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Refilling at Colliford Lake

Report to South West Water plc

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1. Colliford Lake

1.1 INTRODUCTION

There is perceived to be a problem with the length of time it takes Colliford Lake to refill, and the aim of this study is to identify possible causes. The levels for Colliford Lake have been consistently lower than those for the other reservoirs in the area. For example the percentage live capacity for three other reservoirs in the South West region are compared over the 12-month period ending in October 1998. The mean monthly live capacity for Colliford Lake is between 18 and 26 % below the other three reservoirs (Stithians, Roadford and Wimbleball). From computer simulations, using the operational model that incorporates the Colliford Lake system, COSMO, it has been identified by South West Water that there were potential losses from Colliford Lake of approximately 3000 Ml over the course of a year.

The Scoping Study considers the following possibilities:

- Leakage from Colliford Lake. The hydrology of the river to the west of the Dam - the Dewey tributary and the groundwater system underlying Colliford Lake are investigated. A chemical analysis of the water in and around the Lake is made also.

- Unusual climatic conditions since the impounding of Colliford Lake. The changes to evaporation will be assessed.

- The simulation model COSMO, developed as an operational management tool for the local water resources system. This model will be reviewed with reference to the inflows into the Colliford Lake component and the assumption that rainfall is equal to evaporation over the surface of the Lake.

This work has been carried out by the Institute of Hydrology and the British Geological Survey, and the authors gratefully acknowledge the co-operation of South West Water.

1.2 BACKGROUND

Colliford Lake is sited on Bodmin Moor, and was developed in order to supply water to the western, northern and southern areas of Cornwall (Battersby et al, 1985). The reservoir has a capacity of 29100 Ml. Impounding began in 1983 and it was brought on line during the drought of 1984. Colliford Lake was designed to meet the water demand of Cornwall into the next century and augments the River Fowey, for abstraction at Restormel (Figure 1). There are also releases to the De Lank and St Cleer treatment works.

The Colliford Lake catchment has an area of 12.4 km^2 and is open peaty moorland, mainly used for grazing. The lake forms around 35% of the catchment area.

Most of the investigation work characterising the geological system was concentrated on the area beneath the Dam itself (Knill, 1977). The hydrological study of the proposed lake focused attention on the flows in the River Fowey downstream of the lake at the abstraction point and made no reference to the hydrology of the catchment upstream of the lake itself (South West Water, 1975).

The Colliford Dam is a sand embankment dam with an impermeable asphalt membrane (Johnston & Evans, 1985). The foundation of the dam is built on an area of fissured granite typical of the geology of the area. Colliford Lake sits in a small catchment and is fed by 8 or so small streams. To the east of Colliford Lake there is Park Pit, a disused china-clay pit previously operated by English China Clays Plc. To the west of the dam there is the Dewey River which is a tributary of the River Warleggan, and this in turn joins the Fowey upstream of the abstraction site at Restormel.

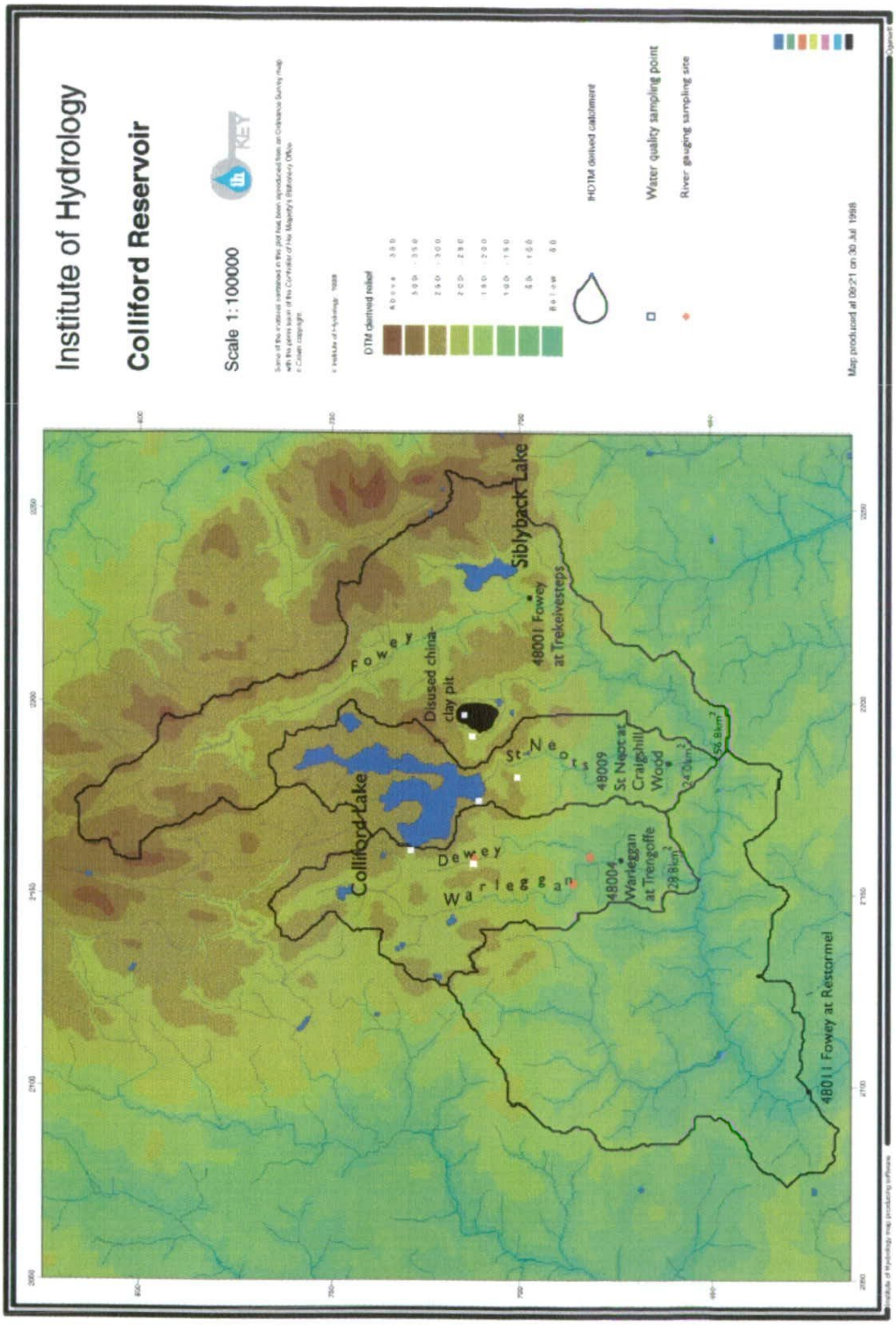

Figure 1 *Colliford Lake and the surrounding catchments to the abstraction point on the Fowey at Restormel*

The Colliford system was enhanced in January 1998 when a pump-storage scheme was completed, providing a link between Restormel and Colliford Lake.

Colliford Lake has been operational during a period of extreme hydrological conditions. The reservoir began to fill and came on line in 1984 during a drought that affected large parts of the country. There has since been an extended period of drought between 1988-92 and again during 1995/6.

In a visit to the lake a tour was taken of the dam and the surrounding area and notes were made concerning the hydrology and hydrogeology of the area. Park Pit, the disused china clay pit to the west of Colliford Lake appeared to be filling with water. There are several springs feeding down into the pit from the direction of the topographical divide between Colliford Lake and Park Pit. There is a cut-off drainage ditch flanking the pit towards this catchment divide, to help reduce the amount of surface water flow to the workings. However, although it was initially thought that the water filling the clay pit may be leakage water from the reservoir, English China Clays, who own the site, reported (pers. comm. ECC, 06/1998) that the impounding of Colliford lake made no impact on the amount of water entering the site.

Observations around the dam suggest that there is groundwater flowing from the east towards Colliford Lake as the granite appeared wet. Inside the embankment, the drainage pipes towards the left bank of the dam (ie towards the west) were flowing and towards the right bank of the dam water was draining out of the pipes but of smaller volume.

The River Dewey to the west of Colliford Lake, was investigated. The soils were wetter on the side closest to the dam than the other side of the catchment. This would suggest that the side closest to the dam may be receiving an import of water from outside the catchment. The area to the west of Simonstone Dam on the western flank of the lake also seemed very wet compared with the rest of the area.

During the first years of operation (1984-1998) the site has been extensively monitored. Records start in 1983 when Colliford Lake was completed. Most of the data are still in manuscript form (see Appendix). The data monitoring programme has been recently revised following a review.

1.3 AIMS OF THE SCOPING STUDY

The aim of the Scoping Study was to identify the reasons why the lake is taking longer than expected to fill.

To assess the incidence of leakage from Colliford Lake the following work was undertaken.

- River flow gauging of the Dewey tributary was undertaken at two sites and this was compared with the flow on the same day as gauged on the neighbouring Warleggan catchment.

- The groundwater system underlying the Lake was re-appraised and the initial geological study was been revisited.

- Six water quality samples were collected to determine if there were any chemical signatures that could link the water in the lake with the water draining towards the China Clay pit, the water draining inside the dam and the water in the Dewey tributary and in the wet area to the left of Simonstone Dam.

Climatic variation

- An initial assessment of the evaporation of the Colliford Lake area is made.

The Colliford Simulation Model COSMO

- The simulation model COSMO was used by South West Water to quantify the losses from the Colliford Lake system. The model was used to investigate the relationship between inflows into the Lake and the difference between observed and simulated outputs for 1995. There is also an assumption in the model that rainfall is equal to evaporation over the surface of Colliford Lake and this was also investigated using MORECS and an assessment of rainfall from neighbouring catchments.

2. Investigation into the losses at Colliford Lake

2.1. RIVER GAUGING

Three sites were gauged; two on the Dewey tributary and one on the Warleggan. The aim of gauging these two tributaries was to investigate whether flow was being increased by seepage from Colliford Lake. The Institute of Hydrology Digital Terrain Model predicted that the two rivers should produce approximately the same runoff, for sites upstream of the confluence of the two rivers.

The area towards Park Pit was not studied here as ECC, the owners of the site did not consider there to have been any impact to the amount of inflow into the pit after the impounding of the lake (Pers comm June, 1998).

There was precipitation on the morning of the sampling, but was frontal in nature, and should not have differentially affected the amount of runoff over the two catchments.

The grid references are featured in Table 3 together with results from the Institute of Hydrology's Digital Terrain Model. The rivers were gauged using an electromagnetic current meter and the sections were sampled at regular intervals. The corresponding estimates of flow using the mid-sample estimation method are also presented in the Table 3. A full breakdown of the results are shown in. Appendix 5.1.

***Table 3** The results of the sample river gauging on the Dewey and Warleggan catchments.*

River	East. (m)	North. (m)	Approx. Catch. area (km^2)	width of section (m)	number of sections	mean flow m^3s^{-1}	IHDTM annual runoff (mm)	IHDTM rainfall (mm)	est. mean annual runoff (mm)	IHDTM catchment PE (mm)
Dewey	215900	071100	2	1.5	3	0.054	998	1509	851.5	511
Dewey	215850	068350	6.2	3	11	0.153	930	1445	778.2	515
Warleggan	214700	068900	14.9	6.5	12	0.3	967	1479	634.9	512

The River Warleggan is a relatively undisturbed catchment and the mean annual runoff upstream of the confluence of the Warleggan and Dewey, estimated by the IHDTM is 1031 mm (grid reference 214950 068800). From actual data from the National River Flow Archive for the gauging station 048004 at grid reference 215900 067400, the value is very similar at 1021 mm. For the Dewey which is ungauged, the IHDTM estimated mean annual runoff is1030 mm (grid reference 216350 069150).

From Table 3 it can be seen that although dealing with very small differences in flow, the sampling site on the Dewey at 6.2 km^2 had 23% more water in runoff terms than in the Warleggan and further upstream the Dewey had 34% more runoff. This could potentially amount to as much as 1725 Ml in a year. But this assumes that this percentage figure remains constant throughout the year and this is unlikely to be the case. There may be variation in the amount of seepage water as a result of water level changes in the lake and corresponding changes to hydraulic gradient.

2.2 THE GROUNDWATER SYSTEM AROUND COLLIFORD LAKE

Bedrock comprises the Bodmin Granite: a coarse-grained biotite granite. Locally, for example in the vicinity of the Park clay pit, the granite is altered with the conversion of feldspars to clay and secondary mica, a process known as kaolinisation. The Park pit is situated over intense alteration at a point where two deep seated fracture systems intersect (Selwood et al, 1998). The unaltered granite contains a subhorizontal joint set and two sub-vertical sets which trend north-west and east-south-east. By analogy to similar granites elsewhere, typical values for hydraulic conductivity of such material near surface could lie in the range up to 1 m d^{-1}, with porosity < 0.02 and storativity <0.01. Groundwater flow and storage is essentially limited to fracture flow. Hydraulic conductivity of the kaolinised granite is likely to be considerable less than the jointed granite, probably <0.1 m d^{-1}. Site investigation records for the dam site indicate hydraulic conductivity values for the granite in the range 10^{-1} to 10^{-3} and exceptionally 10^{-4} m d^{-1}.

The Colliford site is high on Bodmin Moor and, therefore, represents an area of potential groundwater recharge rather than groundwater discharge. Flooding of the site increases the recharge head on the groundwater system and allows for an increased element of groundwater recharge (ie loss from the reservoir to the ground). This may result in enhanced spring discharges in adjacent valleys and in lower lying land, and the promotion of some new spring sources.

There are two narrow containing headlands to the reservoir: one at Simonstone Causeway and the other above the Park Pit. English China Clay report no significant increase in groundwater discharge to their site during and after reservoir filling. However, it is likely that some influence has occurred as the ground above the pit site is extremely wet with numerous small discharges to surface. At Simonstone, there is a distinct marshy area behind the causeway and reports of increased spring discharges in fields lower down. Anecdotal evidence does suggest increased outflow to some fields since the reservoir was commissioned, and notably coinciding with otherwise very dry years in the late 1980s (see Appendix).

Knill (1977) makes an estimate of likely throughflow across these headlands. He assumes that the simple Darcy model for intergranular flow through a porous medium will represent the fissure flow in the granite. He takes a total length of seepage of 3.5 km representing the two main narrow ridge areas. Critically he takes the hydraulic conductivity to be 10^{-1} m d^{-1} and the prevailing hydraulic gradient to be 0.05. This provides a likely loss of 4 500 m^3 d^{-1}. Given the approximations inherent in using the Darcy model, and the unknowns in the data it is preferable to calculate the loss as a range. Given an error in the hydraulic conductivity value of plus/minus one order of magnitude the likely loss lies in the range 450 to 45 000 m^3 d^{-1} (ie 0.2 to 16 Ml $year^{-1}$).

In addition there may be an element of loss from the reservoir floor to deeper seated groundwater flow. This cannot readily be quantified but is another potential loss route.

Knill (1977) goes to great lengths to demonstrate that a groundwater mound will prevent throughflow of groundwater. However, groundwater can flow beneath the mound at any stage provided that a suitable head difference exists. Here also is a further route for reservoir loss.

2.3 WATER QUALITY SAMPLING

Six water samples were collected for chemical analysis. They include raw reservoir water, Park Pit water, spring discharges below Simonstone Causeway and above Park Pit, local stream water and discharge water from the drainage pipes within Colliford Dam. The sample sites can be seen on Figure 1.

Measurements of temperature, pH, specific electrical conductance and bicarbonate concentration were taken in the field. Samples were then returned for further analysis in the Wallingford laboratory. These samples were filtered through 0.45 membrane filters, and one aliquot acidified with ultra-pure concentrated nitric acid to a concentration of 1% v/v. Acidified aliquots will be analysed for main cations and selected trace elements by inductively coupled plasma atomic emission spectrometry, and unacidified aliquots for chloride and nitrate by automated colourimetry.

The analytical results did not show evidence of leakage pathways and the results are tabulated and described in Annex 1.

2.4. AN INITIAL ASSESSMENT OF EVAPORATION

As part of the Scoping Study an assessment of the evaporation from the open water surface of Colliford Lake was made, using both the Meteorological Office Rainfall and Evaporation Calculation System (MORECS), and measurements of open pan evaporation from the Roseware Tank at Cambourne. It was found that the two did not correlate particularly well. A conservative estimate of potential evaporation showed that pre-1988 actual evaporation was estimated to be 6.96 MLD and post 1988 as 7.65 MLD. This amounts to an increase in losses through evaporation of almost 0.7 MLD over the surface of the lake. In assessing the water balance of the system, COSMO would need to take into account this increase in potential evaporation.

2.5. COLLIFORD LAKE SIMULATION MODEL - COSMO

South West Water prepared an in-house operational model of the Colliford Lake system (COSMO) which fed into a larger operational model of water resources strategic planning. This was set up with input files and accounts for the detailed abstraction licences within the system and is used routinely to forecast supply using different demand scenarios into the next century.

The model for Colliford Lake had been run, by South West Water, for 1995 and the corresponding modelled output was compared to the observed. The modelled output was greater than the observed. For the simulated and observed output to match well, the model was 'optimised' using an increased regulation loss of 30% for the entire year. The actual volume of the regulation releases from Colliford Lake for 1995 is 10013.41Ml, hence the volume of the additional loss is 3004.02Ml (or $3E^{+06}$ m^3). This figure is subject to annual variation.

In the manual for COSMO the methodology for the water balance component of the Colliford Lake model was reviewed. The input into the Lake was estimated using modelled inflows, generated synthetically using the Institute of Hydrology's HYRROM rainfall and runoff model. Data from river flow gauging stations on the Fowey at Restormel, Trekeivesteps, and St Neot at Craigshill Wood were also used in the derivation of Colliford Lake inflows. The inflows to the lake were synthesized over the period from 1931 to 1998. It was assumed by the model developers that these early flows had a large error associated with them.

As part of the Scoping Study the hydrology above Colliford Lake was studied. The OS 1:25 000 map series shows eight small tributaries that feed into Colliford Lake. The Institute of Hydrology Digital Terrain Model (IHDTM) (Morris & Flavin, 1990) was used via the program 'GRIDLOOK' and 'TSTCD' to estimate the mean flow into the Lake. Three of them the IHDTM did not recognise but the ones that were found gave mean flows listed in Table 2.

Table 2 Grid references and mean flows derived from the IHDTM for tributaries into Colliford Lake.

Grid Reference	Catchment area (km^2)	Mean Flow (m^3s^{-1})
218450 073700	2.3	0.084
218800 073750	0.9	0.034
217450 073650	0.4	0.013
217200 073550	0.4	0.014
218700 075750	0.2	0.007
Total	4.2	0.152

The points that were picked up by the IHDTM would, when taken together, represent an average daily mean inflow of $0.152m^3s^{-1}$. The current mean daily inflow used in COSMO over the 1961-90 period for Colliford Lake is 0.480 m^3s^{-1}. The difference between these two values amounts to 10344 Ml/year. It is possible that the inflows used in the COSMO model are overestimates.

As part of the Scoping Study, the amount of loss from the Colliford Lake system has been estimated using COSMO. However, if the inflows are overestimated in COSMO, as the results from the Digital Terrain Model would suggest, then the losses from the system may not be as large as first thought.

To test this hypothesis COSMO was re-run for 1995, in July 1998, with inflow files that had been reduced by certain arbitrary magnitudes (see Table 3). The regulation losses were then changed; the plots for each of the runs identified below can be found in the Appendix. They are presented together with the original Colliford inflows, which when run, identified the losses at 30%. There were also two additional runs for the inflows reduced by 20% with losses at 15% and 25%.

***Table 3** Showing the model runs used in the investigation of COSMO.*

Run number	Inflows	Regulation losses
1	reduced by 50%	30%
2	reduced by 50%	20%
3	reduced by 50%	10%
4	reduced by 20%	30%
5	reduced by 20%	20%
6	reduced by 20%	10%
7	reduced by 10%	30%
8	reduced by 10%	20%
9	reduced by 10%	10%

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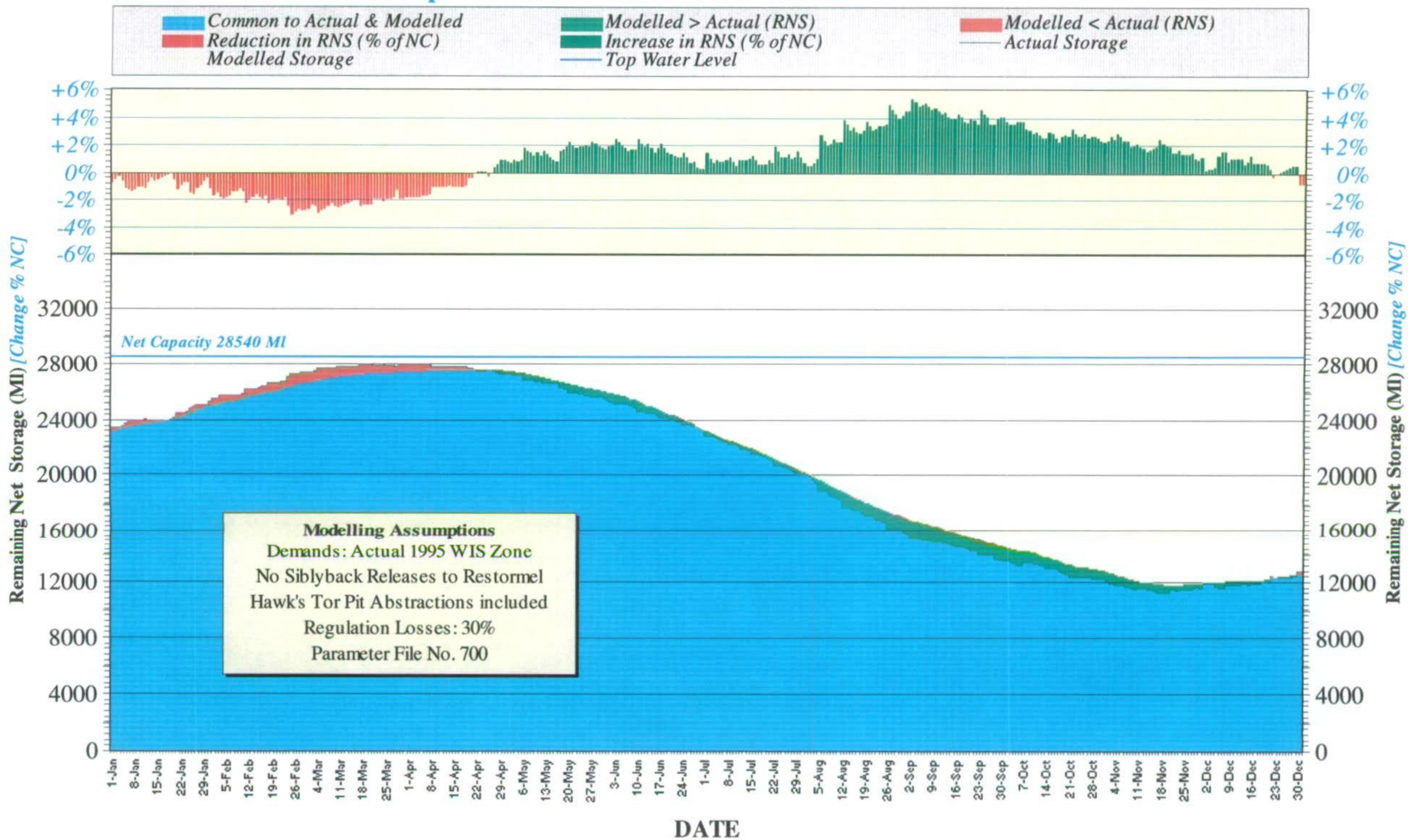
Figure 2(a) COLLIFORD LAKE

Comparison of Actual and Modelled Drawdown in 1995



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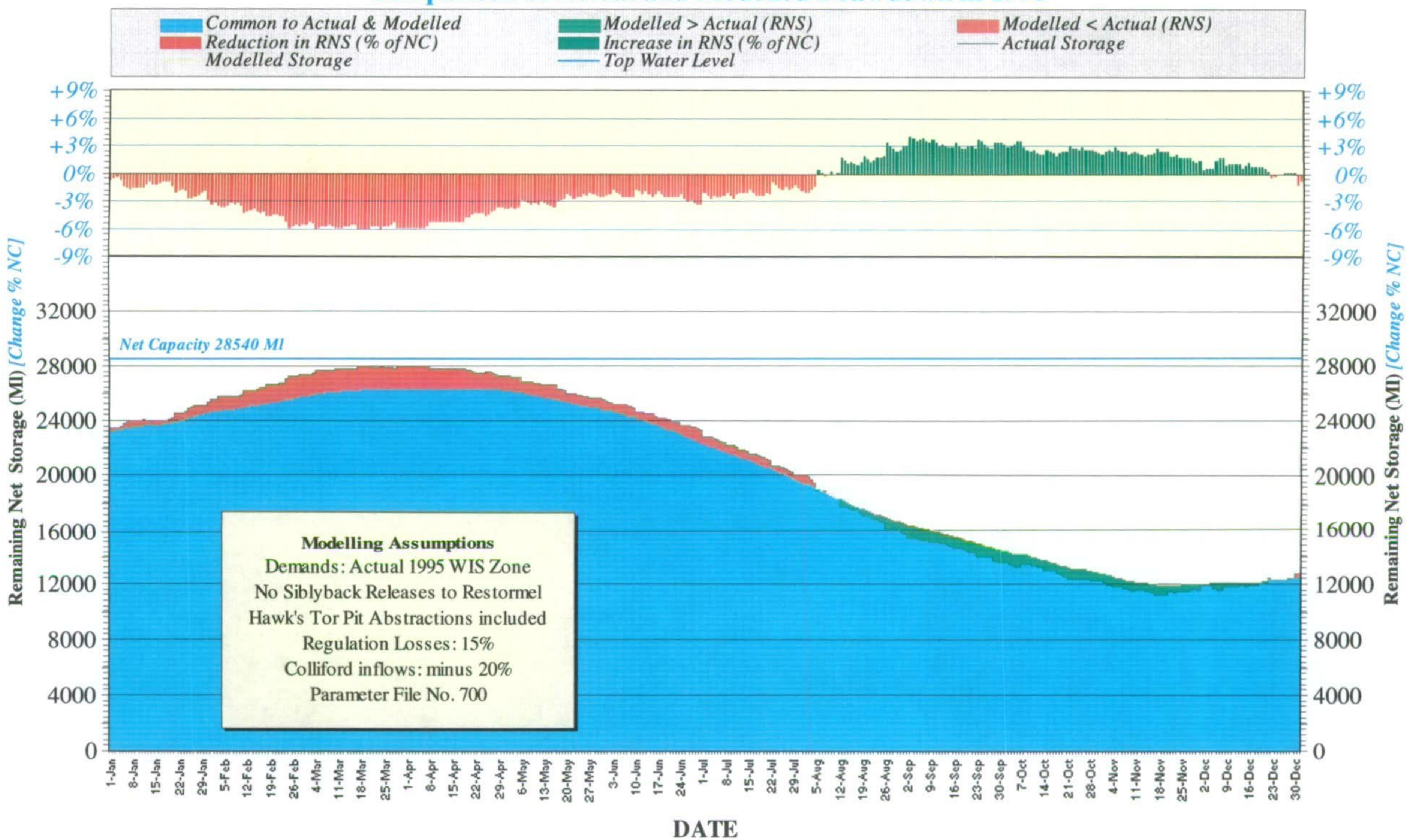
SOUTH WEST WATER

Figure 2(b) COLLIFORD LAKE

Comparison of Actual and Modelled Drawdown in 1995



The aim of this comparison is to highlight the potential problems associated with using COSMO to quantify the 'losses' from the system. It can be seen from Figure 2(a), with the original inflows and regulation losses at 30%, the fit between modelled and observed net storage is good. The comparison plot shown above in Figure 2(b) shows a similar degree of fit between modelled and observed but the inflows have been reduced by 20% and the regulation losses reduced to 15%. If the inflows have been overestimated in the modelling procedure then the losses from the system may be less than first anticipated.

For the most extreme example of the modelled runs performed on the 1995 data in July 1998, the inflows were reduced by 50 % and the regulation losses were modelled at 30 %. The modelled output was consistently below the observed output throughout the year with the difference between modelled and observed reaching as much as 16 % during December.

In the catchment balance of the Colliford Lake system as modelled in COSMO, there is an assumption in the model that rainfall is equivalent to open water evaporation on the lake over the year.

The potential evaporation for the 1961-90 period over the lake (estimated by MORECS) amounts to around 615 mm and the rainfall into the catchment, averaged for the gauging stations in the area, amounts to 1560 mm. The difference between these two values, if one assumes the surface area of the lake to be approximately 35 % of the catchment area (i.e. 4.3km2), is 4068Ml/year, over the surface of the lake. This is an additional input to the lake. A more detailed appraisal of the catchment water balance needs to be made in relation to COSMO, along with the potential for climatic variables to change over time.

3. Conclusions

Flow gauging results, summarised in Table 4, show that there may be leakage from the lake towards the Dewey catchment and that this may account for the time it takes for Colliford Lake to refill. The results of the river gauging show that there is a greater amount of water flowing down the Dewey than expected, and this was compared to the flow in the Warleggan. The flows in the Dewey and the Warleggan should have been similar but flows in the Dewey were around 30% greater.

A detailed conceptual groundwater model is required for the dam catchment and adjacent valleys. The hydraulic processes are described above and these need to be assembled into a schematic conceptual groundwater flow model. This can be developed further into a more comprehensive digital groundwater flow model in order to quantify ranges of groundwater flow to specific discharge areas. Model calibration will include use of surface water flow data.

Although the Scoping Study would suggest losses from the lake could be wholly detected by river flow gauging, this may not necessarily be the case; for example water could be entering into a deep fissure and entering deep percolation. The area to the east of the dam could be monitored using piezometers to see if there are any identifiable channels of leakage. This could also be combined with an assessment of the historical record of piezometer readings taken as part of the Colliford Lake monitoring scheme.

Loss to groundwater seepage export from the reservoir catchment may be as much as 16 Ml year^{-1}. A detailed model of the groundwater system will enable this value to be quantified further.

The initial assessment of evaporation of the Colliford Lake area showed that there has been an increase in potential evaporation over the period of operation of the reservoir (1984-1998). This study identifies the need for a detailed appraisal of the water balance of the Colliford Lake system in order to fully assess the losses.

The results of the investigation into the simulation model COSMO suggests that the initial estimate of 30% regulation losses, which amounted to around 3000 Ml losses in 1995 (Table 4), was an estimate that was dependent on the inflows into the lake. These inflows were studied and compared with the estimates of flow from the Institute of Hydrology's Digital Terrain Model and they were thought to be overestimated. However the assumption in the model that rainfall is equivalent to evaporation over the lake surface may also need to be taken into account when estimating the inflows. From Table 4, a re-assessment of the catchment balance may account for the losses from the lake. The performance of the model over several different years also needs to be assessed, not just for a specific year.

Table 4 *A summary of the results from the assessment of COSMO, river flow gauging and groundwater system of Colliford Lake.*

Variable	Loss/gain to system Ml/year
COSMO Estimated losses for 1995	3004
Excess flow in the River Dewey	1725
Estimated rainfall excess above evaporation over surface of Lake	4068
Difference in surface inflow to Lake	10344
Deep groundwater loss	16

4. Recommendations

4.1. THE APPRAISAL OF INPUT DATA FOR THE COLLIFORD SIMULATION MODEL

In light of the investigation into COSMO, it is recommended that appraisal of methodologies used in the modelling approach and the input data used for the model are assessed periodically. This is to ensure that the model is performing effectively and to take into account the possible changes to the input flows to the model that may occur over long time periods.

It is recommended that the small feeder streams flowing into the lake be subject to some gauging to verify whether the modelled inputs currently used in COSMO are repeatable and sensible. The following steps could be undertaken following a site visit to appraise the possible methods and sites for gauging. (potential options: install structures for routine monitoring over a few months to observe seasonal variation in flows and to compare with COSMO inputs; spot gauging over a 6 month period.). There would need to be subsequent analysis and interpretation of the results, see Table 5.

In COSMO an assumption is made that rainfall is equal to evaporation over the surface of the lake. To validate this assumption estimates of the rainfall and evaporation balance for the reservoir need to be made. To estimate the rainfall on the catchment and the open water surface, a raingauge could be sited on the Colliford catchment which would need to be visited every day - an alternative may be to install a tipping bucket raingauge with a recorder. For evaporation, an assessment of MORECS could be made. It may be possible to verify MORECS estimates of evaporation by installing an evaporation pan in the catchment. The analysis of subsequent data and an assessment of the validity of the assumption in the Colliford Lake Simulation Model will then be required (Table 5).

4.2. AN INVESTIGATION OF LOSSES TO GROUNDWATER FROM COLLIFORD LAKE

The investigation of losses to groundwater either directly through the floor of the lake or across the narrow confining ridges would depend on the collection of hydraulic data using purpose drilled piezometers. Data from some of the existing piezometers could be incorporated but new sites above the Park Pit and at Simonstone would be required. Three 15m deep boreholes at these two sites is proposed, and a further three strategically placed elsewhere with monitoring of water levels for at least 12 months. This would provide data to begin to quantify lake losses in conjunction with surface water flow gauging and lake volume change data. However, this exercise presupposes improvement in input data to the lake, as well as surface outflow data for adjacent valleys.

Investigation of the chemical environment of the dam fill could be carried out by means of an intensive water sampling programme, repeated for a range of different stages in the lake.

Table 5 Summary of recommendations and approximate costs

Task	Approximate time (day)	Approximate cost (£)
Appraise and analyse sites for gauging	2	1000
Analysis of flow data from gauging inflows to Colliford Lake	8	2400
Analysis of rainfall/ evaporation data	5	1500
Drilling and equipping of 6 boreholes		15000
Analysis and interpretation of borehole data		5000
Comprehensive chemical survey of dam fill		12000

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6. Appendix

6.1 DETAILS OF THE DERIVATION OF ESTIMATED FLOWS FOR THE RIVER GAUGING OF THE DEWEY AND WARLEGGAN

Section 1 River Dewey

Catchment area: $2km^2$
Width of section 1.5m.
Distance represents the distance from the left bank.

Distance	Depth	Probe Level	Reading 1	Reading 2	Reading 3	Mean
0.4m	0.31m	0.12m	0.171	0.179	0.177	0.176
0.75m	0.4m	0.16m	0.117	0.112	0.111	0.113
1.15m	0.21m	0.08m	0.078	0.087	0.090	0.085

Flow in each section calculated from the mean section method.

$$Q = \mathrm{sum}\bar{v}a = \mathrm{sum}(i = 1,n)\frac{1}{2}(\bar{v}_{(i-1)} + \bar{v}_{(i)})X\frac{1}{2}(d_{(i-1)} + d_{(i)})X(b_{(i)} - b_{(i-1)})$$

where Q = discharge
a = cross sectional area
v = velocity
i = number of section
d = distance from bank
b = width of sub-section

sub-section 1	$\bar{v}a =$	$0.024m^3s^{-1}$
sub-section 2		$0.018m^3s^{-1}$
sub-section 3		$0.012m^3s^{-1}$

Discharge in Section 1 = $0.054m^3s^{-1}$

Section 2 River Dewey at Pantersbridge

Catchment area = 6km^2
width of section = 3m
Distance represents distance from right bank

Distance	depth	probe depth	Reading 1	Reading 2	Reading 3	Mean
0.4m	0.06m	-	-	-	-	-
0.6m	0.08m	-	-	-	-	-
0.8m	0.15m	0.06m	0.433	0.473	0.476	0.461
1.0m	0.18m	0.07m	0.511	0.542	0.560	0.538
1.2m	0.25m	0.10m	0.478	0.493	0.508	0.493
1.4m	0.27m	0.11m	0.408	0.424	0.401	0.411
1.6m	0.25m	0.10m	0.467	0.467	0.59	0.464
1.8m	0.22m	0.09m	0.352	0.359	0.341	0.351
2.0m	0.26m	0.104m	0.276	0.283	0.312	0.29
2.2m	0.18m	0.07m	0.261	0.274	0.27	0.268
2.4m	0.14m	0.056m	0.096	0.114	0.064	0.091
2.6m	0.14m	0.056m	0.016	0.026	0.014	0.019
2.8m	0.11m	-	-	-	-	-
3.0m	0.11m	-	-	-	-	-

sub-section 1	$\bar{v}a$ =	0.014	m^{3}s^{-1}
sub-section 2		0.016	m^{3}s^{-1}
sub-section 3		0.022	m^{3}s^{-1}
sub-section 4		0.024	m^{3}s^{-1}
sub-section 5		0.023	m^{3}s^{-1}
sub-section 6		0.019	m^{3}s^{-1}
sub-section 7		0.015	m^{3}s^{-1}
sub-section 8		0.012	m^{3}s^{-1}
sub-section 9		5.74E-03	m^{3}s^{-1}
sub-section 10		1.54E-03	m^{3}s^{-1}
sub-section 11		2.66E-04	m^{3}s^{-1}

Discharge for Section 2 0.153 m^{3}s^{-1}

Section 3 River Warleggan

Catchment area: 15km2
width of section: 6.5m
Distance represents distance from left bank

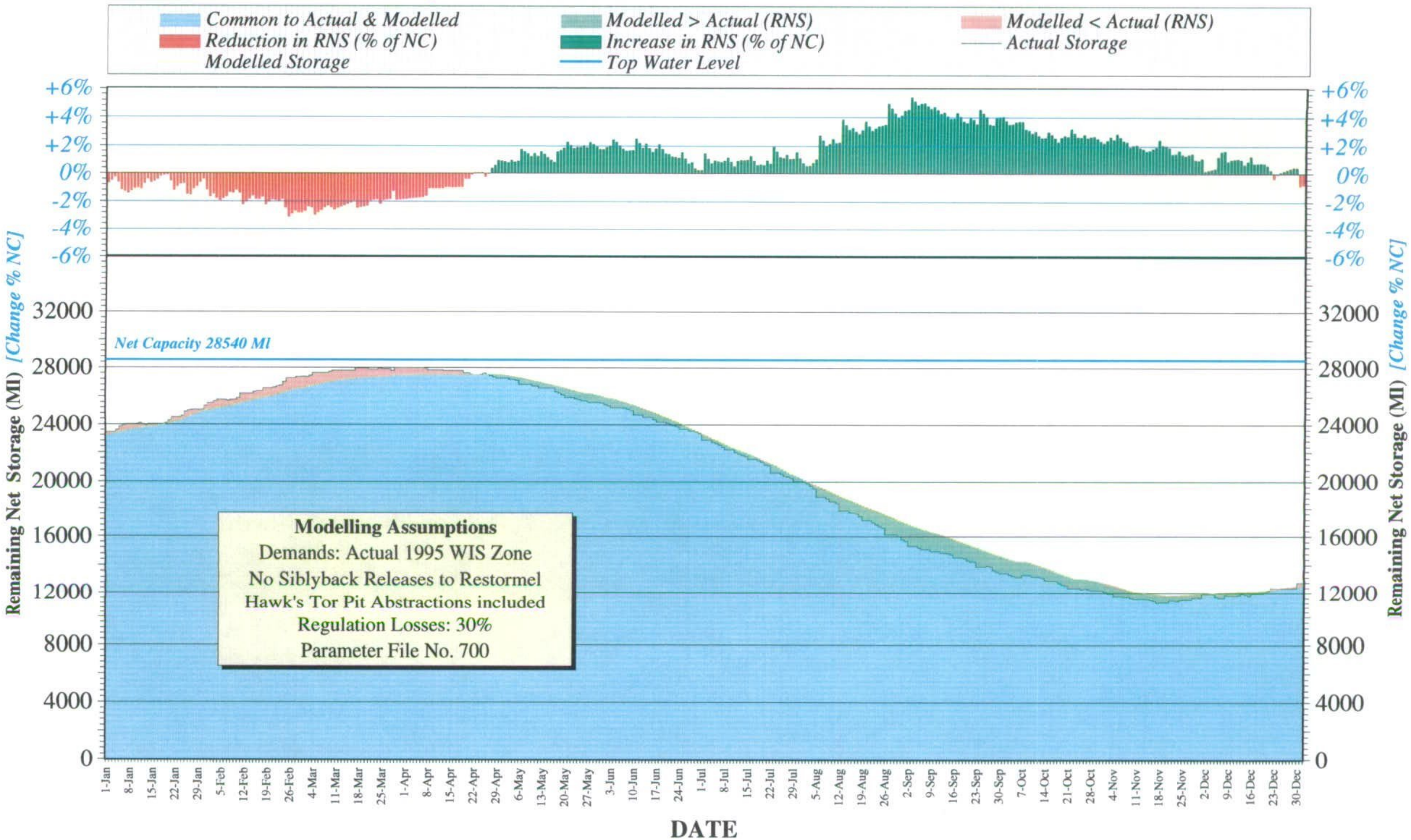
Distance	depth	probe depth	Readin 1	Reading 2	Reading 3	Mean
0.5m	0.14m	0.56m	.030	0.030	0.028	0.0293
1.0m	0.26m	0.105m	0.185	0.143	0.162	0.163
1.5m	0.34m	0.136m	0.330	0.342	0.341	0.338
2.0m	0.36m	0.144m	0.429	0.466	0.391	0.429
2.5m	0.35m	0.14m	0.199	0.178	0.197	0.191
3.0m	0.3m	0.124m	0.151	0.146	0.144	0.147
3.5m	0.22m	0.088m	0.081	0.083	0.036	0.067
4.0m	0.25m	0.10m	0.080	0.081	0.090	0.084
4.5m	0.15m	0.06m	0.030	0.045	0.053	0.043
5.0m	0.3m	0.124m	0.060	0.061	0.065	0.062
5.5m	0.12m	0.048m	0.090	0.113	0.102	0.102
6.0m	0.12m	0.048m	0.106	0.114	0.130	0.12

sub-section 1 $\bar{v}a =$ 5.13E-04 m^3s^{-1}
sub-section 2 9.62E-03 m^3s^{-1}
sub-section 3 0.0376 m^3s^{-1}
sub-section 4 0.0671 m^3s^{-1}
sub-section 5 0.0055 m^3s^{-1}
sub-section 6 0.0275 m^3s^{-1}
sub-section 7 0.0139 m^3s^{-1}
sub-section 8 8.87E-03 m^3s^{-1}
sub-section 9 6.35E-03 m^3s^{-1}
sub-section 10 5.91E-03 m^3s^{-1}
sub-section 11 8.61E-03 m^3s^{-1}
sub-section 12 0.06 m^3s^{-1}

Discharge for Section 3 **0.3 m^3s^{-1}**

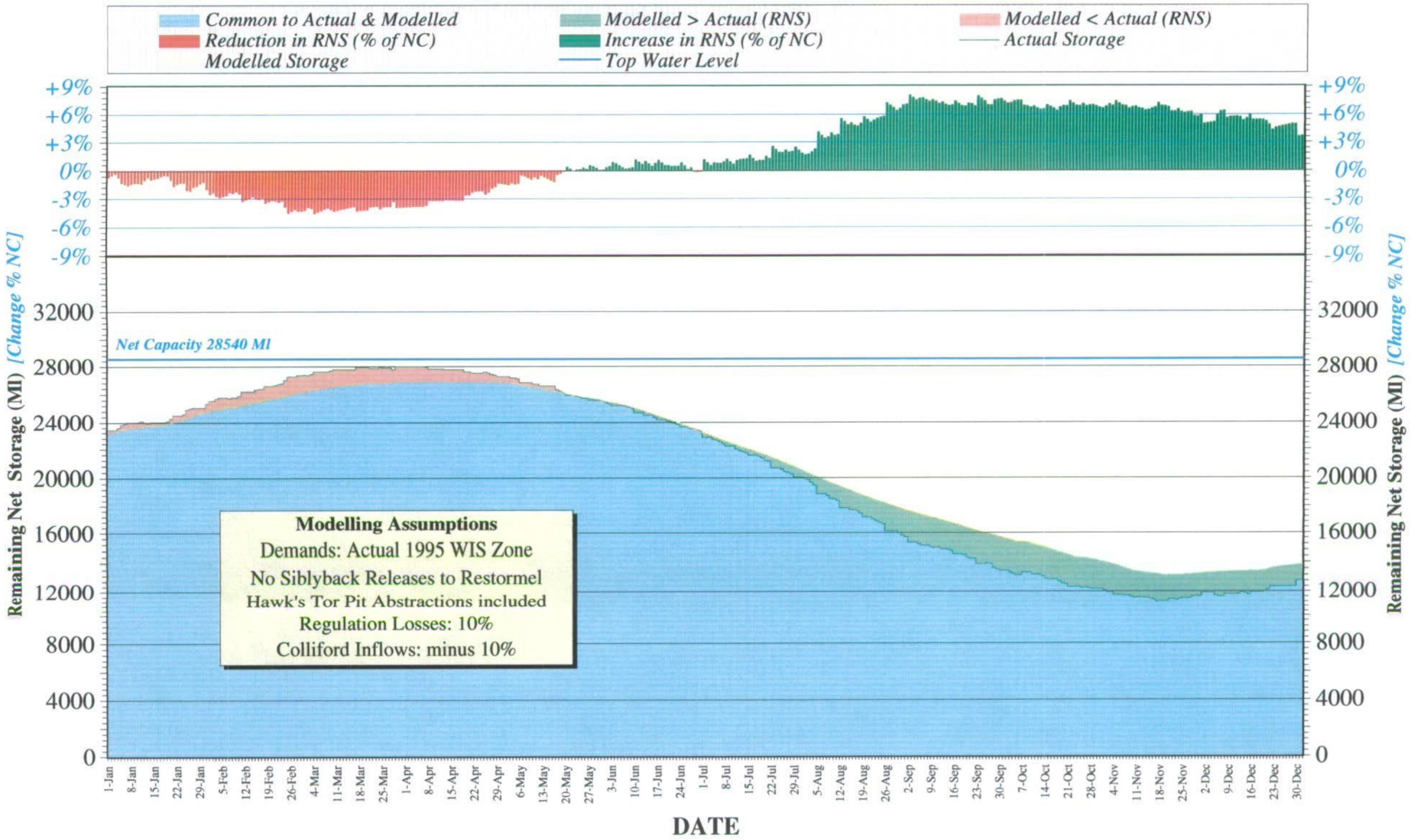
COLLIFORD LAKE

Comparison of Actual and Modelled Drawdown in 1995



COLLIFORD LAKE

Comparison of Actual and Modelled Drawdown in 1995



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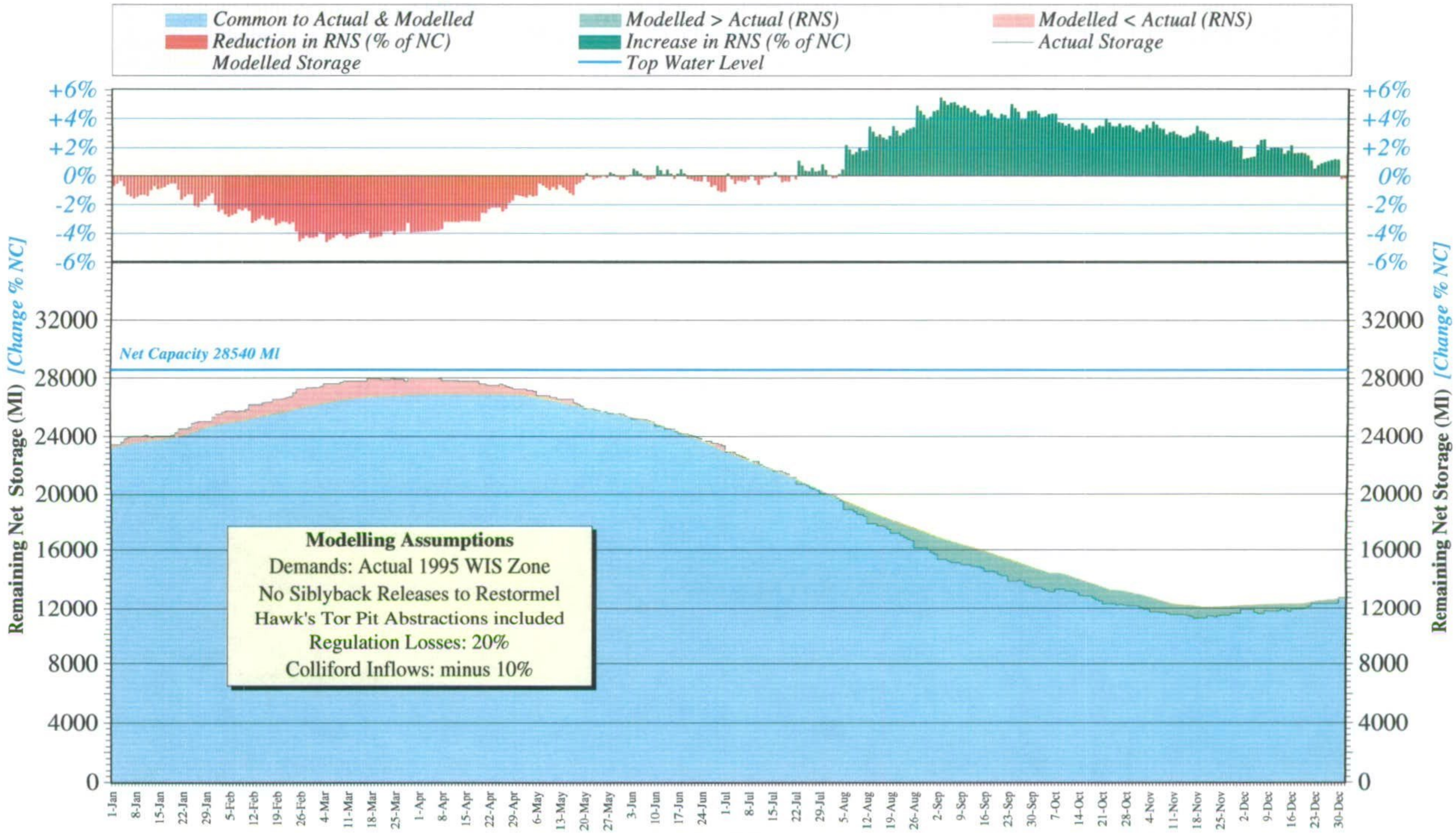
Regulatory and Finance
Directorate

COLLIFORD LAKE

Comparison of Actual and Modelled Drawdown in 1995



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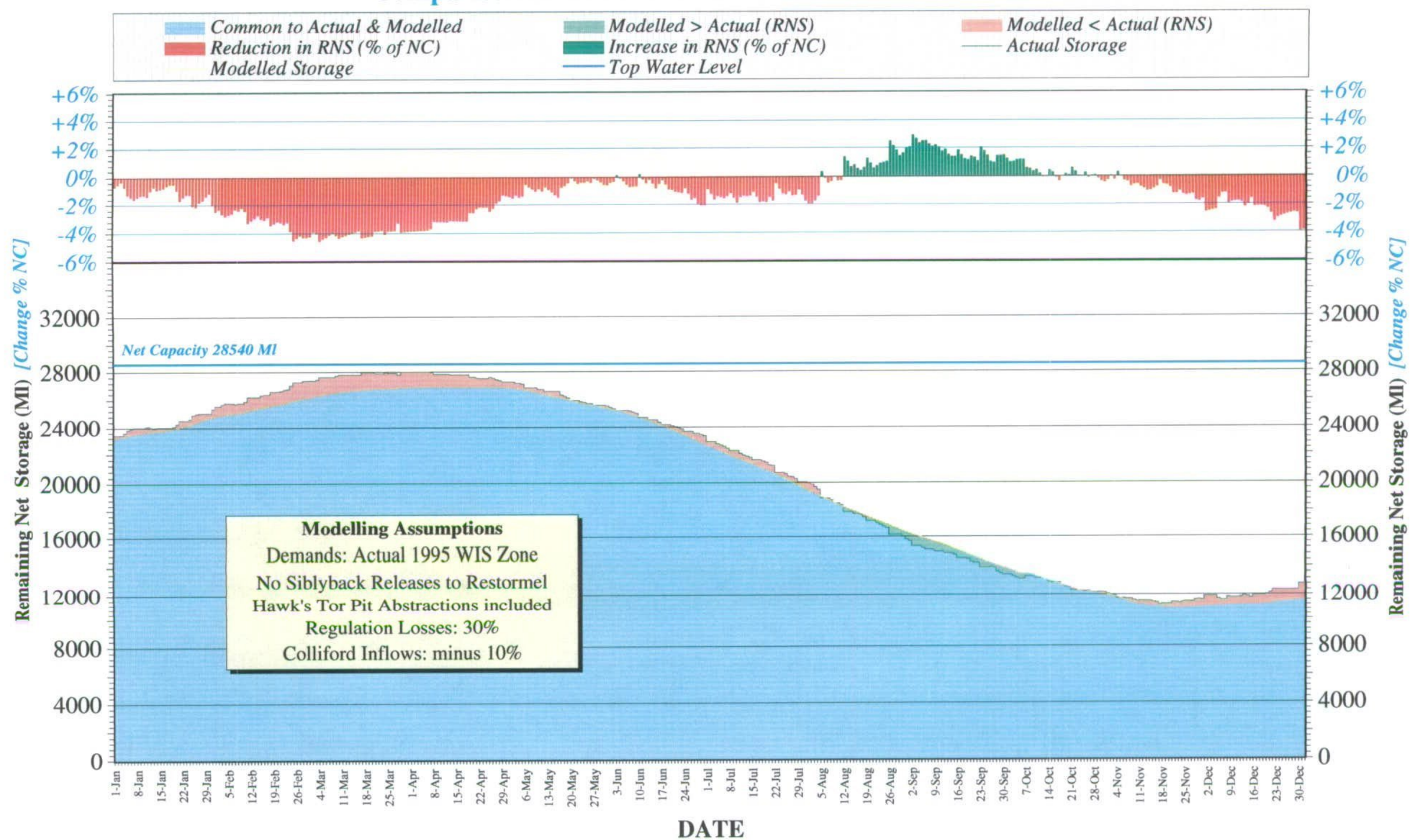
COLLIFORD LAKE

Comparison of Actual and Modelled Drawdown in 1995

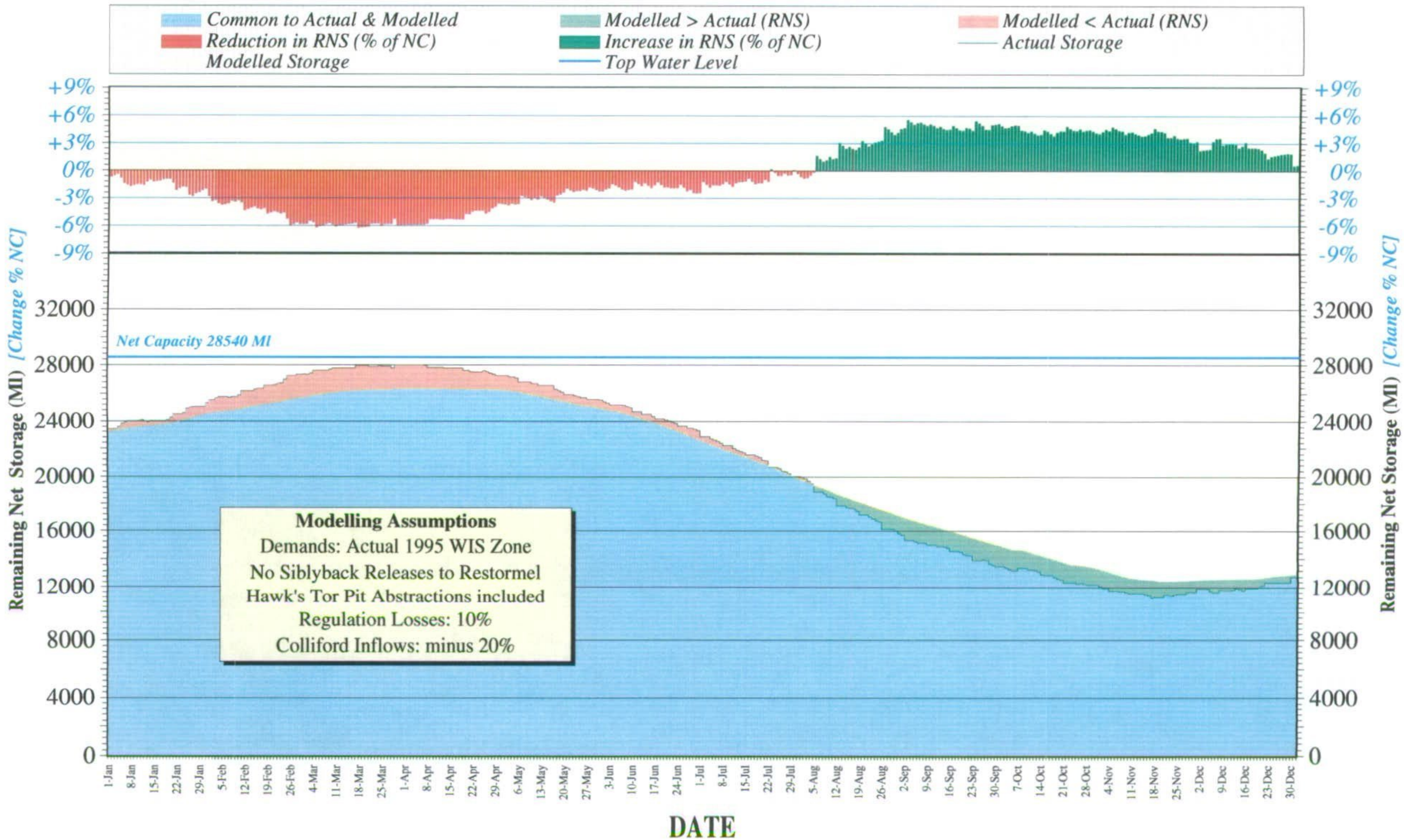


Coll~Act-Mod~Comp.xls

11/16/98

COLLIFORD LAKE

Comparison of Actual and Modelled Drawdown in 1995



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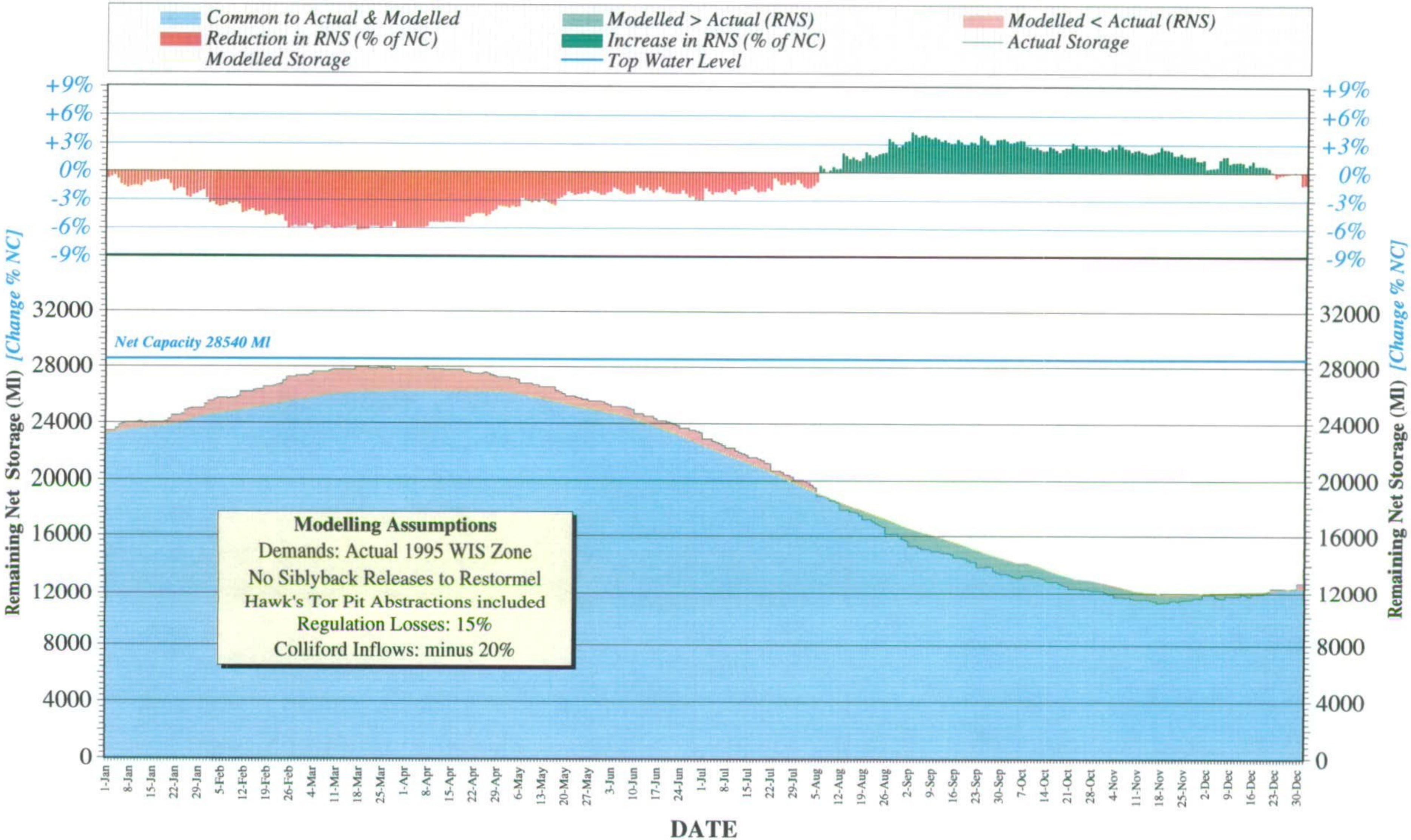
COLLIFORD LAKE

Comparison of Actual and Modelled Drawdown in 1995



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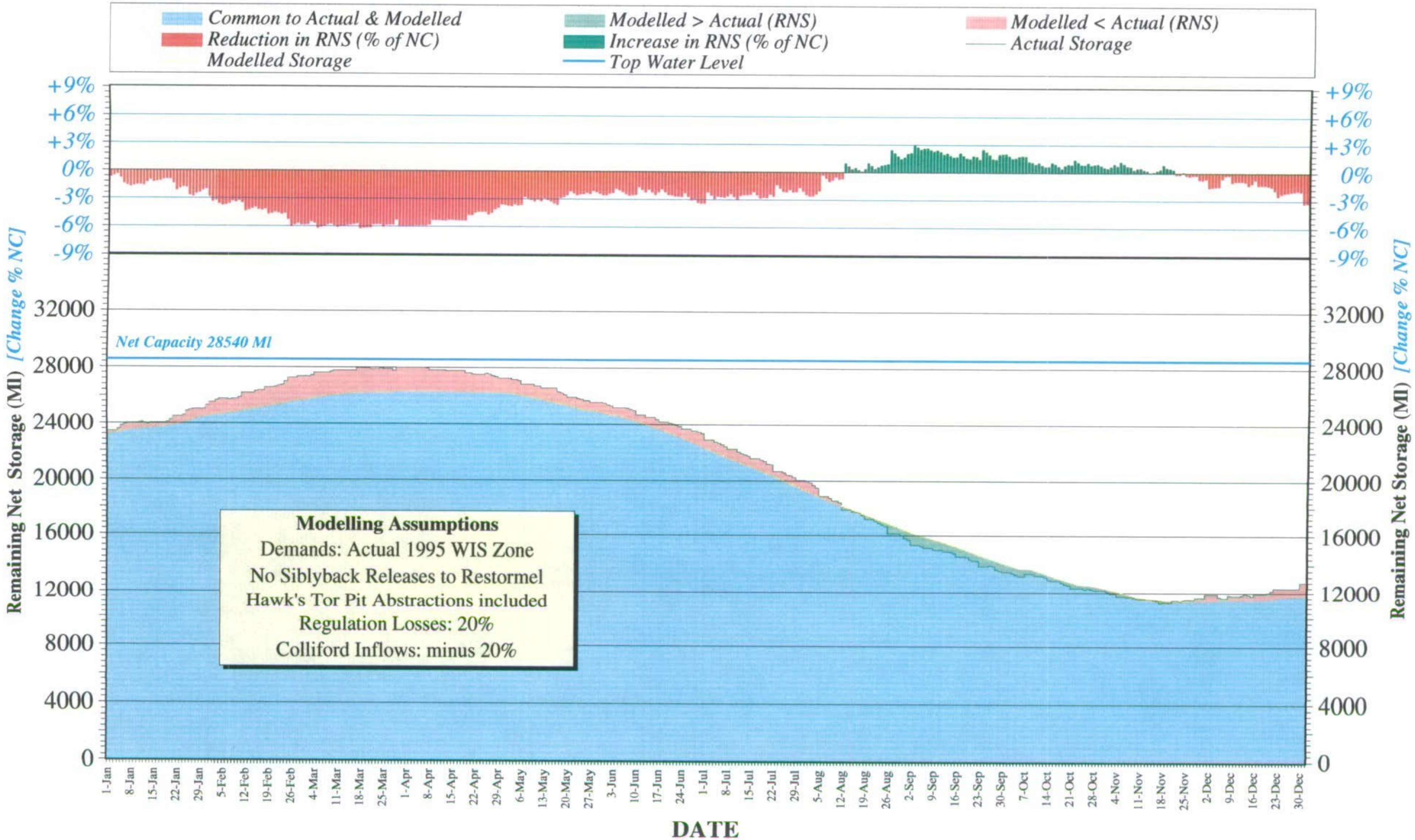
COLLIFORD LAKE

Comparison of Actual and Modelled Drawdown in 1995

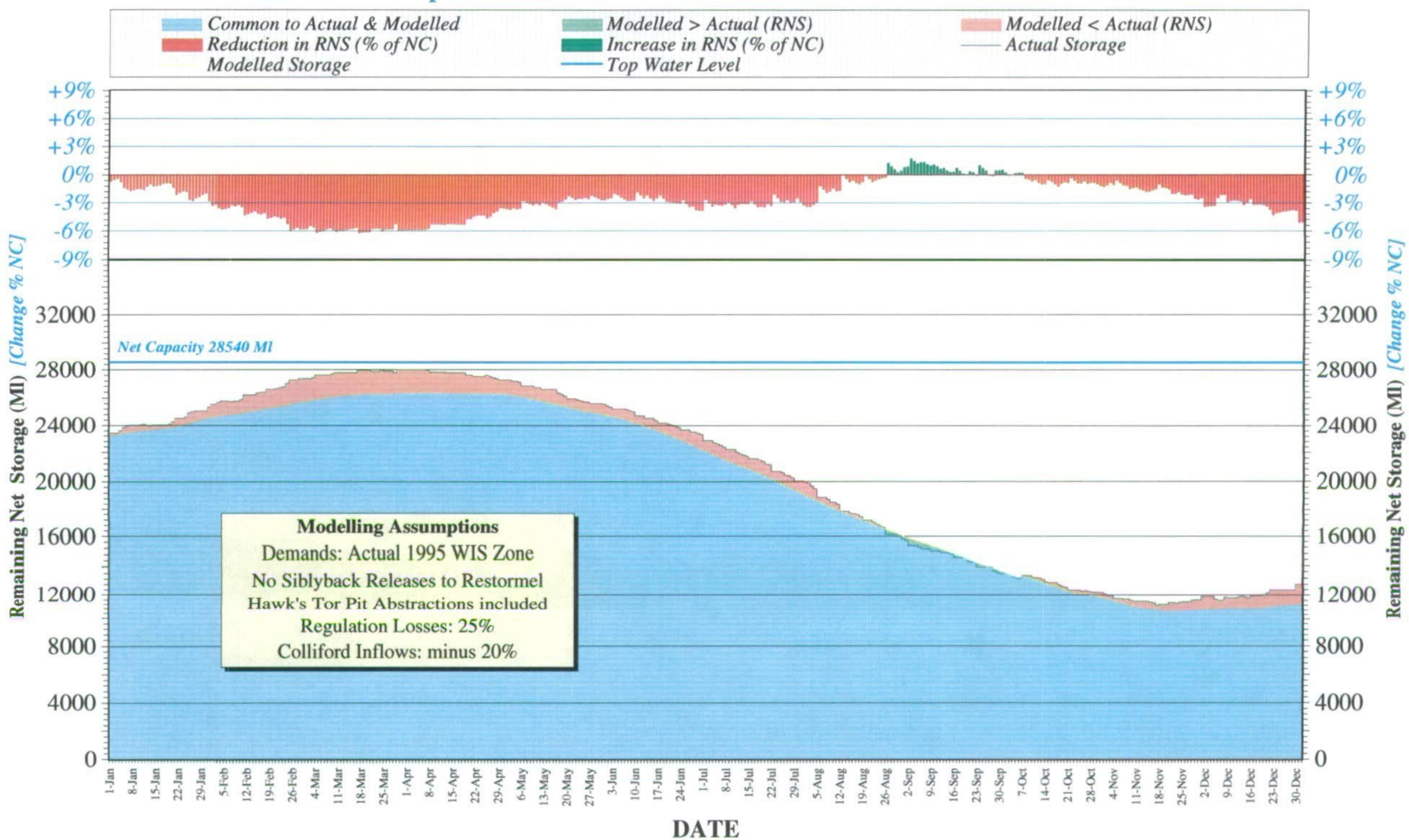


Coll~Act-Mod~Comp.xls

11/16/98

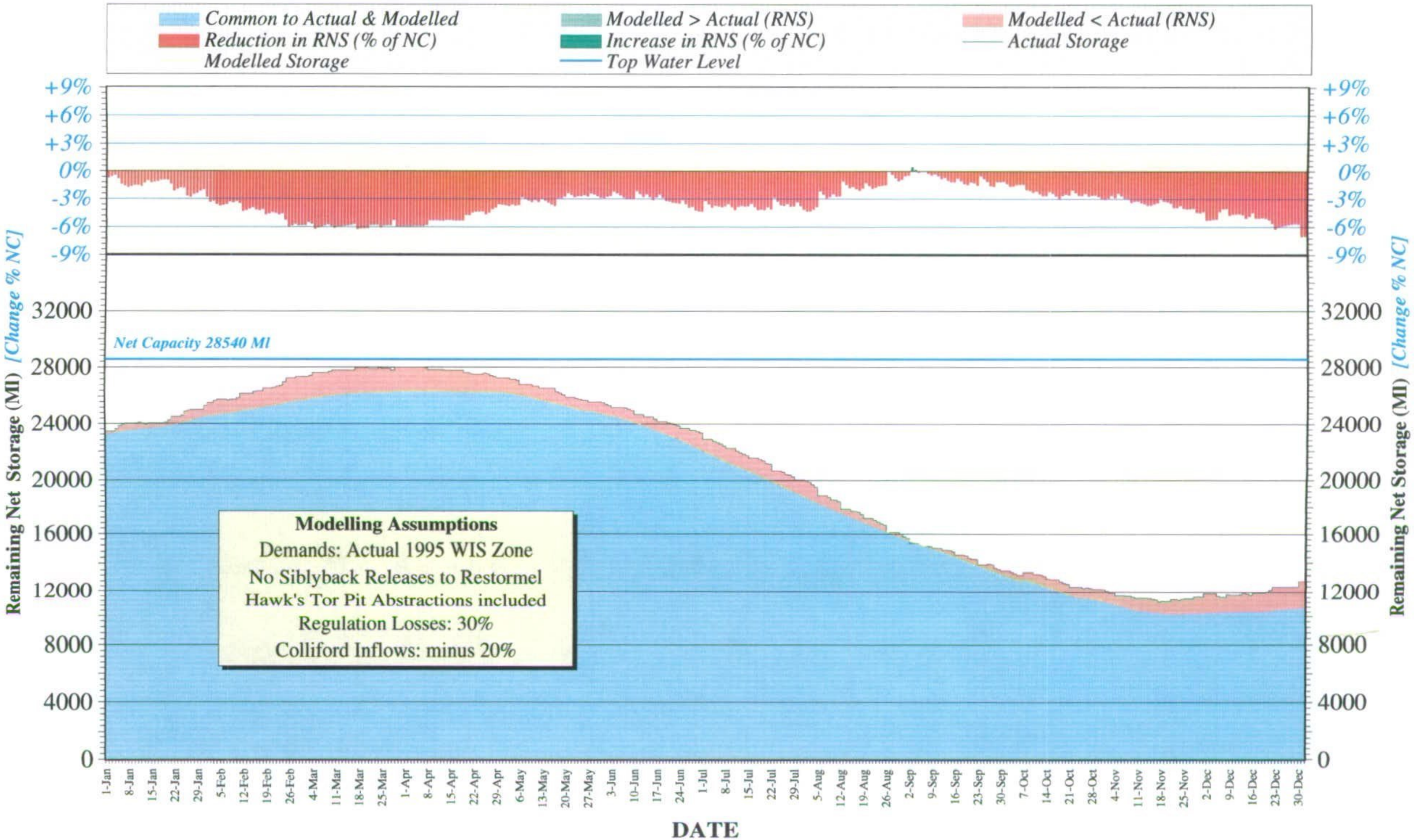
COLLIFORD LAKE

Comparison of Actual and Modelled Drawdown in 1995



COLLIFORD LAKE

Comparison of Actual and Modelled Drawdown in 1995



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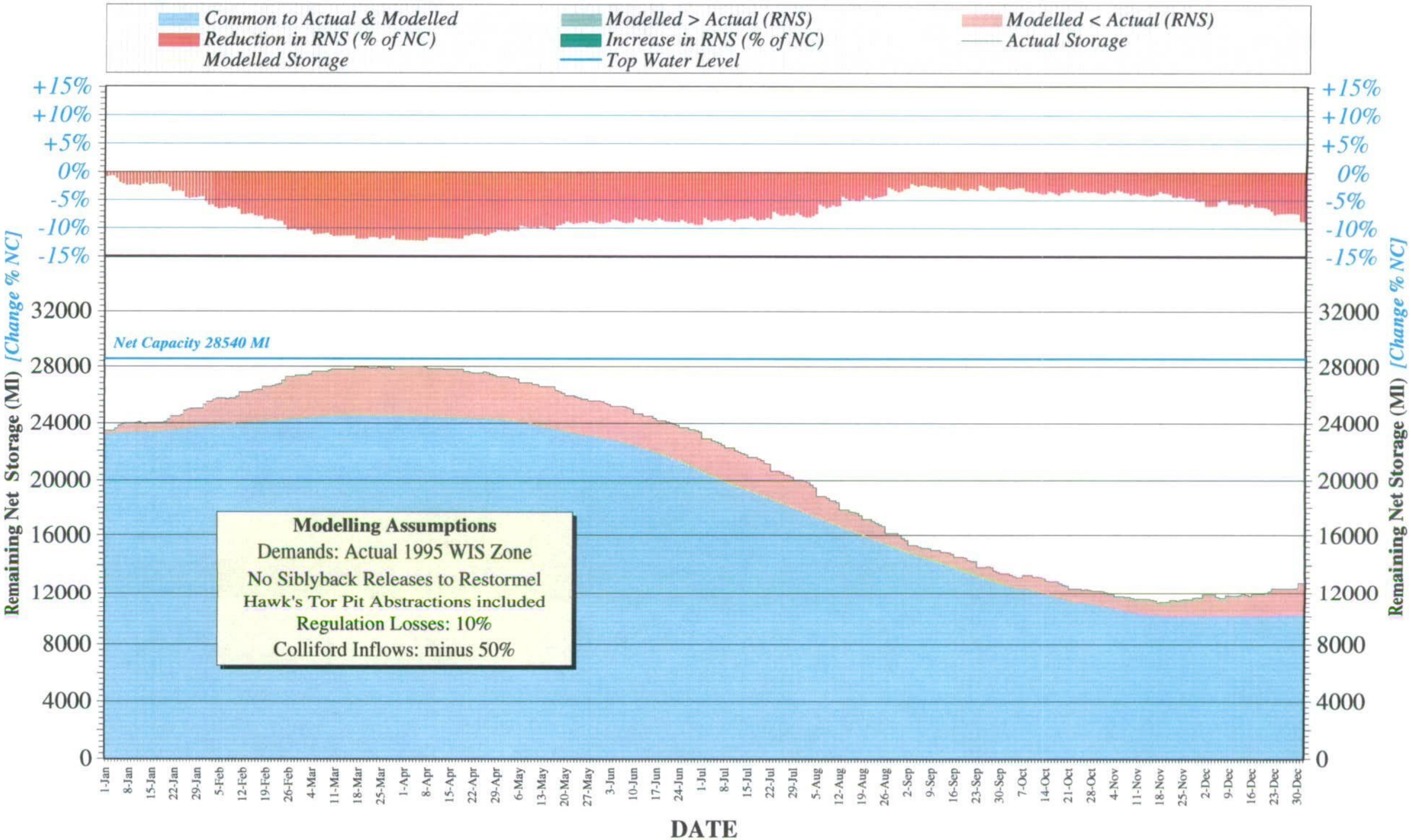
Comparison of Actual and Modelled Drawdown in 1995



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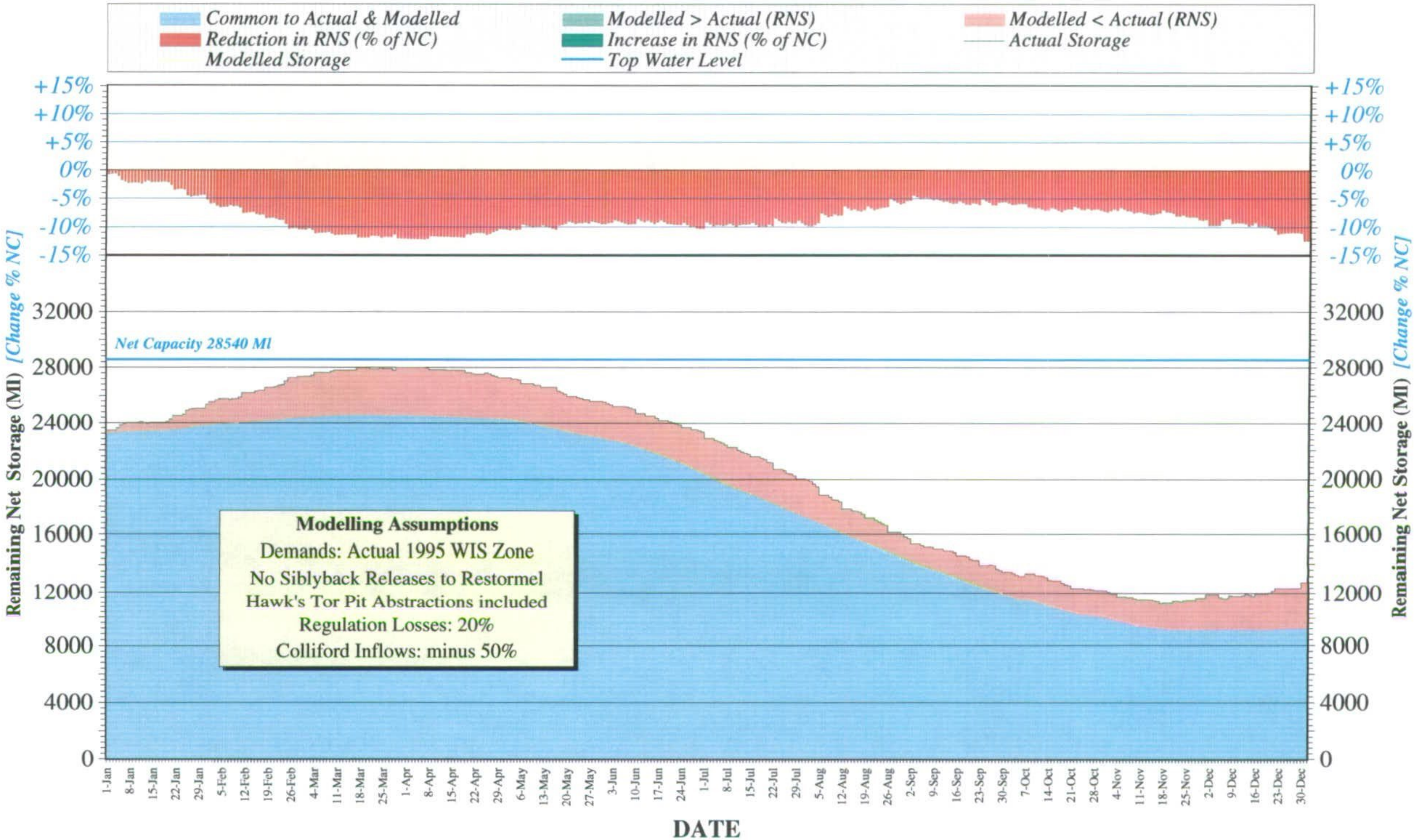
Comparison of Actual and Modelled Drawdown in 1995



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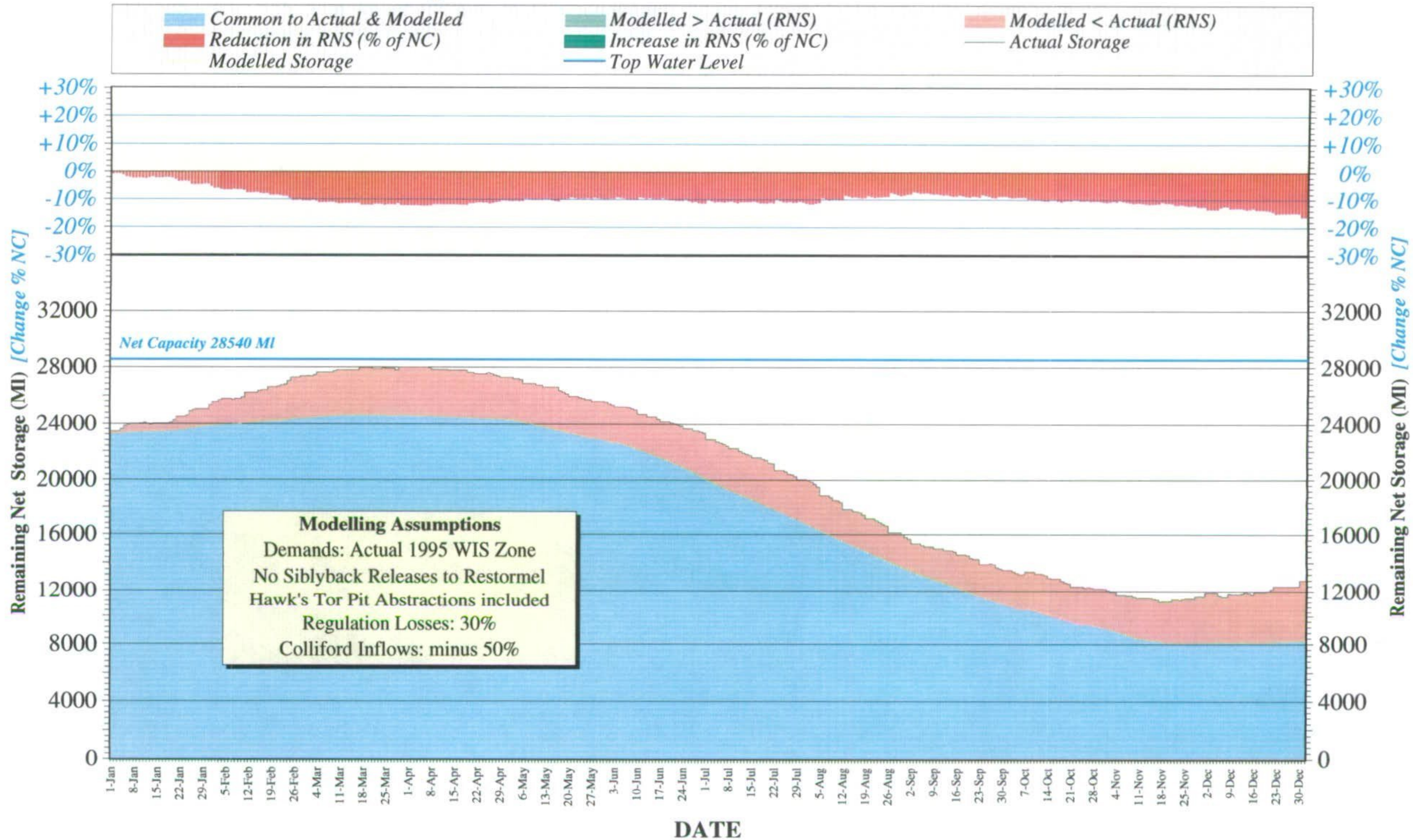
Directorate

SOUTH WEST WATER

COLLIFORD LAKE

Comparison of Actual and Modelled Drawdown in 1995



River Flow Measuring Station Information Sheet

Fowey at Restormel

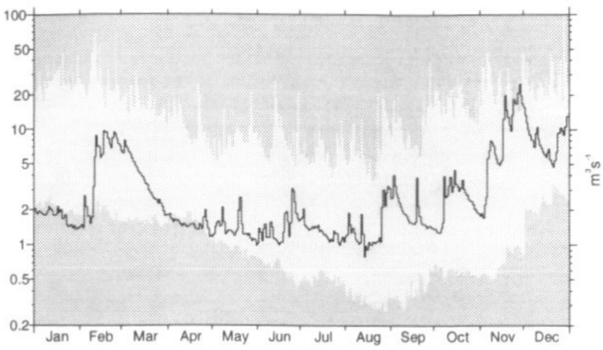
National River Flow Archive
Data Retrieval Service

Measuring Authority: Environment Agency
Grid Reference: 20 (SX) 098 624
Station Type: Compound Crump weir

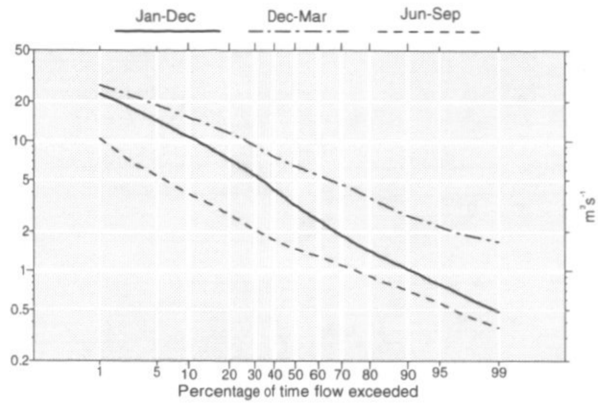
Gauged Flows and Rainfall: 1961-1997
IH Station Number: 48011
Local Number: 4061059

Daily Flow Hydrograph

Max. and min. daily mean flows from 1961 to 1997 excluding those for the featured year (1997; mean flow: 3.51 m^3s^{-1})



Flow Duration Curve



Flow Statistics

(Units: m^3s^{-1} unless otherwise stated)

Mean flow	4.84	
Mean flow (ls^{-1}/km^2)	28.60	
Mean flow ($10^6m^3/yr$)	153.0	
Peak flow / date	223.7	3 Nov 1967
Highest daily mean / date	97.5	27 Dec 1979
Lowest daily mean / date	0.265	28 Aug 1976
10 day minimum / end date	0.284	28 Aug 1976
60 day minimum / end date	0.409	20 Sep 1976
240 day minimum / end date	1.210	23 Oct 1984
10% exceedance (Q10)	10.830	
50% exceedance (Q50)	3.197	
95% exceedance (Q95)	0.785	
Mean annual flood		
IH Baseflow index	0.63	

Rainfall and Runoff

	Rainfall (1961-1997) mm					Runoff (1961-1997) mm				
	Mean	Max/Yr		Min/Yr		Mean	Max/Yr		Min/Yr	
Jan	180	365	1974	25	1962	146	274	1974	28	1997
Feb	129	285	1990	5	1965	118	312	1974	39	1993
Mar	124	235	1981	37	1990	93	192	1981	26	1993
Apr	82	188	1966	10	1984	61	120	1994	23	1997
May	89	198	1993	11	1991	45	102	1983	16	1990
Jun	87	193	1971	8	1992	33	119	1993	11	1984
Jul	91	206	1965	7	1983	28	77	1968	9	1984
Aug	106	222	1986	13	1981	30	96	1986	5	1976
Sep	120	307	1974	30	1971	38	161	1974	10	1984
Oct	142	285	1987	20	1978	68	186	1981	10	1978
Nov	174	308	1997	77	1983	104	237	1982	14	1978
Dec	177	335	1965	54	1991	140	331	1965	47	1991
Year	1501	2055	1974	1220	1975	904	1388	1974	632	1989

Station and Catchment Characteristics

Station level	(mOD)	9.2
Sensitivity	(%)	7.8
Bankfull flow		145.8
Catchment area	(km^2)	169.1
Maximum altitude	(mOD)	420
FSR slope (S1085)	(m/km)	9.15
1961-90 rainfall (SAAR)	(mm)	1436
FSR stream frequency (STMFRQ)	(junctions/km^2)	
Urban extent	(0-1)	0.0022
Flood Attenuation Index	(0-1)	0.9196

Station and Catchment Description

Compound Crump profile weir, crest lengths 3.5m and 13m (total). Piers at 1.75m, wing walls at 2.5m. Flood banks contain flows up to wing wall height. U/s cableway, fish counter. Substantial modifications to flow from associated PWS abstraction, Colliford and Sibleyback reservoirs and other PWS exports.

Moderate relief catchment whose headwaters drain the kaolinised granite of Bodmin Moor. Middle and low reaches drain Devonian slates and grits. Some valley storage in gravels. Low grade agriculture, grazing and forestry.

Factors Affecting Runoff

- Reservoir(s) in catchment affect runoff.
- Runoff reduced by public water supply abstraction.
- Regulation from surface water and/or ground water.

Summary of Archived Data

Gauged Flows and Rainfall

	0 1 2 3 4	5 6 7 8 9
1960s	- F c b A	A A B B A
1970s	A B A A A	A A A A A
1980s	A A A A A	A A A A A
1990s	A A A A A	A C A

Key:

	All rain-fall	Some or no rain-fall
All daily, all peaks	A	a
All daily, some peaks	B	b
All daily, no peaks	C	c
Some daily, all peaks	D	d
Some daily, some peaks	E	e
Some daily, no peaks	F	f
No gauged flow data	=	-

Naturalised Flows

Key:

All daily, all monthly	A
Some daily, all monthly	B
Some daily, some monthly	C
Some daily, no monthly	D
No daily, all monthly	E
No daily, some monthly	F
No naturalised flow data	=

River Flow Measuring Station Information Sheet

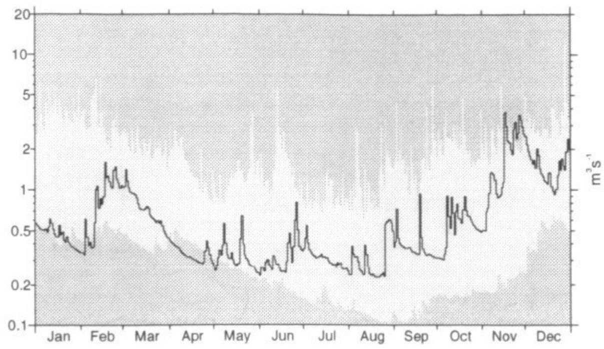
Warleggan at Trengoffe

National River Flow Archive
Data Retrieval Service

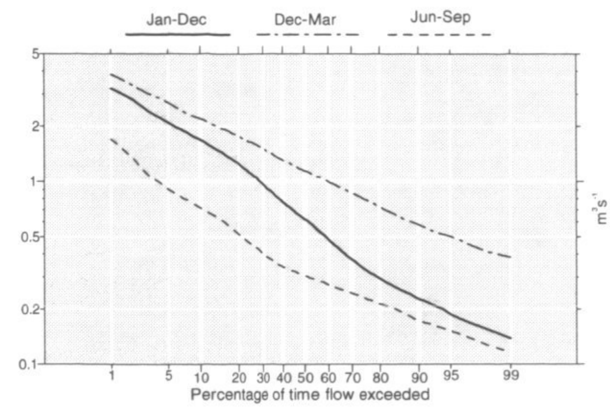
Measuring Authority:	Environment Agency	Gauged Flows and Rainfall:	1969-1997
Grid Reference:	20 (SX) 159 674	IH Station Number:	48004
Station Type:	Compound Crump weir	Local Number:	4161060

Daily Flow Hydrograph

Max. and min. daily mean flows from 1969 to 1997 excluding those for the featured year (1997; mean flow: 0.67 m^3s^{-1})



Flow Duration Curve



Flow Statistics

(Units: m^3s^{-1} unless otherwise stated)

Mean flow	0.82	
Mean flow (ls^{-1}/km^2)	32.40	
Mean flow ($10^6m^3/yr$)	25.8	
Peak flow / date	15.4	28 Nov 1973
Highest daily mean / date	12.4	27 Dec 1979
Lowest daily mean / date	0.101	27 Aug 1976
10 day minimum / end date	0.105	29 Aug 1976
60 day minimum / end date	0.130	19 Sep 1984
240 day minimum / end date	0.284	29 Oct 1984
10% exceedance (Q10)	1.685	
50% exceedance (Q50)	0.622	
95% exceedance (Q95)	0.188	
Mean annual flood	9.3	
IH Baseflow index	0.73	

Rainfall and Runoff

	Rainfall (1970-1997) mm					Runoff (1969-1997) mm				
	Mean	Max/Yr		Min/Yr		Mean	Max/Yr		Min/Yr	
Jan	182	323	1974	28	1997	156	273	1974	49	1997
Feb	130	282	1990	9	1986	132	278	1974	53	1992
Mar	120	223	1981	37	1997	108	168	1978	43	1993
Apr	76	151	1972	8	1984	75	150	1994	35	1997
May	80	195	1993	12	1991	55	104	1983	29	1990
Jun	86	176	1980	7	1992	45	157	1993	21	1984
Jul	89	183	1988	4	1983	37	78	1993	16	1984
Aug	104	216	1986	13	1981	39	101	1986	13	1976
Sep	121	299	1974	31	1986	46	172	1974	18	1984
Oct	146	285	1987	22	1978	72	176	1993	22	1978
Nov	173	304	1997	80	1983	110	189	1994	24	1978
Dec	170	293	1993	55	1991	146	226	1993	72	1991
Year	1477	1844	1974	1179	1975	1021	1531	1974	761	1989

Station and Catchment Characteristics

Station level	(mOD)	70.3
Sensitivity	(%)	10.0
Bankfull flow		40.80
Catchment area	(km^2)	25.3
Maximum altitude	(mOD)	308
FSR slope (S1085)	(m/km)	17.48
1961-90 rainfall (SAAR)	(mm)	1442
FSR stream frequency (STMFRQ)	(junctions/km^2)	1.66
Urban extent	(0-1)	0.0013
Flood Attenuation Index	(0-1)	0.9728

Station and Catchment Description

Three-bay compound Crump profile weir, crest lengths 1.52m and 8.53m (total). Wing walls at 1.67m. Flood banks contain flows up to wing wall height. The only gauged natural catchment on Bodmin Moor.

The upper 70% drains the kaolinised granite. The relief is moderate to steep. The lower 30% traverses metamorphosed Devonian slates. Baseflow high for an upland catchment owing to storage in the granite.

Factors Affecting Runoff

- Natural to within 10% at the 95 percentile flow.

Summary of Archived Data

Gauged Flows and Rainfall

	0 1 2 3 4	5 6 7 8 9
1960s	- - - - -	- - - - e
1970s	A A A A A	A A A A B
1980s	A A A A A	A A A A A
1990s	A A A A A	A C A

Key:	All rainfall	Some or no rainfall
All daily, all peaks	A	a
All daily, some peaks	B	b
All daily, no peaks	C	c
Some daily, all peaks	D	d
Some daily, some peaks	E	e
Some daily, no peaks	F	f
No gauged flow data	=	-

Naturalised Flows

Key:

All daily, all monthly	A
Some daily, all monthly	B
Some daily, some monthly	C
Some daily, no monthly	D
No daily, all monthly	E
No daily, some monthly	F
No naturalised flow data	=

River Flow Measuring Station Information Sheet

St Neot at Craigshill Wood

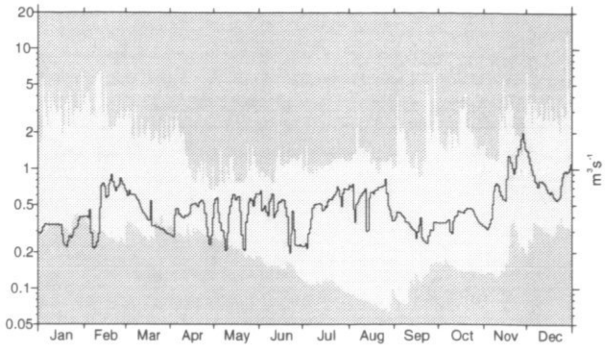
Measuring Authority: Environment Agency
Grid Reference: 20 (SX) 184 662
Station Type: Compound Crump weir

Gauged Flows and Rainfall: 1971-1997
IH Station Number: 48009
Local Number: 4161062

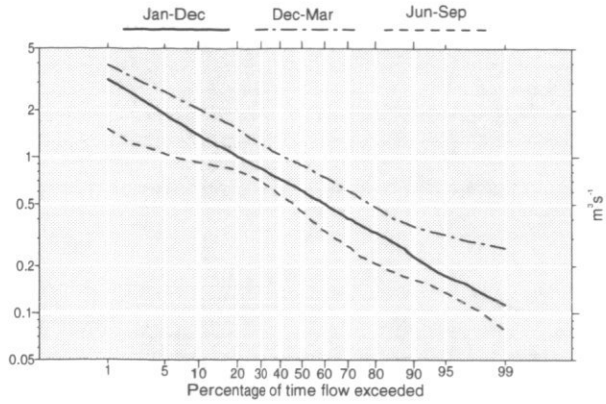
National River Flow Archive
Data Retrieval Service

Daily Flow Hydrograph

Max. and min. daily mean flows from 1971 to 1997 excluding those for the featured year (1997; mean flow: 0.51 m^3s^{-1})



Flow Duration Curve



Flow Statistics

(Units: m^3s^{-1} unless otherwise stated)

Mean flow	0.76	
Mean flow (ls^{-1}/km^2)	33.40	
Mean flow (10^6m^3/yr)	23.9	
Peak flow / date	21.1	27 Dec 1979
Highest daily mean / date	13.3	27 Dec 1979
Lowest daily mean / date	0.064	26 Aug 1976
10 day minimum / end date	0.067	28 Aug 1976
60 day minimum / end date	0.086	13 Sep 1976
240 day minimum / end date	0.303	7 Dec 1978
10% exceedance (Q10)	1.393	
50% exceedance (Q50)	0.607	
95% exceedance (Q95)	0.174	
Mean annual flood	9.8	
IH Baseflow index	0.63	

Rainfall and Runoff

	Rainfall (1971-1997) mm					Runoff (1971-1997) mm				
	Mean	Max/Yr		Min/Yr		Mean	Max/Yr		Min/Yr	
Jan	189	410	1974	29	1997	137	308	1974	37	1997
Feb	136	301	1990	9	1986	134	304	1974	33	1993
Mar	126	216	1981	40	1993	104	183	1978	40	1996
Apr	78	157	1972	8	1984	68	126	1994	38	1996
May	87	205	1993	12	1991	57	96	1972	26	1971
Jun	90	176	1982	9	1992	59	113	1994	18	1976
Jul	90	186	1988	10	1983	72	353	1987	13	1976
Aug	107	232	1986	15	1981	63	136	1995	9	1976
Sep	126	334	1974	35	1986	63	213	1974	19	1977
Oct	155	298	1987	23	1978	75	179	1976	17	1978
Nov	178	321	1997	76	1983	93	182	1974	25	1978
Dec	182	312	1993	57	1991	130	257	1979	40	1991
Year	1544	2238	1974	1311	1983	1054	1645	1974	708	1997

Station and Catchment Characteristics

Station level	(mOD)	70.5
Sensitivity	(%)	12.1
Structurefull flow		32.00
Catchment area	(km^2)	22.7
Maximum altitude	(mOD)	339
FSR slope (S1085)	(m/km)	17.97
1961-90 rainfall (SAAR)	(mm)	1511
FSR stream frequency (STMFRQ)	(junctions/km^2)	1.63
Urban extent	(0-1)	0.0034
Flood Attenuation Index	(0-1)	0.6354

Station and Catchment Description

Three-bay compound Crump profile weir, crest lengths 1.75m and 5.5m (total). Wing walls at 1.7m. Flood banks contain flows up to wingwall height, fully modular. Natural flow regime until 1983, when Colliford reservoir began to fill. Since, river regulation and PWS exports.

70% of upper catchment on granite intrusion of Bodmin Moor. Hill tops are rounded with some peat, valleys can be steep. Lower 30% underlain by metamorphosed Devonian slates. Entirely rural before reservoir built; some abandoned china clay pits. Baseflow high from storage in kaolinised granite.

Factors Affecting Runoff

- Reservoir(s) in catchment affect runoff.
- Runoff reduced by public water supply abstraction.
- Regulation from surface water and/or ground water.
- Runoff increased by effluent returns.

Summary of Archived Data

Gauged Flows and Rainfall

	0 1 2 3 4	5 6 7 8 9
1970s	= E A A A	A A A A A
1980s	A = = = =	= = = C C
1990s	C C A A A	A A A

Key:

	All rainfall	Some or no rainfall
All daily, all peaks	A	a
All daily, some peaks	B	b
All daily, no peaks	C	c
Some daily, all peaks	D	d
Some daily, some peaks	E	e
Some daily, no peaks	F	f
No gauged flow data	=	-

Naturalised Flows

Key:

All daily, all monthly	A
Some daily, all monthly	B
Some daily, some monthly	C
Some daily, no monthly	D
No daily, all monthly	E
No daily, some monthly	F
No naturalised flow data	=

River Flow Measuring Station Information Sheet

Fowey at Trekeivesteps

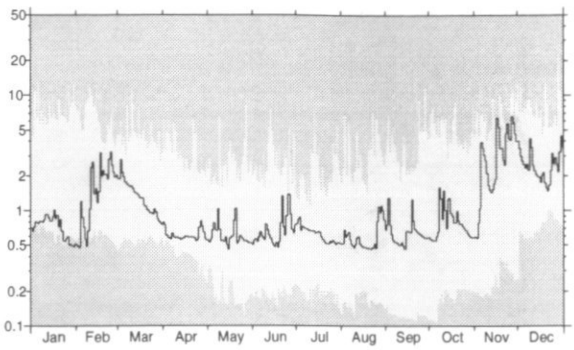
National River Flow Archive
Data Retrieval Service

Measuring Authority: Environment Agency
Grid Reference: 20 (SX) 227 698
Station Type: Compound Crump weir

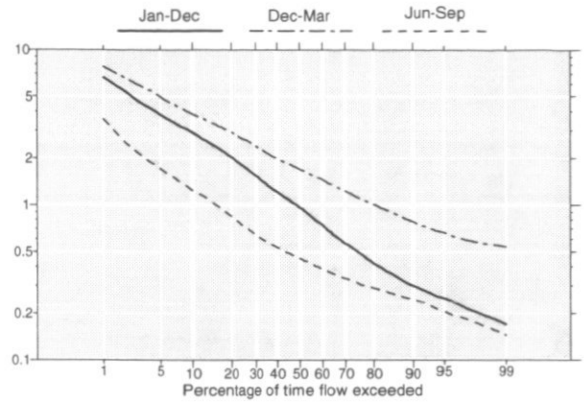
Gauged Flows and Rainfall: 1957-1997
IH Station Number: 48001
Local Number: 4261065

Daily Flow Hydrograph

Max. and min. daily mean flows from 1957 to 1997 excluding those for the featured year (1997; mean flow: 1.17 m^3s^{-1})



Flow Duration Curve



Flow Statistics

(Units: m^3s^{-1} unless otherwise stated)

Mean flow	1.36	
Mean flow (ls^{-1}/km^2)	36.90	
Mean flow ($10^6m^3/yr$)	42.8	
Peak flow / date	38.8	27 Dec 1979
Highest daily mean / date	23.1	27 Dec 1979
Lowest daily mean / date	0.105	5 Oct 1959
10 day minimum / end date	0.113	5 Oct 1959
60 day minimum / end date	0.164	16 Oct 1959
240 day minimum / end date	0.431	25 Nov 1995
10% exceedance (Q10)	2.918	
50% exceedance (Q50)	0.960	
95% exceedance (Q95)	0.248	
Mean annual flood		
IH Baseflow index	0.63	

Rainfall and Runoff

	Rainfall (1957-1997) mm					Runoff (1957-1997) mm				
	Mean	Max/Yr		Min/Yr		Mean	Max/Yr		Min/Yr	
Jan	203	378	1974	30	1963	177	317	1974	53	1992
Feb	141	352	1990	5	1965	139	323	1990	51	1992
Mar	134	281	1981	20	1961	114	242	1981	42	1993
Apr	96	216	1966	12	1984	80	168	1994	30	1990
May	96	219	1993	13	1991	59	118	1983	14	1990
Jun	94	193	1958	10	1975	44	151	1993	16	1976
Jul	105	249	1965	15	1983	40	127	1965	15	1984
Aug	123	272	1958	18	1981	48	188	1958	14	1989
Sep	132	329	1974	18	1959	57	227	1974	9	1959
Oct	168	329	1987	21	1978	94	245	1960	16	1978
Nov	190	348	1959	89	1983	137	252	1959	22	1978
Dec	200	384	1959	63	1991	173	331	1959	66	1991
Year	1682	2145	1960	1316	1975	1163	1642	1974	810	1976

Station and Catchment Characteristics

Station level	(mOD)	187.9
Sensitivity	(%)	8.0
Bankfull flow		49.40
Catchment area	(km^2)	36.8
Maximum altitude	(mOD)	420
FSR slope (S1085)	(m/km)	5.67
1961-90 rainfall (SAAR)	(mm)	1636
FSR stream frequency (STMFRQ)	(junctions/km^2)	
Urban extent	(0-1)	0.0007
Flood Attenuation Index	(0-1)	0.9382

Station and Catchment Description

Three-bay compound Crump profile weir, crest lengths 1.52m and 5.49m (total) superseded a broad-crested weir with central notch (limited accuracy, flow overestimated) on 4/10/68. Flood embankments ensure the full range is gauged. Substantial flow modification from associated PWS abstraction, Sibleyback Res. operation and exports.

Moderate relief, wet moorland catchment on the Bodmin Moor Granite. Extensive hill and valley peat deposits. Kaolinised granite moderates direct runoff response.

Factors Affecting Runoff

- Reservoir(s) in catchment affect runoff.
- Runoff reduced by public water supply abstraction.
- Regulation from surface water and/or ground water.

Summary of Archived Data

Gauged Flows and Rainfall

	0	1	2	3	4	5	6	7	8	9
1950s	-	-	-	-	-	-	-	e	A	A
1960s	A	A	A	A	E	A	A	E	E	E
1970s	A	A	A	A	A	A	A	A	A	A
1980s	A	A	A	A	A	A	A	A	B	A
1990s	A	A	A	B	A	A	C	A		

Key:

	All rain-fall	Some or no rain-fall
All daily, all peaks	A	a
All daily, some peaks	B	b
All daily, no peaks	C	c
Some daily, all peaks	D	d
Some daily, some peaks	E	e
Some daily, no peaks	F	f
No gauged flow data	=	-

Naturalised Flows

	0	1	2	3	4	5	6	7	8	9
1960s	-	-	-	-	F	B	A	C	C	C

Key:

All daily, all monthly	A
Some daily, all monthly	B
Some daily, some monthly	C
Some daily, no monthly	D
No daily, all monthly	E
No daily, some monthly	F
No naturalised flow data	=

6.4 LIST OF DATA HOLDINGS FOR COLLIFORD LAKE

List of data holdings for Colliford Lake at South West Water
Source - files at St Austell Office
Contact - Dave Bridges

General flow information Weekly readings 1991-98	units
Rainfall	mm
Discharge over weir gauge	m
Discharge overflow	m
Simonstone outfall	mm
Simonstone stream	mm
Drainage flows V1	
Drainage flows W1	
Drainage flows inspection gallery west depth	
Drainage flows inspection gallery west flow	
Drainage flows inspection gallery east depth	
Drainage flows inspection gallery east flow	

Gallery drain flows	A= dry	B= damp	
Readings irregular monthly 1992-98			
Foundation(lower) and membrane			
Drain Number	Volume (ml)	Time	Flow
16L, 17EL, 17 WL, 18EL, 18WL, total east, total west	totals in l/m (month)		
summary	East side	foundation	membrane
summary	West side	"	"
summary	total	"	"
V notches	depth	flow	

Hydraulic Piezometers					
Readings irregular (approximately monthly) 1990-98					
Res level	Transdu cer	Datum level mAOD Digital readout values	Piezometer Head	Piezometer Tip Level	Pressure at tip
Section A (rock)	AR1-AR6				
Section A (fill)					
Section B (rock)					
Section B (fill)					
Section C (fill)					
Section D (fill)					

Borehole Standpipe Piezometers Readings irregular 1990-97					
	Borehole number	OD level (Top of standpipe)	Water Depth (m)	Water level (O.D?)	Remarks
West wing	PW1 up/s PW2-PW7				
West Downstream					
East Downstream					
East wing					
west					
crest					
Simonstone dam flows	outfall manhole				

Joint Movements Readings irregular 1991-97	day/month/year	top	bottom
Culvert Wall			
Gallery Wall			
Gallery Roof			

Hydraulic overflow settlement cells	culvert centreline	U/S under membrane
	CE1 CM1 CW1	E3 E2 CM2 W2 W3 W4 W5
Readings irregular		
1982-98		
Date		
Res Level		
Installation level		
Reading sequence E? W		
Gauge board zero level		
Initial manometer reading		
Initial cell level		
manometer reading		
cell level		
difference		

Simonstone Dam	Drainage record sheet		
Readings irregular (monthly/bi monthly) 1991-98			
Reservoir level	date		
Manhole	Flows or No Flow	Remarks	
N5 both Longitudinal and Embankment			
N4 both Longitudinal and Embankment			
N3 both Longitudinal and Embankment			
N2 both Longitudinal and Embankment			
N1 both Longitudinal and Embankment			
Outfall N. Longitudinal/Road drain/ s. Longitudinal	Flows	Outfall manhole	Measurement Chamber
	Depth over V notch		
	Flow gpd		
S1 both Embankment and Longitudinal			
S2 both Embankment and Longitudinal			
S3 both Embankment and Longitudinal			
S4 both Embankment and Longitudinal			
S5 both Embankment and Longitudinal			
S6 both Embankment and Longitudinal			

Main Drainage Flows	(measurement inside manholes)						
Readings monthly 1991-98							
Date	Reservoir Level	Gallery West Depth Flow (gpd)	Gallery East Depth Flow (gpd)	Total Galle ry	West side W1 Depth Flow	Total (V1) Depth Flow	East side V1- W1

Pressure Relief Well Flows

Readings monthly 1991-96

Date	Reservoir Level	PRW No 1 Depth (m) Flow (gpd)	PRW No 2	PRW No 3	PRW No 4	PRW No 5	Total

Subsidiary Drainage Flows

Readings monthly (sometimes bi-monthly)

1991-98

Date	Reservoir Level	Manhole E2		Drain by compressor house		Remarks
		West Notch Depth (mm)	Flow (gpd)	East Notch Depth (mm)	Flow (gpd)	Volume Time Flow(gpd)

6.5 ANECDOTAL EVIDENCE FROM LOCAL LANDOWNER MAY 1998

On our first visit to Colliford Lake we approached a local landowner whilst in the Dewey catchment and asked her about the area and the Lake. She informed us that a farm owner who had since moved on, had trouble with drainage in his fields that were on the Colliford Lake side of the Dewey catchment. She also said that South West Water put in drains in about 1988 as the fields were unusable as they were too wet to graze cattle on.

Refilling at Colliford Lake
Annex 1: Water Quality Sampling Results.

Report to South West Water plc

This report is an official document prepared under contract between South West Water plc and the Natural Environment Research Council. It should not be quoted without permission of both NERC and South West Water plc.

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A1. WATER QUALITY SAMPLING

Six samples of water were collected for water quality analysis. They include raw reservoir water, Park Pit water, spring discharges below Simonstone Causeway and above Park Pit, local steam water and discharge water from the drainage pipes within Colliford Dam.

Measurement of temperature, pH, specific electrical conductance and bicarbonate concentration were taken in the field. Samples were then returned for further analysis in the Wallingford laboratory. These samples were filtered through 0.45 membrane filters, and one aliquot acidified with ultra-pure concentrated nitric acid to a concentration of 1% v/v. Acidified aliquots will be analysed for main cations and selected trace elements by inductively coupled plasma atomic emission spectrometry, and unacidified aliquots for chloride and nitrate by automated colorimetry.

The analytical results are listed in Table 1. Anion / cation balances for the analyses are acceptable save for Colliford Dam No. 25 Drain which has an imbalance of 24% with Fe as Fe but still 10% with Fe as Fe^{2+}.

The three surface waters, Colliford Raw Water, Park Pit Pond and Dewey Bridge are weakly mineralised waters dominated by the ions Na and Cl; the relatively high temperature of the first two samples reflects the shallow 'beach' conditions of a summers day at which sampling was carried out. The other three samples: Park Pit Gate Spring, Colliford Dam No.25 Drain and the discharge below Simonstone Causeway are also dominated by Na and Cl.

The typical Ca and HCO_3 dominance of groundwater is not evident in any of these samples probably because of the local input of Na from kaolinite. The Park Pit and Dewey Bridge samples are beginning to show maturity with regard to Si saturation. Groundwater baseflow to the surface waters is likely to be small although soil interflow may exist, and groundwater circulation arriving at the other sample points is also of small overall volume. Thus all samples most probably represent surface runoff or soil interflow perhaps with a small element of groundwater that has been transported short distances through shallow flowpaths in available joints and fractures in the granite.

The Colliford Dam No 25 Drain discharge contains a high concentration of Fe and Mn indicative of a low pH regime, a reduced environment, or an organic influence pertaining to colloidal iron. In all probability, dam water is passing up into the sand fill and leaching metals from the fill under organic conditions, aided by relatively low pH. The source of the iron is unclear, possible it derives from the breakdown of mica in the fill, but in any event it represents only the removal of 25 kg Fe in 20 years given a total drainage of 2 $l\ s^{-1}$ since the dam was commissioned. It is strange that the drainage water should be more acid than the water in the reservoir - perhaps acid groundwater is seeping up into the dam fill, but unlikely given the presence of the grout curtain beneath the dam.

Elevated Fe and Mn observed at the Simonstone Causeway discharge is similarly not easily accountable, whereas the Fe in the Park Pit Spring more likely reflects the pH of this water, probably soil interflow with some flow through the granular weathered material below the soil cover. Slightly elevated F concentrations in the Park Pit catchment and the Dewey River may reflect local differences in the granite and overlying soil mineralogy. Otherwise there is little difference between the surface and other waters.

Given the high Fe and Mn concentrations in some samples, it is reassuring to note that there are no significant concentrations of other trace metals. However, there is a very high I concentration in the Colliford Dam No 25 Drain. Is it possible that there was some form of chemical stabilizer mixed with the fill material during construction?

A2. CONCLUSIONS

The water chemistry as sampled at six locations indicates a Na dominated shallow and surface water system. The occurrence of high Fe and Mn concentrations in drainage water from the dam infill derives from an as yet unidentified source.

Further work is required on the provenance of Fe and Mn in water draining from the dam infill. Although the integrity of the fill is not in question some knowledge of the chemical environment within the fill is desirable.

***Table 1** Water quality sampling - analytical results*

a) major ions (mg l^{-1})

Location	Grid Reference	Temp °C	pH	SEC µS cm^{-1}	Na	K	Ca	Mg	HCO_3	SO_4	Cl	NO_3-N	NO_2-N	NH_4-N	Si
Colliford Raw Water	21750710	15.4	6.9	87	7.7	1.0	3.3	1.1	6	4.9	13.7	<0.2	<0.003	0.02	0.1
Park Pit Pond	21950710	15.4	6.9	87	7.8	1.8	2.1	1.6	7	6.2	12.8	<0.2	<0.003	<0.01	3.3
Park Pit Gate Spring	21870712	12.6	6.3	69	5.4	<0.5	2.3	0.9	4	3.0	9.0	<0.2	<0.003	0.01	0.8
Colliford Dam No 25 Drain	21790709	10.7	6.0	133	7.3	1.0	3.6	0.9	41	2.0	13.6	<0.2	<0.003	0.82	1.8
Simonstone Drain	21640729	10.6	6.8	90	8.7	1.1	3.6	1.2	4	8.2	13.8	0.4	<0.003	0.07	1.9
Dewey Bridge	21590711	12.0	6.9	81	7.9	1.0	2.6	1.3	3	4.8	13.0	0.6	<0.003	<0.01	2.7

b) trace and metals ($\mu gm\ l^{-1}$)

Location	Sr	Ba	Li	B	Fe	Mn	Cu	Zn	Al	F	I
Colliford Raw Water	13	3	<7	<30	90	5	<20	<20	<100	48	12.2
Park Pit Pond	15	5	<7	<30	30	5	<20	<20	<100	147	5.3
Park Pit Gate Spring	8	4	<7	<30	450	17	<20	<20	<100	133	3.4
Colliford Dam No 25 Drain	11	4	<7	<30	18600	2080	<20	<20	200	16	171
Simonstone Drain	13	5	<7	<30	140	173	<20	<20	200	76	25.4
Dewey Bridge	12	5	<7	<30	90	34	<20	<20	100	135	6.4

c) others (mg l^{-1})

Location	P - Total	Be	Sc	Y	Co	La	Cd	Zr	Cr	Ni	Mo	Pb
Colliford Raw Water	<0.5	<0.001	<0.002	<0.003	<0.02	<0.02	<0.03	<0.02	<0.04	<0.05	<0.1	<0.2
Park Pit Pond	<0.5	<0.001	<0.002	<0.003	<0.02	<0.02	<0.03	<0.02	<0.04	<0.05	<0.1	<0.2
Park Pit Gate Spring	<0.5	<0.001	<0.002	<0.003	<0.02	<0.02	<0.03	<0.02	<0.04	<0.05	<0.1	<0.2
Colliford Dam No25 Drain	<0.5	<0.001	<0.002	0.003	<0.02	<0.02	<0.03	<0.02	<0.04	<0.05	<0.1	<0.2
Simonstone Drain	<0.5	<0.001	<0.002	<0.003	<0.02	<0.02	<0.03	<0.02	<0.04	<0.05	<0.1	<0.2
Dewey Bridge	<0.5	<0.001	<0.002	<0.003	<0.02	<0.02	<0.03	<0.02	<0.04	<0.05	<0.1	<0.2