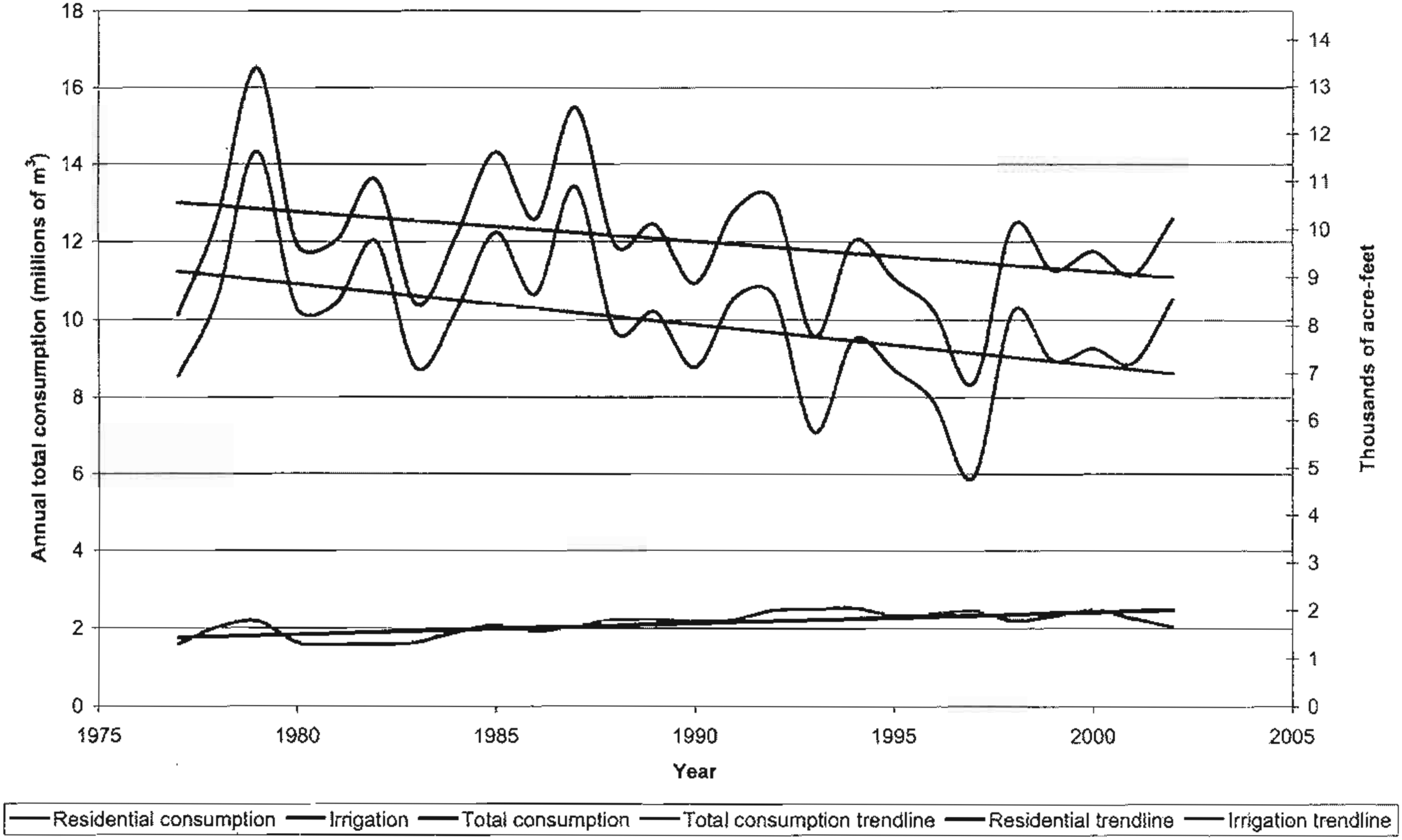

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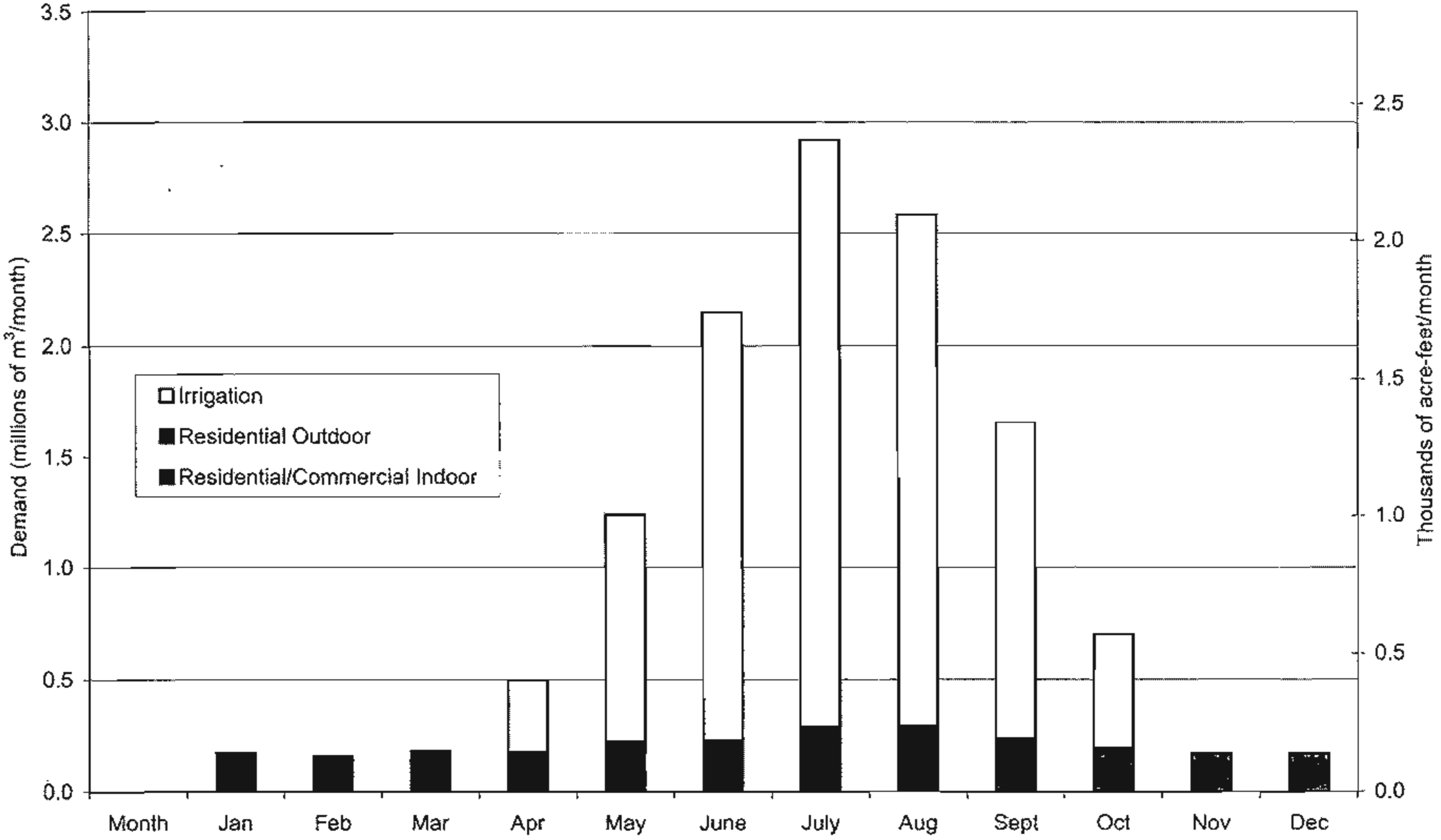
Figure 3.2: 2002 Disaggregated Water Demand



Demand Summary.xls - Figure 3.2

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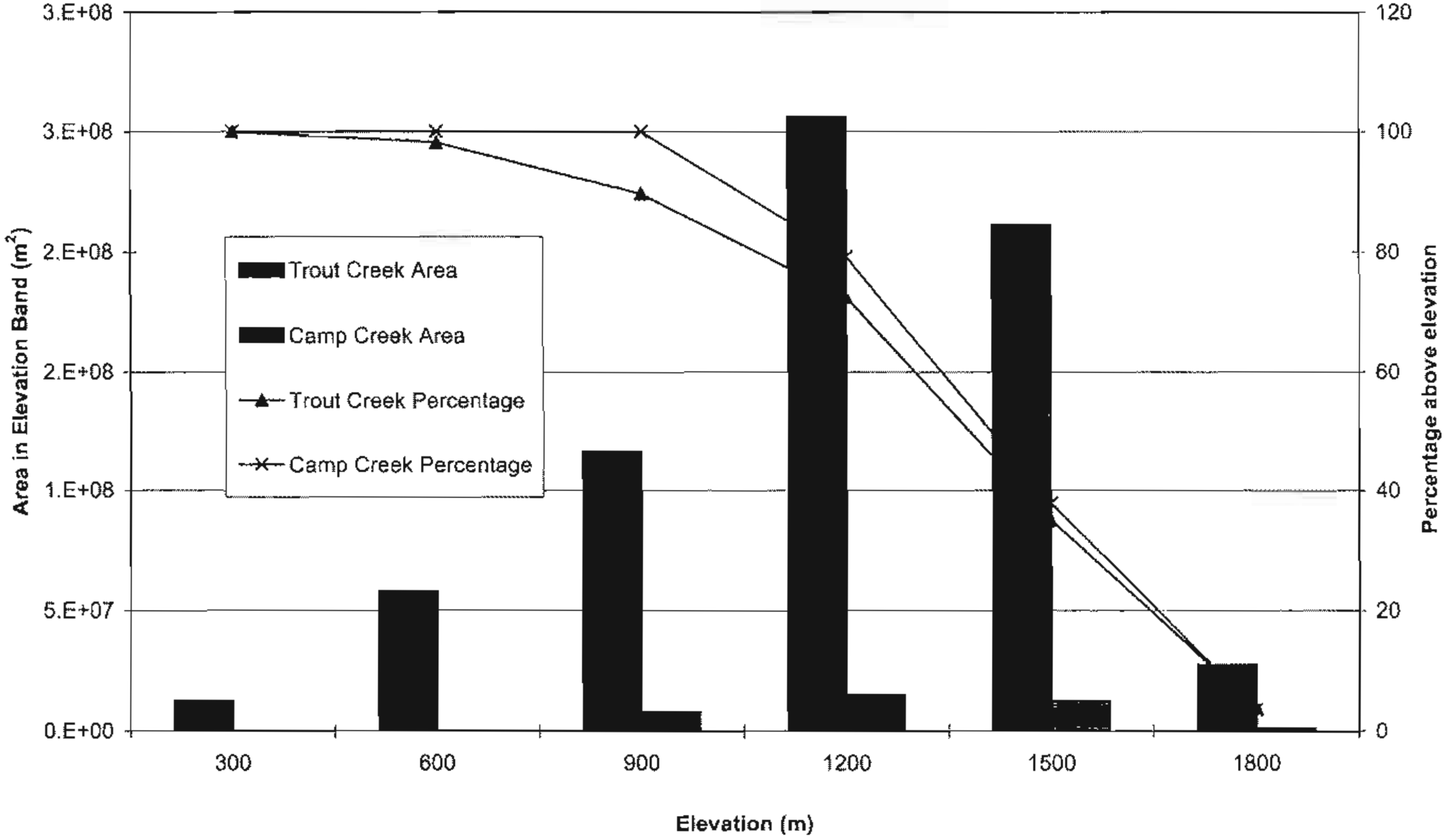
Figure 4.1: Comparison of Area Elevations for Camp and Trout Creek (without Darke Creek)



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Trout Creek Water Balance.xls - Area Elevation

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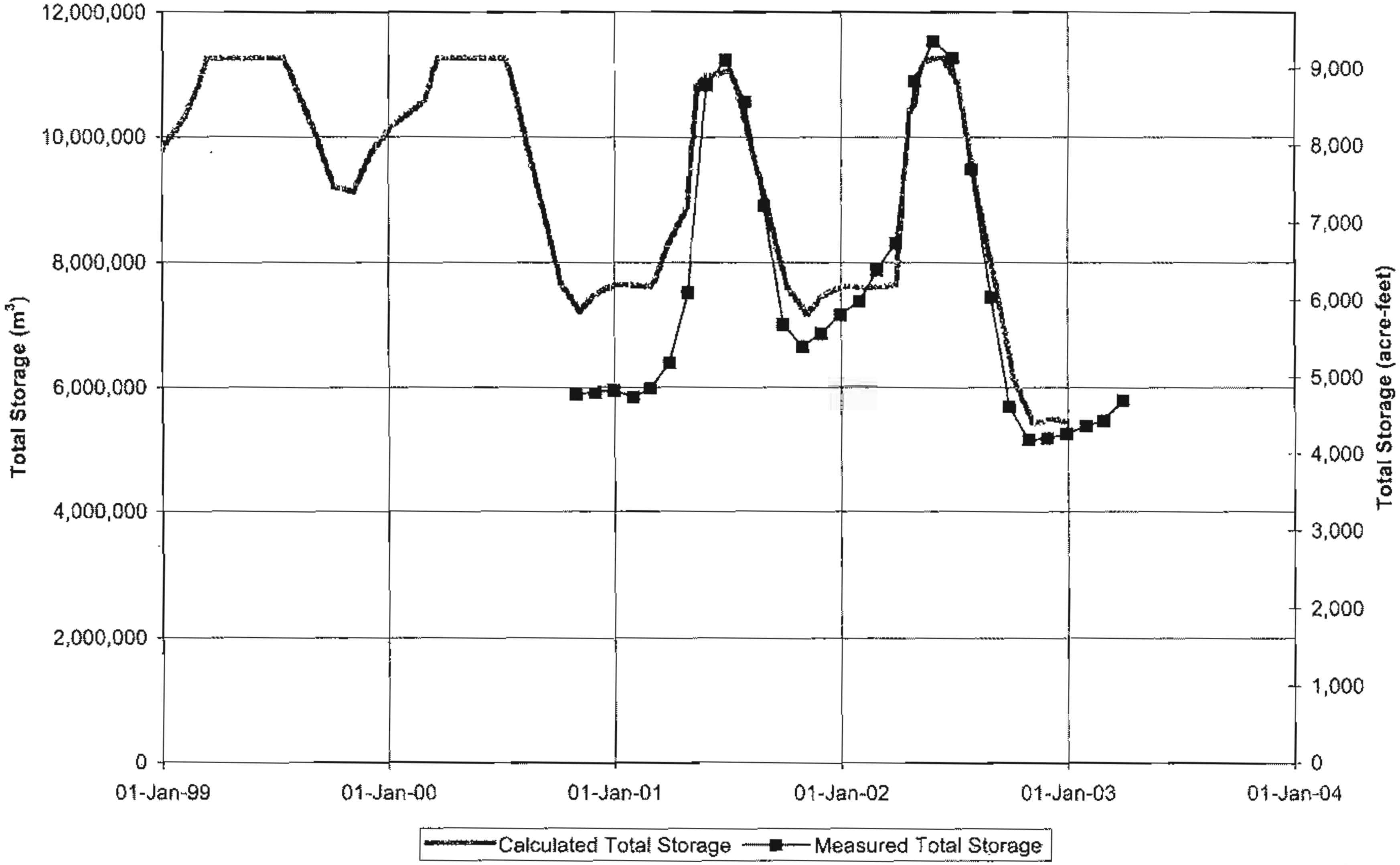
Figure 4.2: Measured and Calculated Total Volume of Water in Storage



Water Balance Check Stage 1.xls -Chart1

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Figure 5.1: Monthly distribution of flows and demands in a drought year

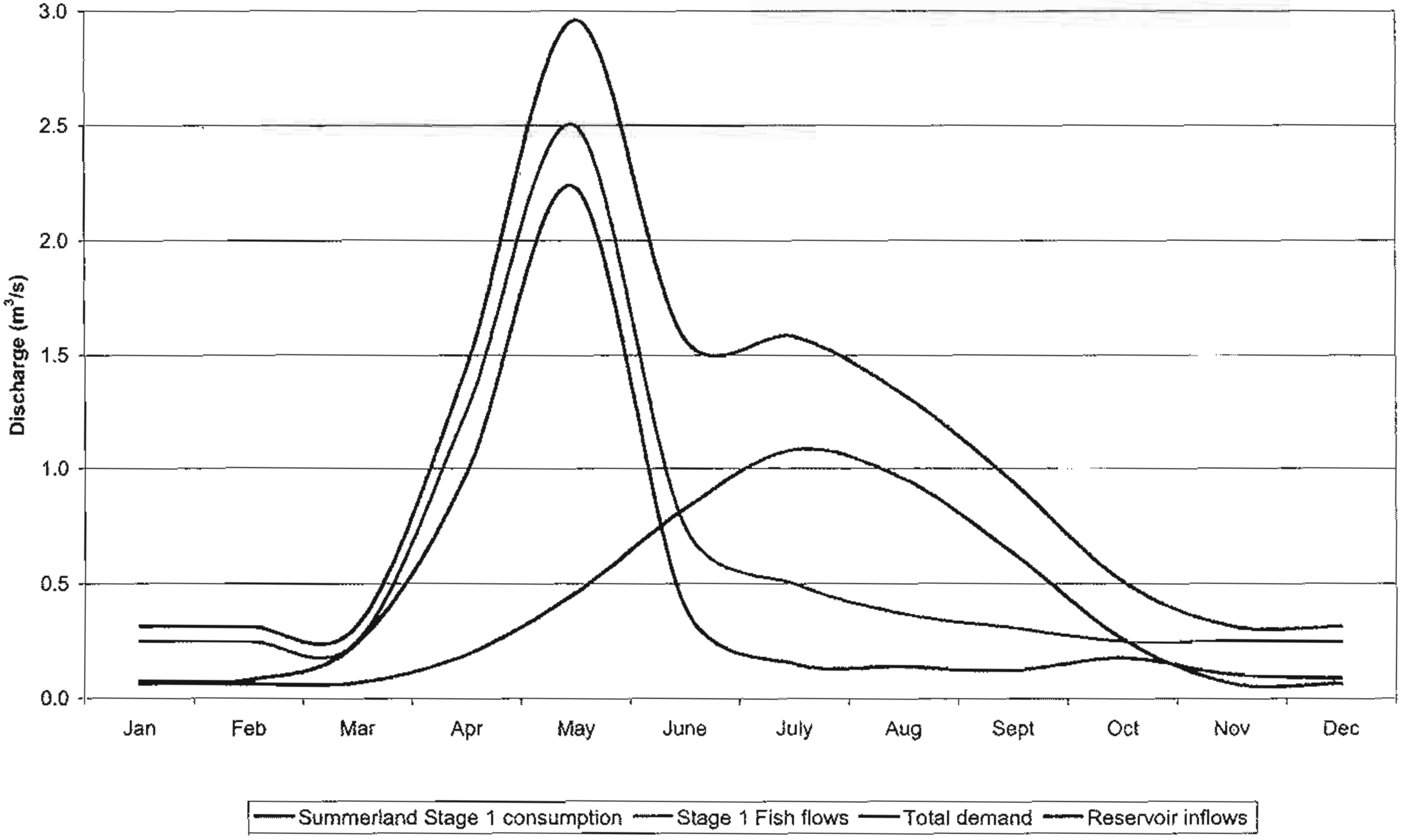

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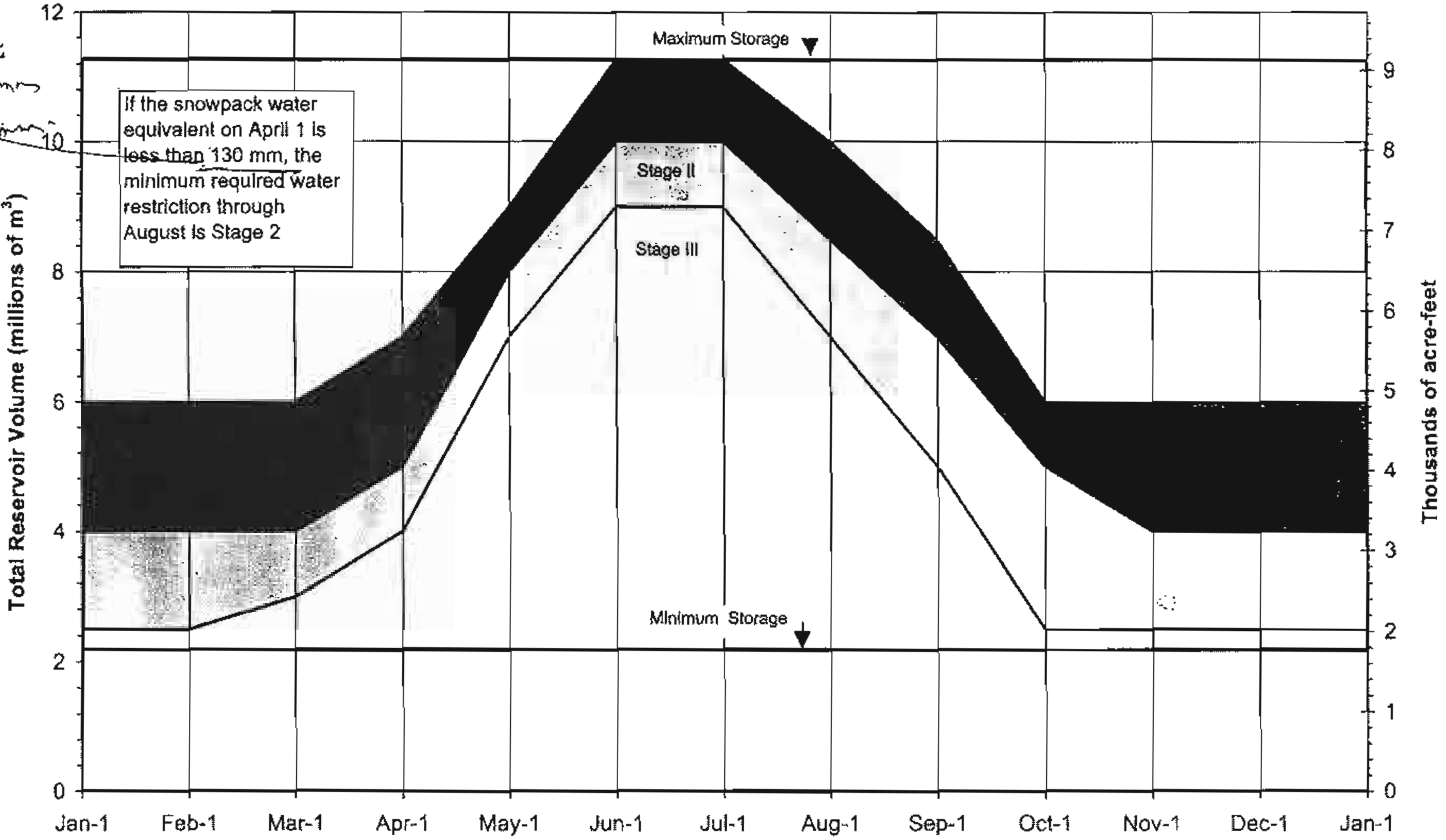
Figure 5.2: Reservoir Operating Policy

ARR 1 AVG
2F02 - 222mm
2F11 - 178mm



If the snowpack water equivalent on April 1 is less than 130 mm, the minimum required water restriction through August is Stage 2

Operation Policy.xls - Operation Policy Chart