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Eastern and Midlands Region

Appendix B

Hydrodynamic and Water Quality Modelling Report

MARCON COMPUTATIONS INTERNATIONAL
Advanced Engineering and Environmental Solutions

Water Supply Project – Dublin Region

DA2: Hydrodynamic and Water Quality Modelling

DA2.2: Final Options Appraisal Report

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1. INTRODUCTION

The flushing characteristics of Lough Derg and Parteen Basin were assessed for the October 1994 – December 1995 time period. This period was chosen as it encompassed periods both of extreme high flows in the Shannon system (January 1995) and extreme low flows (August/September 1995). The 1994/1995 time period was also used as a reference year during the SEA process for calibration of models and options appraisal.

The flushing characteristics of Lough Derg and Parteen Basin were assessed for the October 1994 – December 1995 time period using the 2016 calibrated MIKE 3 model parameter settings where possible. It was not possible to fully transpose the 2016 calibrated model configuration to the 1994-1995 simulation period as certain model boundary conditions were not available, or not available at the same temporal resolution. The difference between the model configurations is presented in Table 1 below. The sensitivity of the 2016 calibrated model parameters to these differences are examined.

	2016 Model			**1995 Model**		
	Location	**Data**	**Frequency**	**Location**	**Data**	**Frequency**
Water Levels	Portumna	Recorded	15 minute	Portumna	N/A	N/A
	Parteen	Recorded	15 minute	Parteen	Recorded	Daily
Discharges	Shannon	Recorded	15 minute	Shannon	Inferred	Daily
	Parteen Basin	Recorded	Hourly	Parteen Basin	Recorded	Daily
	Minor rivers	Calculated	Daily	Minor rivers	Calculated	Daily
Meteorology	Met station MS02	Recorded	15 minute	N/A	N/A	N/A

Table 1: Differences in boundary conditions between 2016 and 1995 models.

2. MODEL SENSITIVITY

2.1. Portuma Boundary Condition

The original boundary condition from the 1995 flushing characterisation study at Portumna was specified as a combination of water surface level (ESB records) and river discharge (pre-existing RPS Mike11 model). This was found to produce inaccurate results and so recourse was made to using the estimated river discharge at Portumna from ESB back-routing calculations only, further modified after the method used in the original SEA study.

The result of the above was that the predicted water surface levels from the First Pass model came into line with recorded levels at Portumna. There existed however, on average, a 5-10mm difference between First Pass modelled water levels and recorded water levels at Portumna. At the time it was anticipated that with a more accurate representation of the river channel geometry downstream of Portumna, combined with accurate recorded current speeds (and thus volumetric flow rates) the 5-10mm discrepancy would be resolved during the calibration exercise.

An alternate boundary condition at Portumna was examined during the course of running the 450:50 variable abstraction scenario. This consisted of applying both the recorded ESB water levels and the modified ESB backrouted inflows, in combination, to ascertain the improvement in water level predictions in the model.

Using the above alternate, combined boundary condition at Portumna, the flushing time predictions were approximately half those presented in the original First Pass Modelling Report. The impact of each abstraction scenario also drops significantly, from approximately 42 days impact above baseline as reported in the First Pass Modelling Report to only 4 days impact above baseline flushing times when using the alternate, combined boundary condition at Portumna.

The accuracy of either of the above solutions was unknown as no field data was available at the time. To determine the accuracy of the of the above solutions, the 2016 calibrated model solution was executed using recorded water surface level and river discharges at Portumna (CalibratedModel) and again using only recorded river discharges at Portumna

(PortumnaDischargeOnly). All other boundary conditions and parameterisation in the 2016 calibrated model solution remained unchanged.

The water surface levels predicted by both solutions (CalibratedModel & PortumnaDischargeOnly) have been compared against the water level recorders located at Coolbawn Marina towards the north of the lough, and Kincora Marina towards the south of the lough and presented in Figure 1 and Figure 2 respectively.

The water current speeds predicted by both solutions (CalibratedModel & PortumnaDischargeOnly) have been compared against the two vertical Acoustic Doppler Current Profile (ADCP) recorders in Lough Derg, at locations OL02 and OL09 and presented in Figure 3 and Figure 4 respectively.

It is apparent from the figures below that adopting a discharge boundary only at Portumna results in a noticeable decrease in accuracy from the calibrated model solution.

Water surface levels at Coolbawn (closest water level gauge to Portumna) show an underprediction of between 5-10mm when employing only a discharge boundary at Portumna. Water surface levels at Kincora, just upstream of the village of Ballina/Killaloe show an underprediction of up to 5mm when employing only a discharge boundary at Portumna.

Water current speeds at the OL02 ADCP location are significantly underpredicted when employing only a discharge boundary at Portumna. Water current speeds at the OL09 ADCP location are also significantly underpredicted when employing only a discharge boundary at Portumna.

The analyses supported adopting the alternate boundary condition at Portumna as examined during the course of running the 450:50 variable abstraction, and subsequently used as the boundary condition for the 2016 model calibration.

The present flushing characterisation study of Lough Derg contained in this report has been undertaken on the above basis and represents the most accurate assessment of flushing characteristics of Lough Derg.

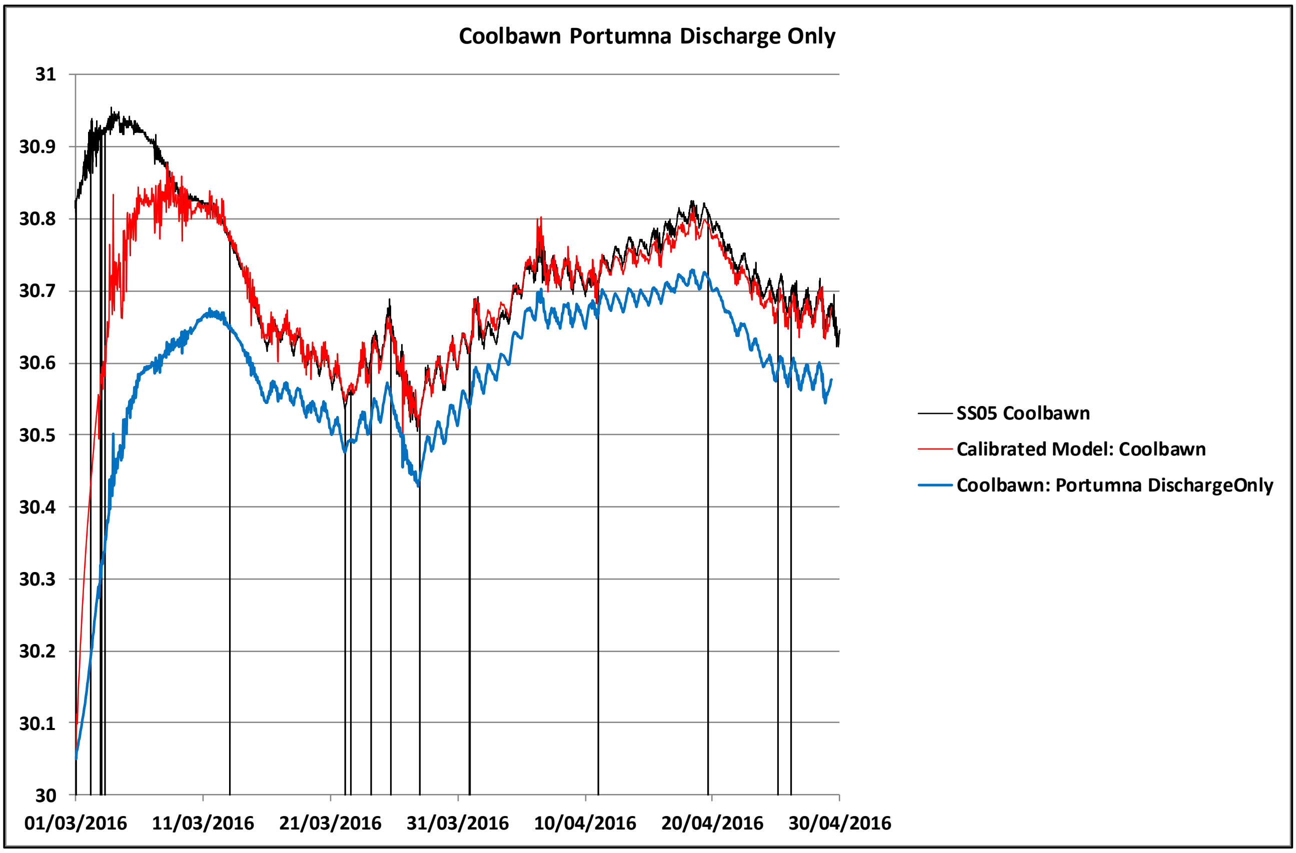

Figure 1: Sensitivity of water level predictions at Coolbawn to Portumna boundary conditions

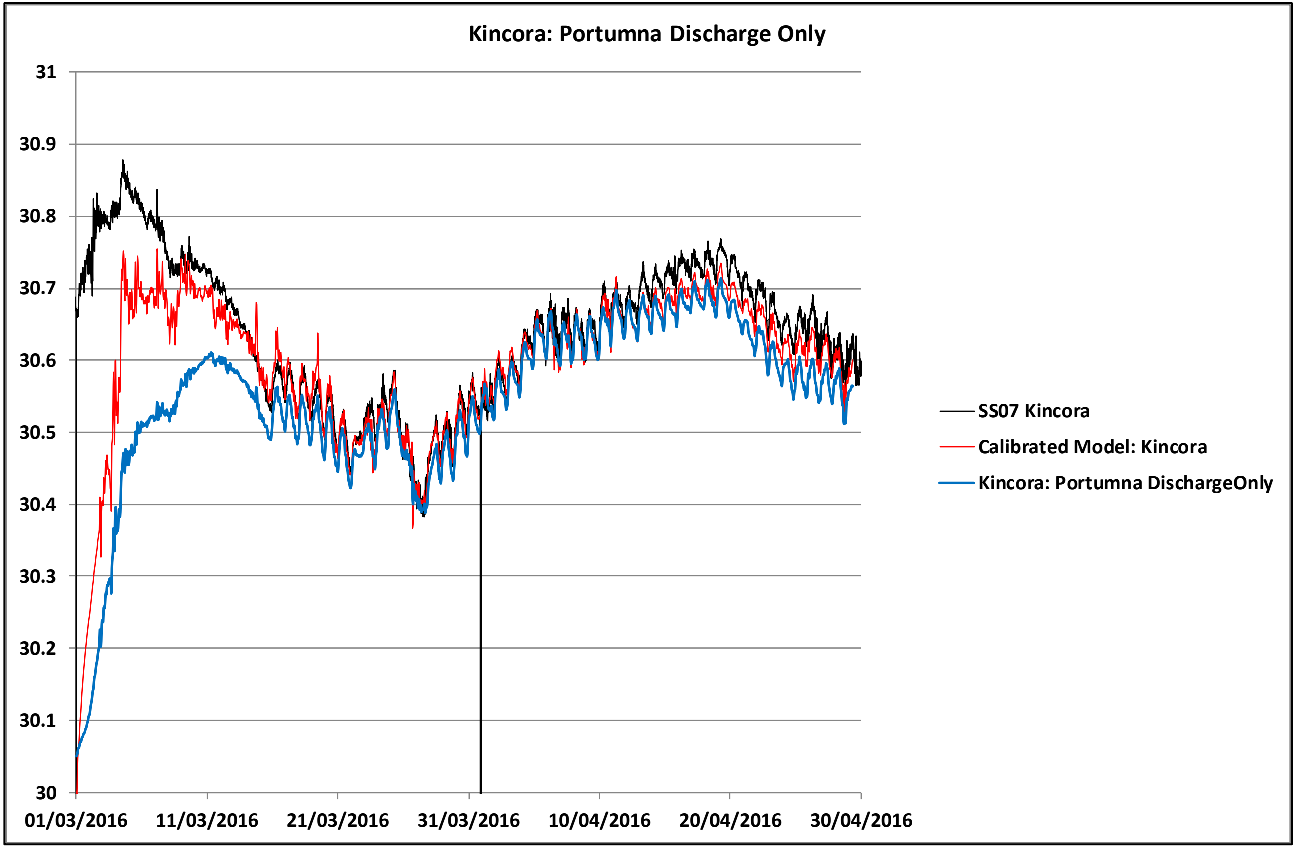

Figure 2: Sensitivity of water level predictions at Kincora to Portumna boundary conditions

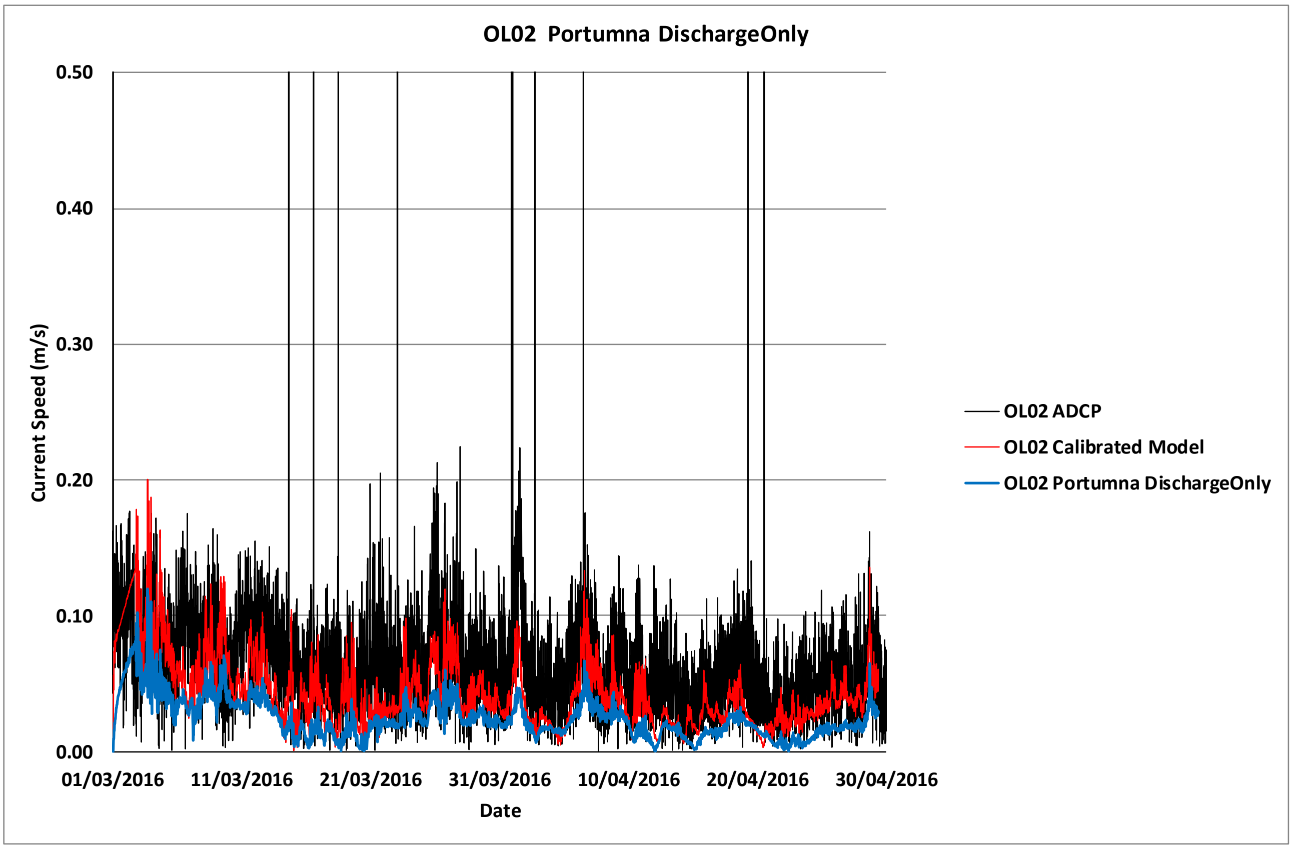

Figure 3: Sensitivity of water current speeds at OL02 to Portumna boundary conditions

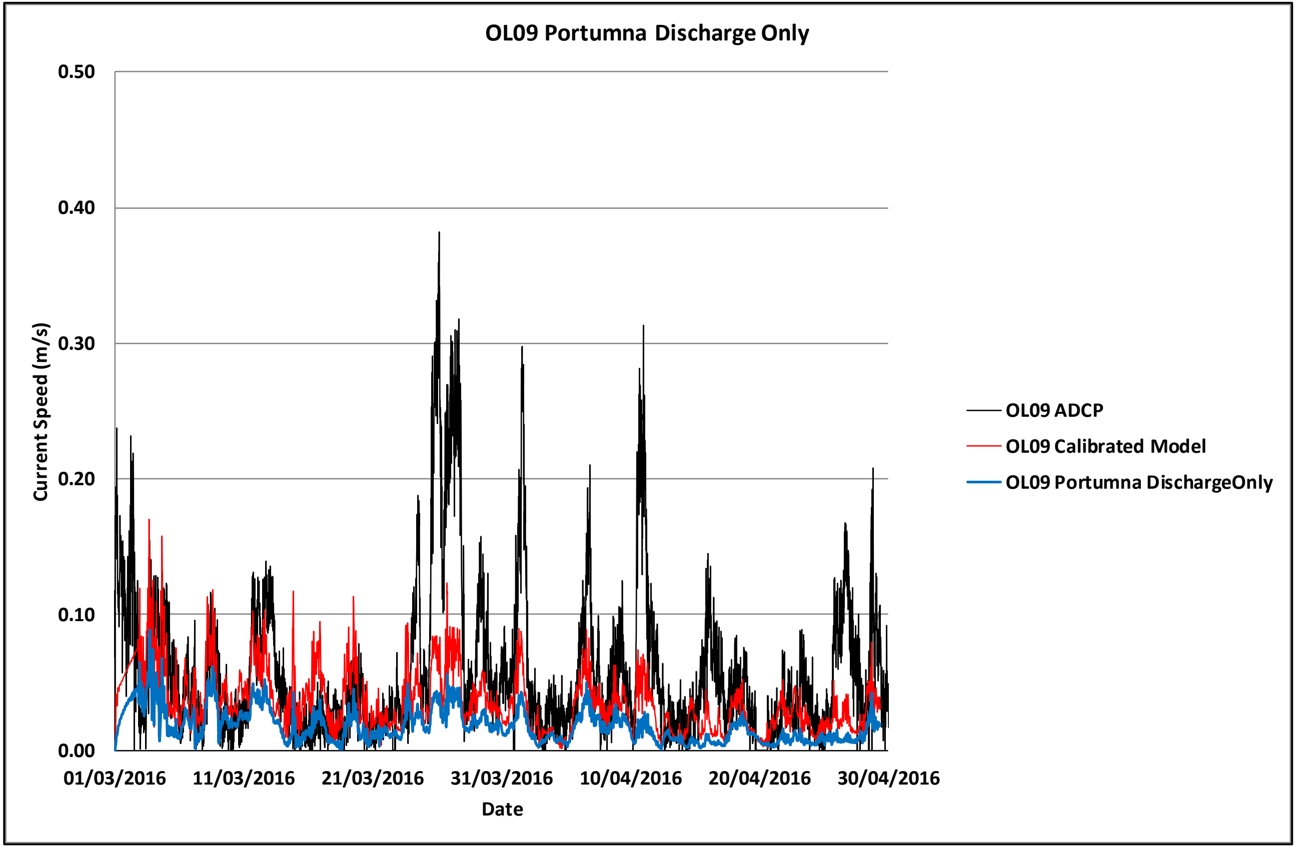

Figure 4: Sensitivity of water current speeds at OL09 to Portumna boundary conditions

2.2. Frequency of Boundary Forcing.

The original 1995 flushing characterisation study specified daily values of recorded water levels and daily average discharge flows at both Portumna Bridge and Parteen. This was the highest frequency at which data was collected at that time. The 2016 calibrated model uses much higher frequency boundary conditions; water levels at both Portumna Bridge and Parteen at 15 minute intervals, discharge at Portumna Bridge at 15 minute intervals and combined discharges through Ardnacrusha and Parteen Weir at hourly intervals.

To determine the impact of daily boundary conditions on the model solution, the 2016 calibrated model was executed using the high frequency recorded water surface levels and discharges at Portumna and Parteen (CalibratedModel) and again using daily boundary conditions at Portumna and Parteen (DailyBoundary). All other boundary conditions and parameterisation in the 2016 calibrated model solution remained unchanged.

The water surface levels predicted by both solutions (CalibratedModel & DailyBoundary) have been compared against the water level recorders located at Coolbawn Marina towards the north of the lough, and Kincora Marina towards the south of the lough and presented in Figure 5 and Figure 6 respectively.

The water current speeds predicted by both solutions (CalibratedModel & DailyBoundary) at both OL02 and OL09 ADCP locations show no appreciable variation, as presented in Figure 7 and Figure 8.

It is apparent from the figures below that adopting daily boundary conditions at Portumna and Parteen does not result in any noticeable decrease in accuracy in current speeds, and only minor decrease in accuracy with respect to water surface levels when compared against the calibrated model solution.

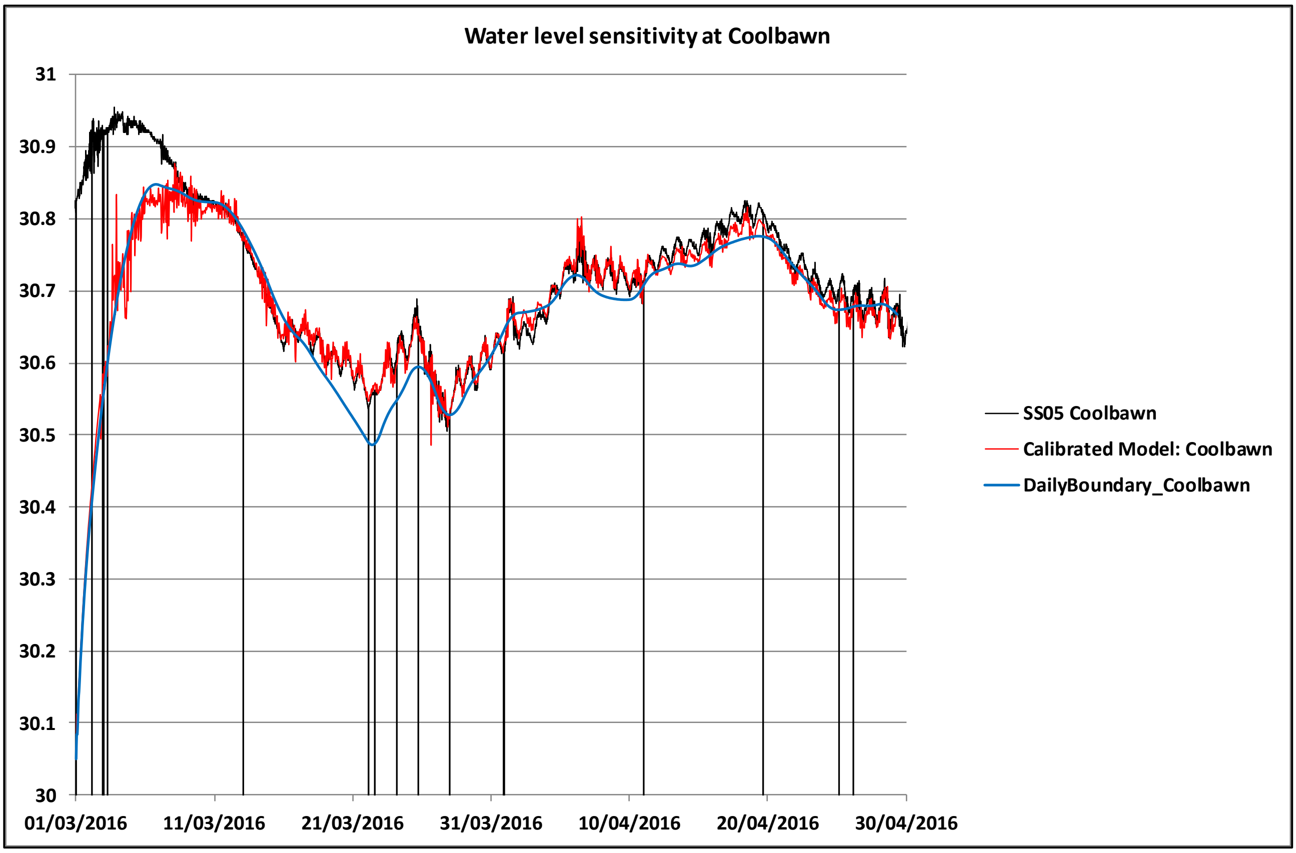

Figure 5: Sensitivity of water level predictions at Coolbawn to daily boundary conditions.

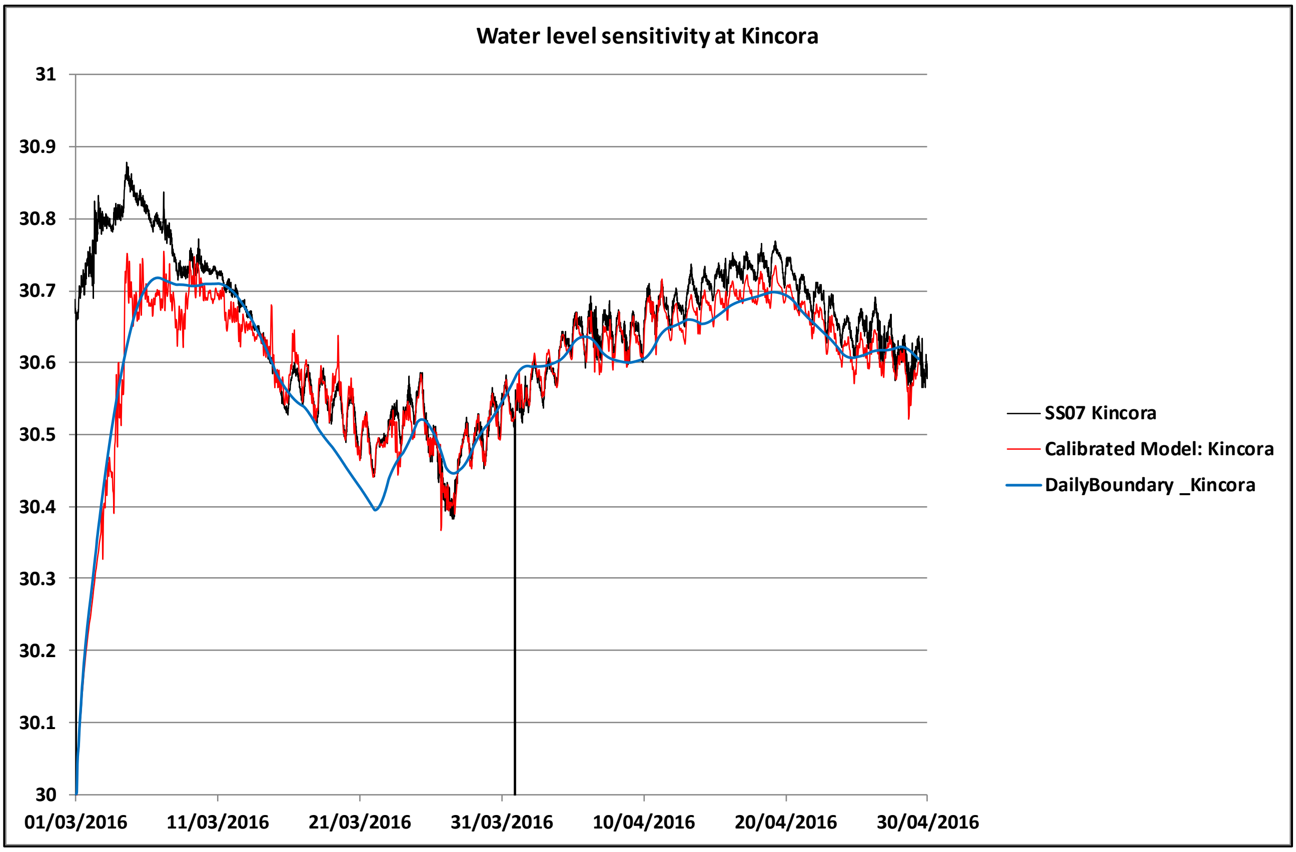

Figure 6: Sensitivity of water level predictions at Kincora to daily boundary conditions.

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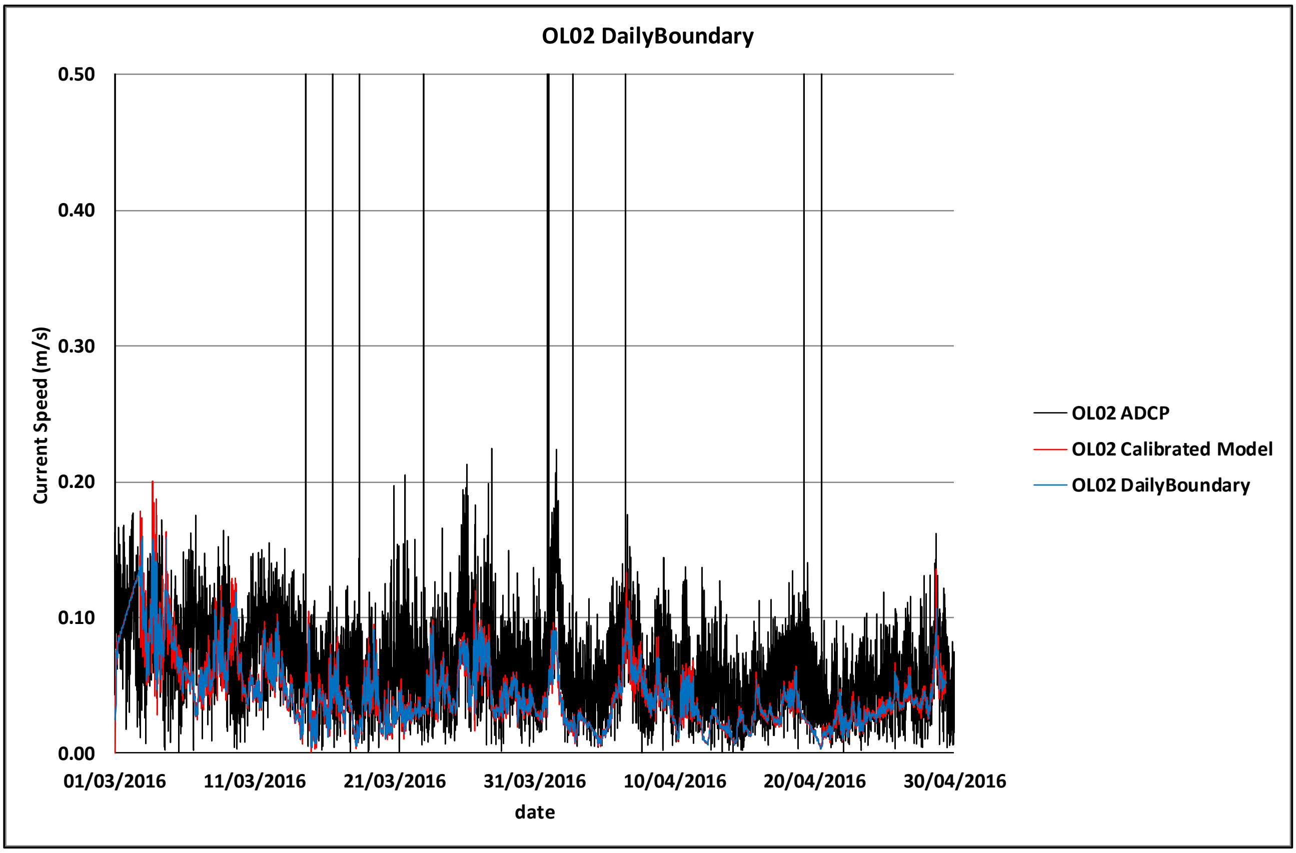

Figure 7: Sensitivity of water current speeds at OL02 to daily boundary conditions

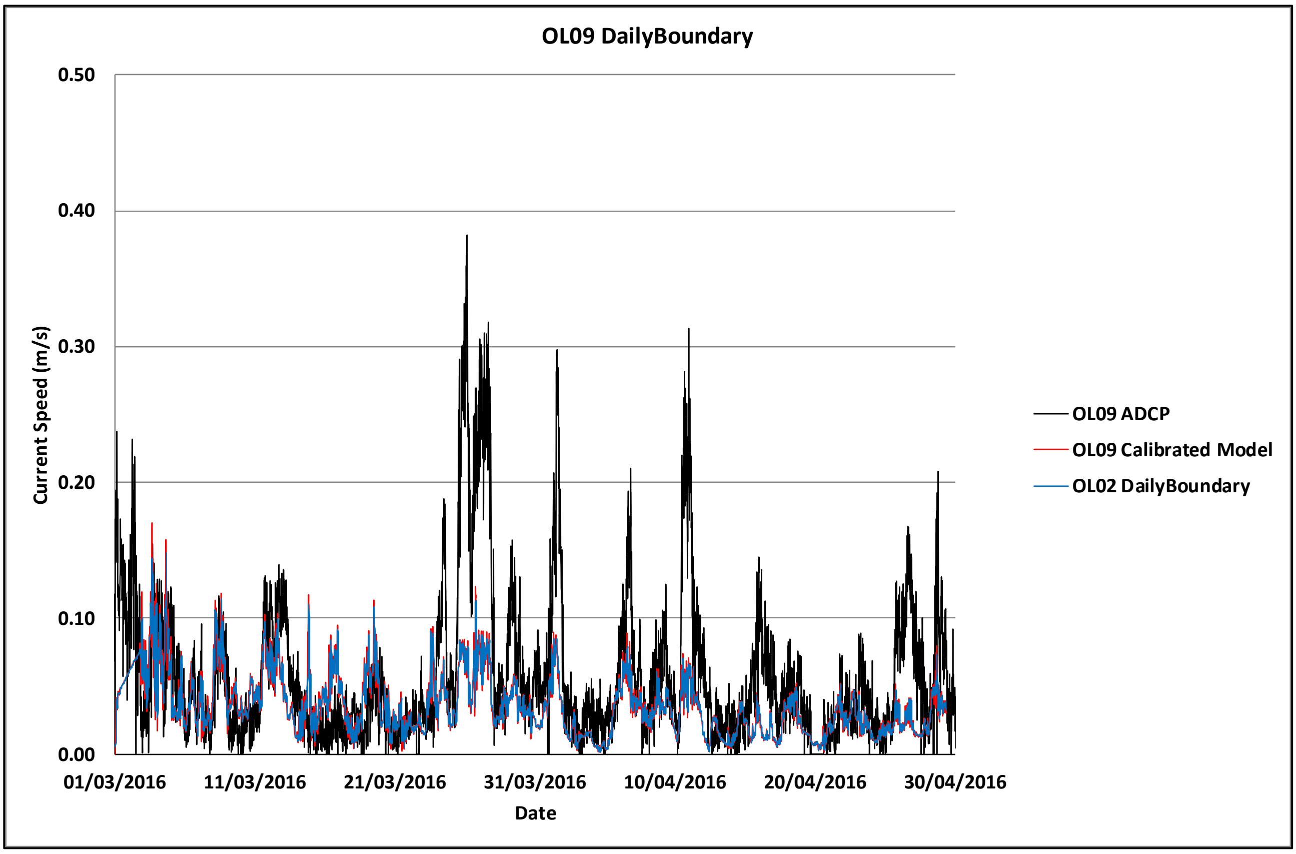

Figure 8: Sensitivity of water current speeds at OL09 to daily boundary conditions

3. MODEL SCENARIOS

3.1. Boundary Conditions

3.1.1. Water Levels

Water levels at both the upstream and downstream boundaries of the model study area were defined to the model from daily water levels recorded by ESB and made available to the project and are presented in Figure 9.

3.1.2. River Flows

The main inflowing river boundary condition for the present study, the River Shannon at Portumna, was extracted from the calibrated MIKE 11 model at hourly intervals.

Four of the nineteen additional inflowing rivers had MIKE NAM catchment models developed and calibrated during the SEA process. Those catchments were; Ballyfinboy, Nenagh, Graney, and Kilcrow. The river flows from those catchments for the 1994/1995 period were extracted at daily intervals from the respective calibrated NAM models.

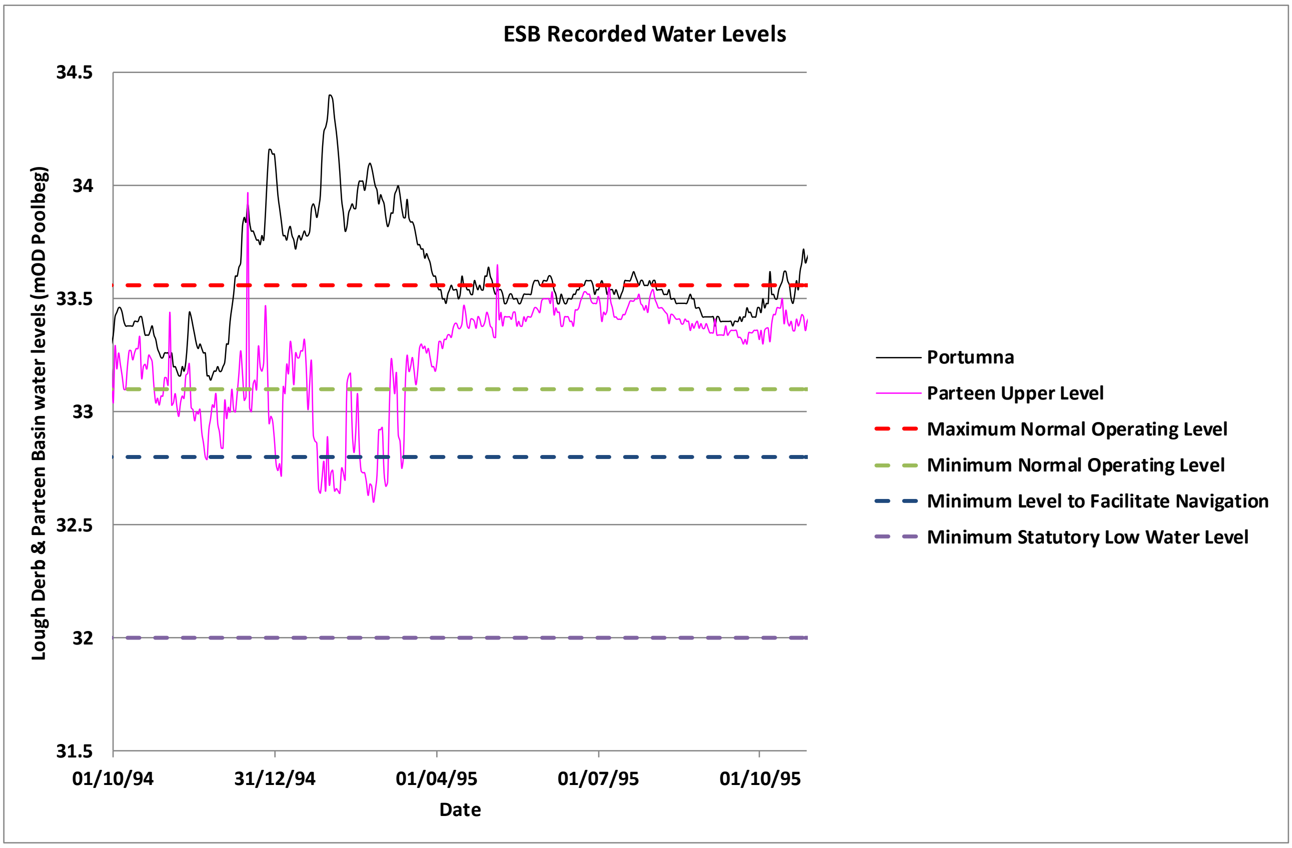

Figure 9: Recorded water levels at Portumna and Parteen Weir for period of present study

Thus the remaining river flows for the 1994/1995 period for the fifteen catchments draining to Lough Derg / Parteen Basin were calculated using gauged area transposition from adjoining / adjacent gauged catchments. The hydrographs for all inflows are presented in Figure 10. The hydrographs for the nineteen smaller river boundaries are presented separately in Figure 11 for clarity.

The River Shannon at Portumna, as calculated, accounted for 82.1% of the inflows to Lough Derg during the 1994/1995 period. The four river catchments accounted for 13.2%. The other fifteen river catchments combined, for which inflows were extrapolated based on gauge area transposition, represented approximately 5% of the total inflows to Lough Derg / Parteen Basin.

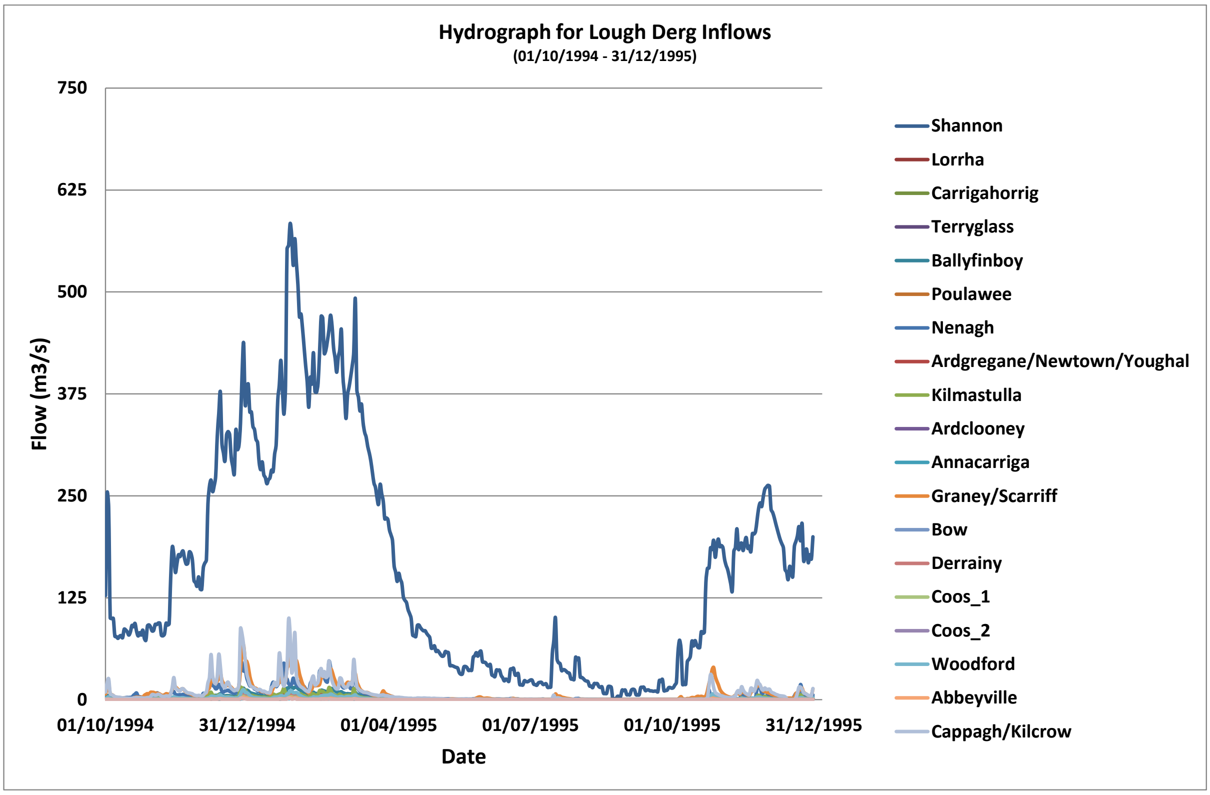

Figure 10: Hydrograph of all Lough Derg inflows (Oct 1994 – Dec 1995)

The outflowing boundary condition represented the combined discharge down the Headrace Canal and through the sluices at Parteen Weir and was specified from average daily values provided by ESB for the 1994/1995 period. The outflow boundary was defined as the sum of the recorded daily average flow through Ardnacrusha and the calculated average daily flow through Parteen Weir.

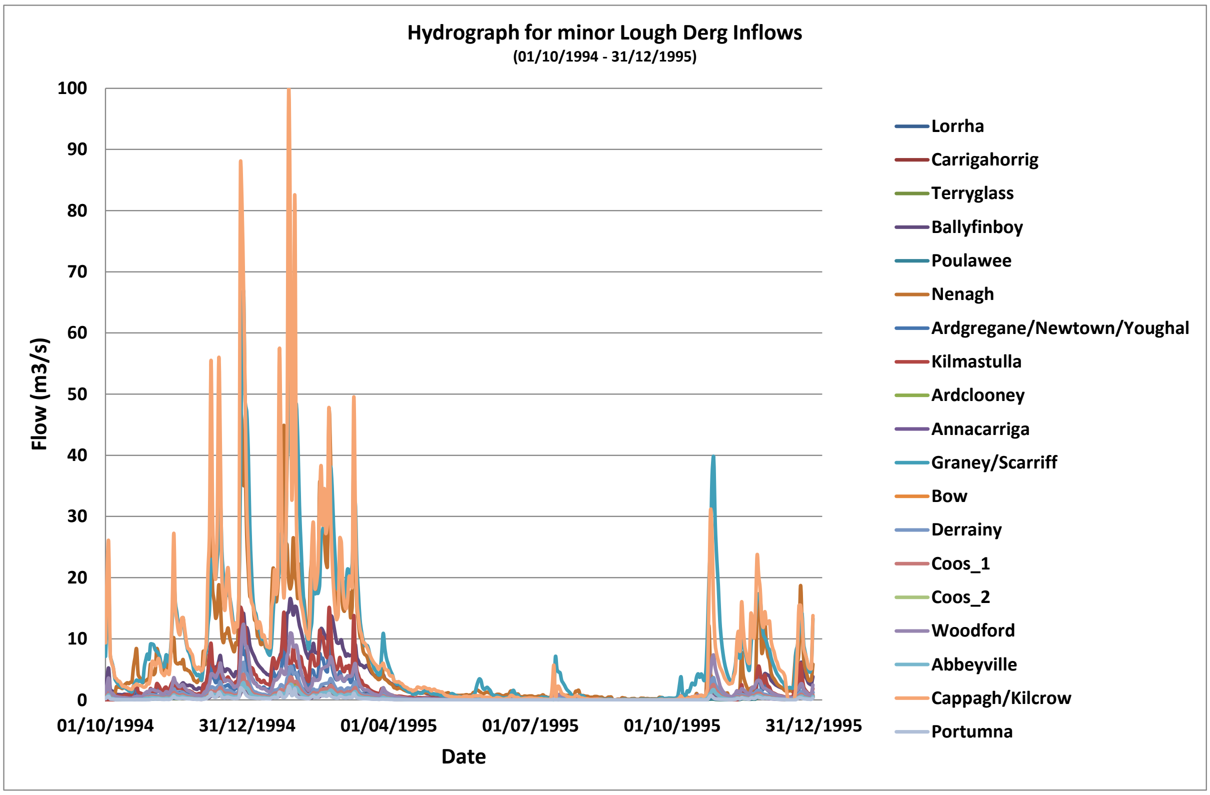

Figure 11: Hydrograph of Lough Derg inflows excluding River Shannon (Oct 1994 – Dec 1995)

3.1.3. Boundary Modifications

To account for the change in volume of the lake water due to evaporation, recourse was made to the ESB's management strategy for the maintenance of water levels. The difference in water levels from one day to the next recorded across the Portumna, Killaloe and Parteen Weir water levels (and allowing for discharge through Parteen Weir and Ardnacrusha) produces a change in storage within Lough Derg and Parteen Basin. This daily change in storage is the balance of total inflowing waters to the lake less all discharges (incl. evaporation) over the course of a given day. Knowing the change in storage, and the discharges from the lake, it was possible to back-route the flows and calculate what the net inflow to the lake was for any given day. The ESB's recorded outflows and back-routed calculations for the Lough Derg inflows are presented in Figure 12.

The ESB's back-routed inflows to Lough Derg were compared against the total inflows modelled for the present study. This comparison was done for instantaneous inflows, as presented in Figure 13. The modelled inflows show relatively good agreement against the ESB's back-routed calculations during winter 1994-1995 and spring 1995, but the modelled inflows are appreciably greater than the calculated inflows during the April – October 1995 period as shown below in Figure 13.

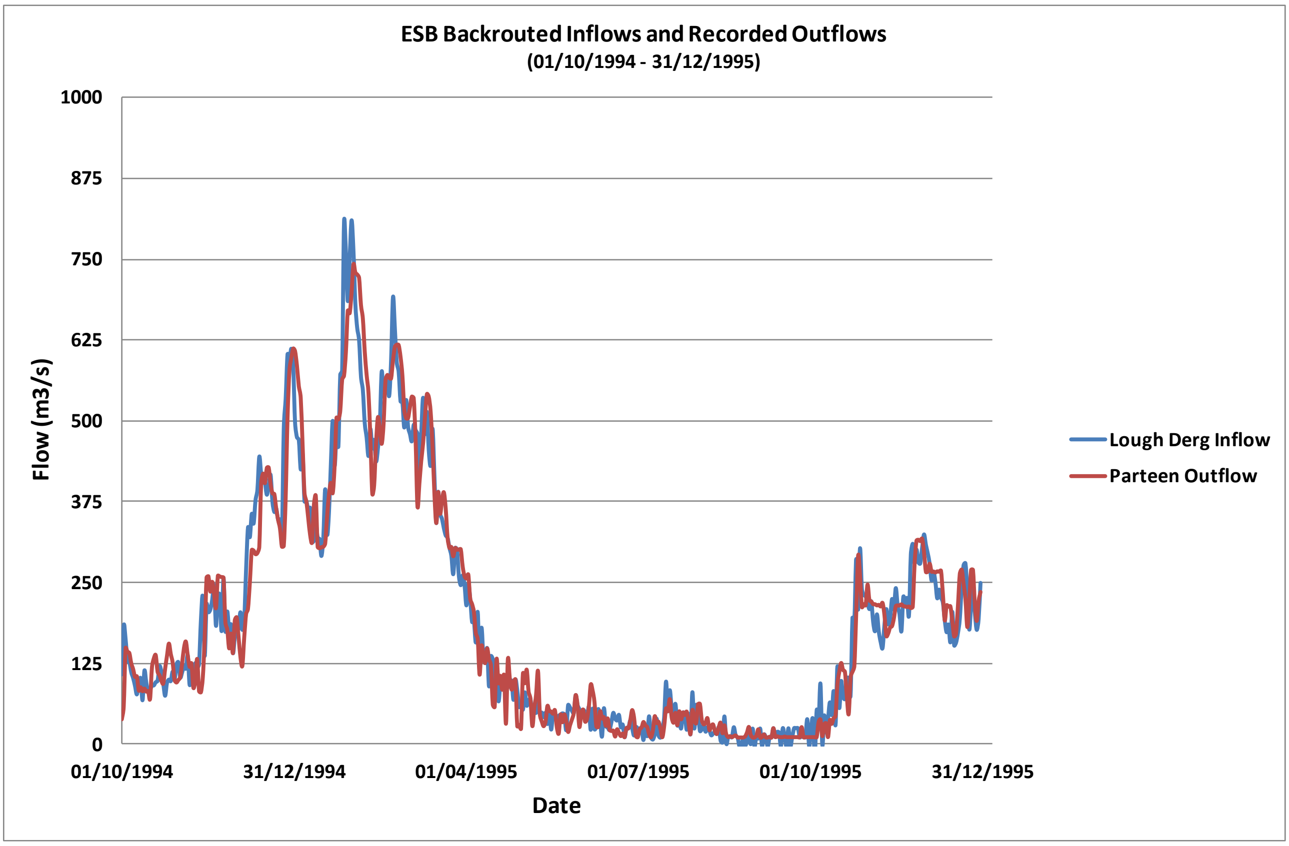

Figure 12: ESB back-routed inflows and recorded outflows.

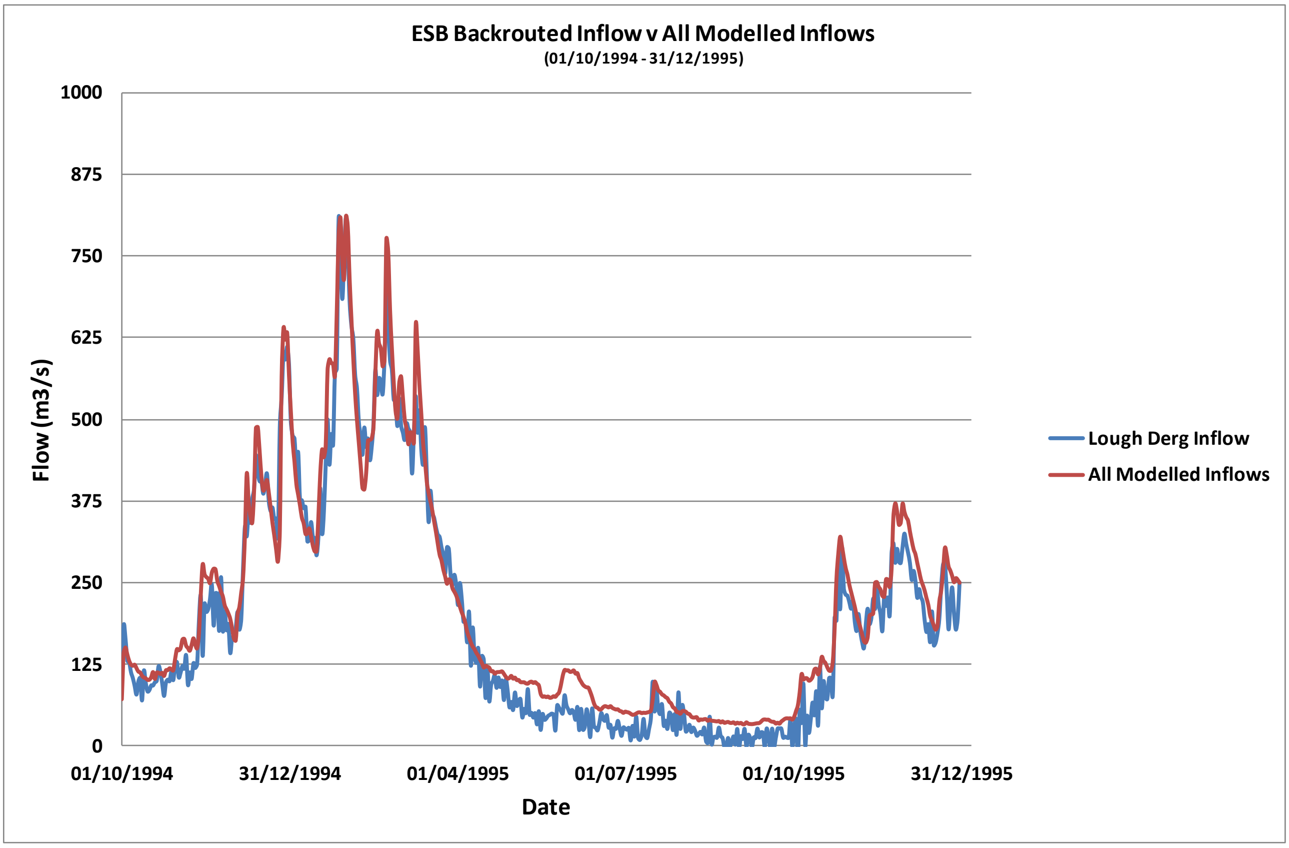

Figure 13: ESB Backrouted Inflows and All Modelled Inflows

This increase of flow through the lake during the summer and autumn seasons was attributed to the exclusion of the evaporation boundary layer at the lake's surface (as mentioned previously), rather than a systemic error in the modelling of the main Shannon inflow/outflow and the nineteen smaller river inflows.

All inflows to Lough Derg were adjusted through the application of a correction factor, derived from the ESB's back-routed calculation of daily average flows into Lough Derg, which account for the effects of evaporation on the water body.

The correction factor applied an average weekly modification to the modelled inflows from 1st April 1995 to 31st October 1995. The effect of employing the correction factors is presented in Figure 14, showing all modelled inflows and corrected modelled inflows against the ESB's back-routed calculated inflow.

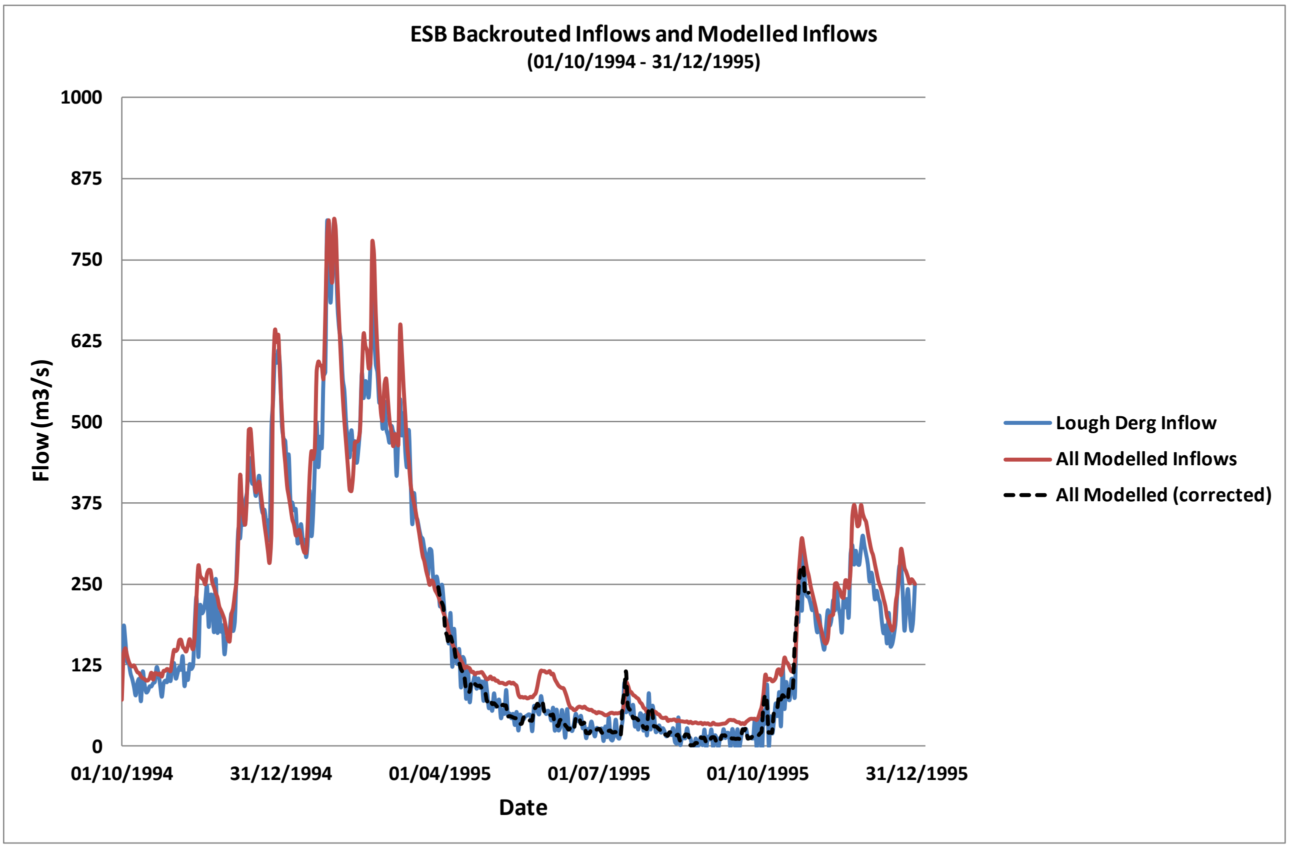

Figure 14: ESB back-routed inflows, all modelled inflows and corrected modelled inflows

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4. FLUSHING TIME METHOD

Many definitions of the term flushing time exist in the literature and it is often used interchangeably with other characteristics describing the water exchange processes, predominantly with the term residence time. The definition of flushing time used in this study is described as follows.

Considering that the mass of material contained within a certain area in a reservoir at time t=0 to be M_0, and the amount of the material which still remains in that area of the reservoir at time t to be $M_{(t)}$, the flushing time distribution function, ψ(t), of the material can be defined as:

$$\varphi(t) = -\frac{1}{M_o}\frac{dM(t)}{dt} \qquad (1)$$

$M_{(t)}$ then is the amount of the material whose flushing time is larger than t. Thus, the average flushing time, T_f, is given by:

$$T_f = \int_0^{\infty} t\varphi(t)\,dt \qquad (2)$$

Introducing a remnant function, r(t), such that:

$$r(t) = \frac{M(t)}{M_o} \qquad (3)$$

equation (2) can be re-written to show that:

$$T_f = \int_0^{\infty} r(t)dt \qquad (4)$$

For a reservoir of constant volume, the mass of the material in equations (1) and (3) can be replaced by its concentration. It has also been shown in literature that in a well-mixed body of water T_f equals the e-folding time, T_e, which is the time required to reduce the initial mass of an instantaneous injection of a tracer by a factor of e, (ie. to approximately 37% of initial concentration).

This definition of flushing time is based on detailed spatial distribution of tracer in the waterbody and on tracking temporal changes of its content, and therefore it can be easily applied in conjunction with numerical model simulations to examine spatio-temporal transport pathways in the waterbody.

To summarise, the flushing time for each computational cell in the model domain can be calculated as the time required to reduce the initial concentration of a solute to 37% of that initial value.

5. MODEL SCENARIOS

5.1. Scenario Five: Summer - baseline (no abstraction)

This scenario simulated the existing hydrodynamic regime in Lough Derg during summer low flow conditions.

The model was initialised from cold start conditions of zero velocity fields with an initial water surface level of 33.3m OD commensurate with recorded data.

All in-flowing and out-flowing boundaries were specified with the respective flows from the hydrographs previously presented.

The model was spun up for a 31 day period to ensure a realistic hydrodynamic regime had developed throughout the water body, from 1st Mar 1995 to 1st Apr 1995, at which point a hot-start restart file was created.

The flushing time analysis simulation was then initialised from the hot-start file on 1st Apr 1994 and was executed for a 215 day period from 1st Apr 1995 to 31st Oct 1995.

An initial 100.0 mg/l concentration of conservative tracer was specified uniformly throughout the water body. All inflowing rivers were specified with a constant 0.0 mg/l concentration.

5.2. Scenario Six: Summer - constant abstraction in northeast Lough Derg

This scenario simulated the hydrodynamic regime in Lough Derg during summer low flow conditions with constant abstraction located in the northeastern corner of Lough Derg at coordinates 588500E 702800N. This scenario had been investigated as Option B during the SEA process.

The abstraction was defined at a constant rate of 350 Ml/day (4.05 m^3/s). The flow through the downstream boundary at Parteen Weir / Ardnacrusha Headrace was reduced accordingly to compensate for the abstraction rate, whilst maintaining the statutory minimum flow of 10m^3/s to the natural course of the River Shannon through Parteen Weir.

For the majority of the time this resulted in no change in water level as the abstraction was compensated for by reducing the Ardnacrusha power generation flow. However, during periods when Ardnacrusha was not generating power (i.e. drought periods) the simulated abstraction continues abstracting water. This resulted in additional water being abstracted from the system during drought conditions. Once the drought had concluded the deficit in water volume was recovered by reducing the Ardnacrusha power generation flow, until such time as water levels return to what they would have been had there been no abstraction.

The abstraction profile and compensated outflows through Parteen Weir / Ardnacrusha Headrace are presented below in Figure 15. The changes to water level due to the constant abstraction regime are presented in Figure 16.

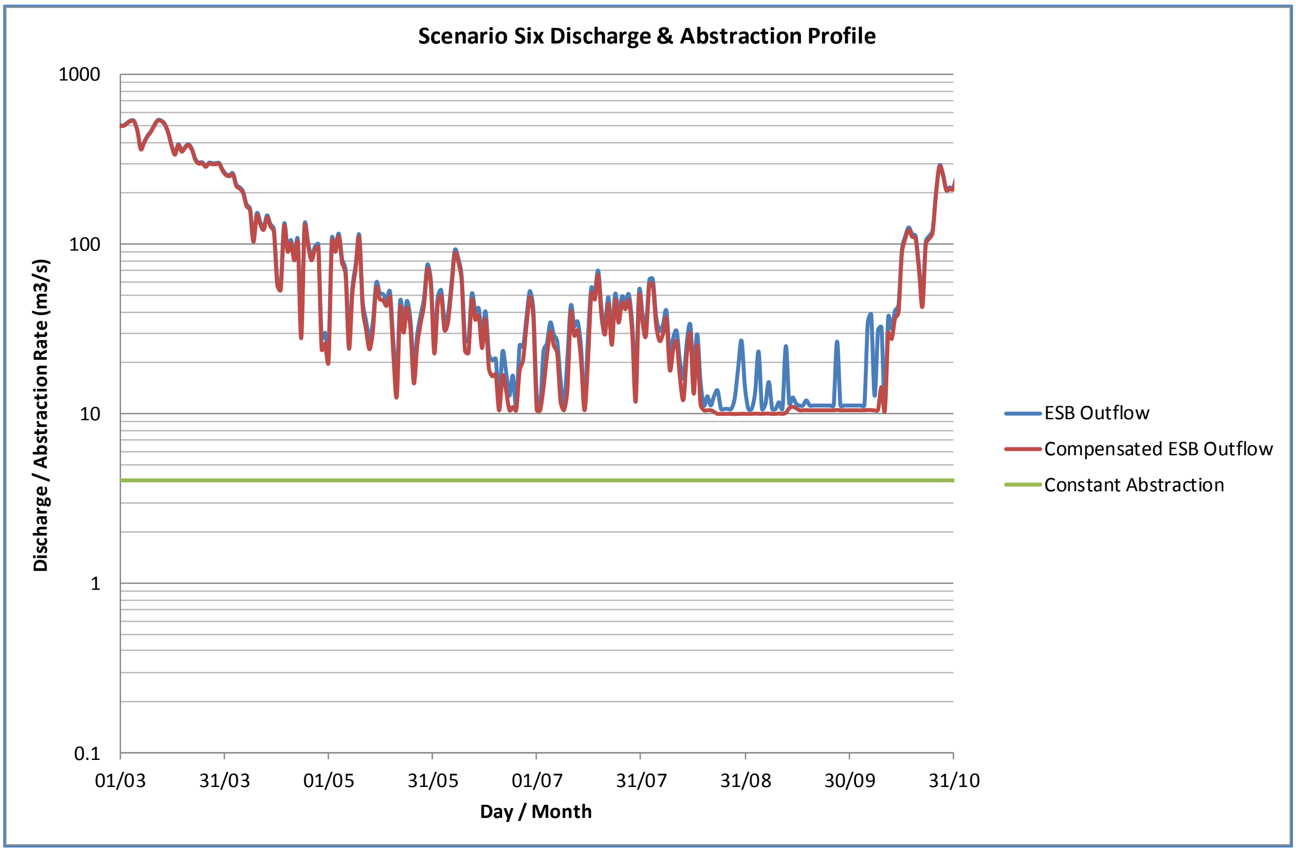


Figure 15: Scenario Six - ESB Discharge Profiles and Abstraction Profile

The model was initialised from cold start conditions of zero velocity fields with an initial water surface level of 33.3m OD commensurate with recorded data.

The model was spun up for a 31 day period to ensure a realistic hydrodynamic regime had developed throughout the water body, from 1st Mar 1995 to 1st Apr 1995, at which point a hot-start restart file was created.

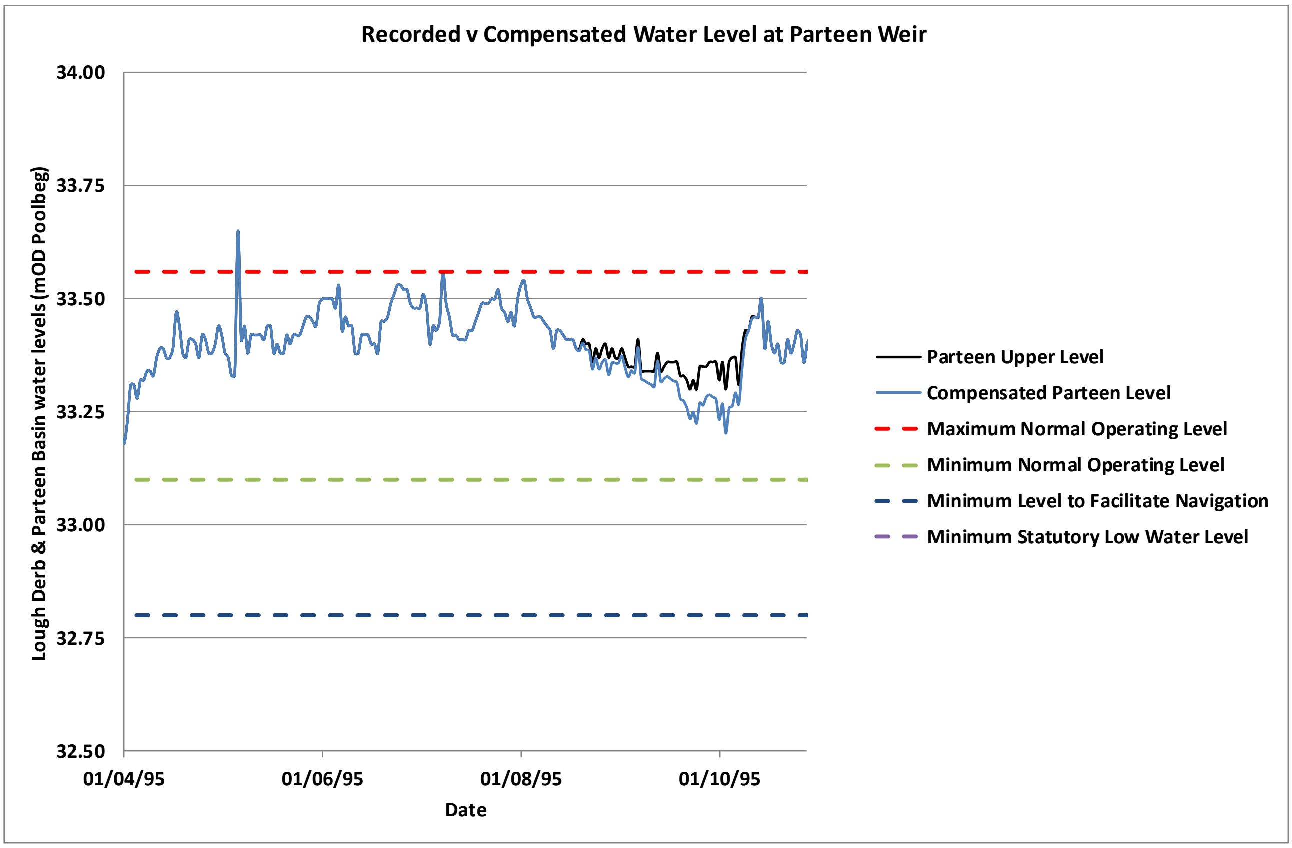


Figure 16: Scenario Six – Recorded v Compensated water levels due to constant abstraction profile.

The flushing time analysis simulation was then initialised from the hot-start file on 1st Apr 1994 and was executed for a 215 day period from 1st Apr 1995 to 31st Oct 1995.

An initial 100.0 mg/l concentration of conservative tracer was specified uniformly throughout the water body. All inflowing rivers were specified with a constant 0.0 mg/l concentration.

5.3. Scenario Seven: Summer - variable abstraction in northeast Lough Derg

This scenario simulated the hydrodynamic regime in Lough Derg during summers flow conditions with a variable abstraction located in the northeastern corner of Lough Derg at coordinates 588500E

702800N. This scenario is associated with raw water storage at Garryhinch in the midlands and had been investigated as Option F2 during the SEA process

The abstraction was defined as having a variable rate of abstraction over the course of a year. For two months of the year, from 15th August to 15th October the abstraction operates at a rate of 50 Ml/day (0.579 m^3/s), for the remaining 10 months of the year the abstraction operates at a rate of 410 Ml/day (4.745 m^3/s).

The flow through the downstream boundary at Parteen Weir / Ardnacrusha Headrace was reduced accordingly to compensate for the variable abstraction rate, whilst maintaining the statutory minimum flow of $10m^3/s$ to the natural course of the River Shannon through Parteen Weir. This proposed abstraction profile resulted in no change in water level. The abstraction profile and compensated outflows through Parteen Weir / Ardnacrusha Headrace are presented in Figure 17.

The model was initialised from cold start conditions of zero velocity fields with an initial water surface level of 33.3m OD commensurate with recorded data.

The model was spun up for a 31 day period to ensure a realistic hydrodynamic regime had developed throughout the water body, from 1st Mar 1995 to 1st Apr 1995, at which point a hot-start restart file was created. The flushing time analysis simulation was then initialised from the hot-start file on 1st Apr 1994 and was executed for a 215 day period from 1st Apr 1995 to 31st Oct 1995.

An initial 100.0 mg/l concentration of conservative tracer was specified uniformly throughout the water body. All inflowing rivers were specified with a constant 0.0 mg/l concentration.

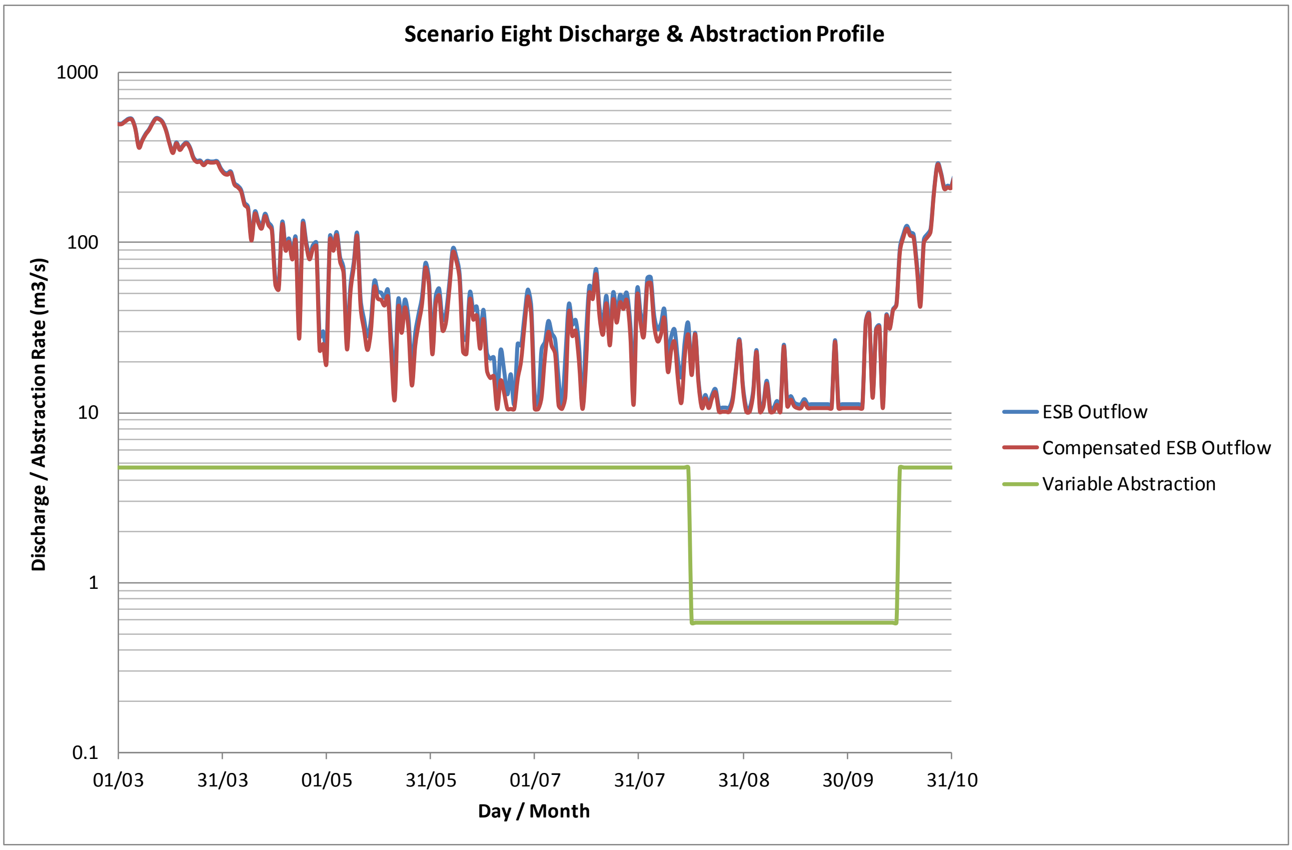


Figure 17: Scenario Seven - ESB Discharge Profiles and Abstraction Profile

5.4. Scenario Eight: Summer - constant abstraction in Parteen Basin

This scenario simulated the hydrodynamic regime in Lough Derg during summer flow conditions with constant abstraction located in Parteen Basin at coordinates 570000E 670800N. This scenario had been investigated as Option C during the SEA process.

The abstraction was defined at a constant rate of 350 Ml/day (4.05m^3/s). The flow through the downstream boundary at Parteen Weir / Ardnacrusha Headrace was reduced accordingly to compensate for the abstraction rate, whilst maintaining the statutory minimum flow of 10m^3/s to the natural course of the River Shannon through Parteen Weir.

Similar to scenario six (northeast constant abstraction), for the majority of the time this resulted in no change in water level as the abstraction was compensated for by reducing the Ardnacrusha power generation flow. However, during periods when Ardnacrusha was not generating power (i.e. drought periods) the simulated abstraction continues abstracting water. This resulted in additional water being abstracted from the system during drought conditions. Once the drought had concluded the deficit in water volume was recovered by reducing the Ardnacrusha power generation flow, until such time as water levels return to what they would have been had there been no abstraction.

The abstraction profile and compensated outflows through Parteen Weir / Ardnacrusha Headrace were presented previously in Figure 15. The changes to water level due to the constant abstraction regime wre presented previously in Figure 16.

The model was initialised from cold start conditions of zero velocity fields with an initial water surface level of 33.3m OD commensurate with recorded data.

The model was spun up for a 31 day period to ensure a realistic hydrodynamic regime had developed throughout the water body, from 1st Mar 1995 to 1st Apr 1995, at which point a hot-start restart file was created.

The flushing time analysis simulation was then initialised from the hot-start file on 1st Apr 1994 and was executed for a 215 day period from 1st Apr 1995 to 31st Oct 1995.

An initial 100.0 mg/l concentration of conservative tracer was specified uniformly throughout the water body. All inflowing rivers were specified with a constant 0.0 mg/l concentration.

5.5. Scenario Nine: Summer - 450:50 variable abstraction in NE Lough Derg

This scenario simulated the hydrodynamic regime in Lough Derg during summers flow conditions with a variable abstraction located in the northeastern corner of Lough Derg at coordinates 588500E 702800N. This scenario is associated with raw water storage at Garryhinch in the midlands and had been investigated as Option F2 during the SEA process

The abstraction was defined as having a variable rate of abstraction over the course of a year. For three months of the year, from 15th July to 15th October the abstraction operates at a rate of 50 Ml/day (0.579 m^3/s), for the remaining 9 months of the year the abstraction operates at a rate of 450 Ml/day (5.208m^3/s).

The flow through the downstream boundary at Parteen Weir / Ardnacrusha Headrace was reduced accordingly to compensate for the variable abstraction rate, whilst maintaining the statutory minimum flow of 10m^3/s to the natural course of the River Shannon through Parteen Weir. This proposed abstraction profile resulted in no change in water level. The abstraction profile and compensated outflows through Parteen Weir / Ardnacrusha Headrace are presented in Figure 18 .

The model was initialised from cold start conditions of zero velocity fields with an initial water surface level of 33.3m OD commensurate with recorded data.

The model was spun up for a 31 day period to ensure a realistic hydrodynamic regime had developed throughout the water body, from 1st Mar 1995 to 1st Apr 1995, at which point a hot-start restart file was created. The flushing time analysis simulation was then initialised from the hot-start file on 1st Apr 1994 and was executed for a 215 day period from 1st Apr 1995 to 31st Oct 1995.

An initial 100.0 mg/l concentration of conservative tracer was specified uniformly throughout the water body. All inflowing rivers were specified with a constant 0.0 mg/l concentration.

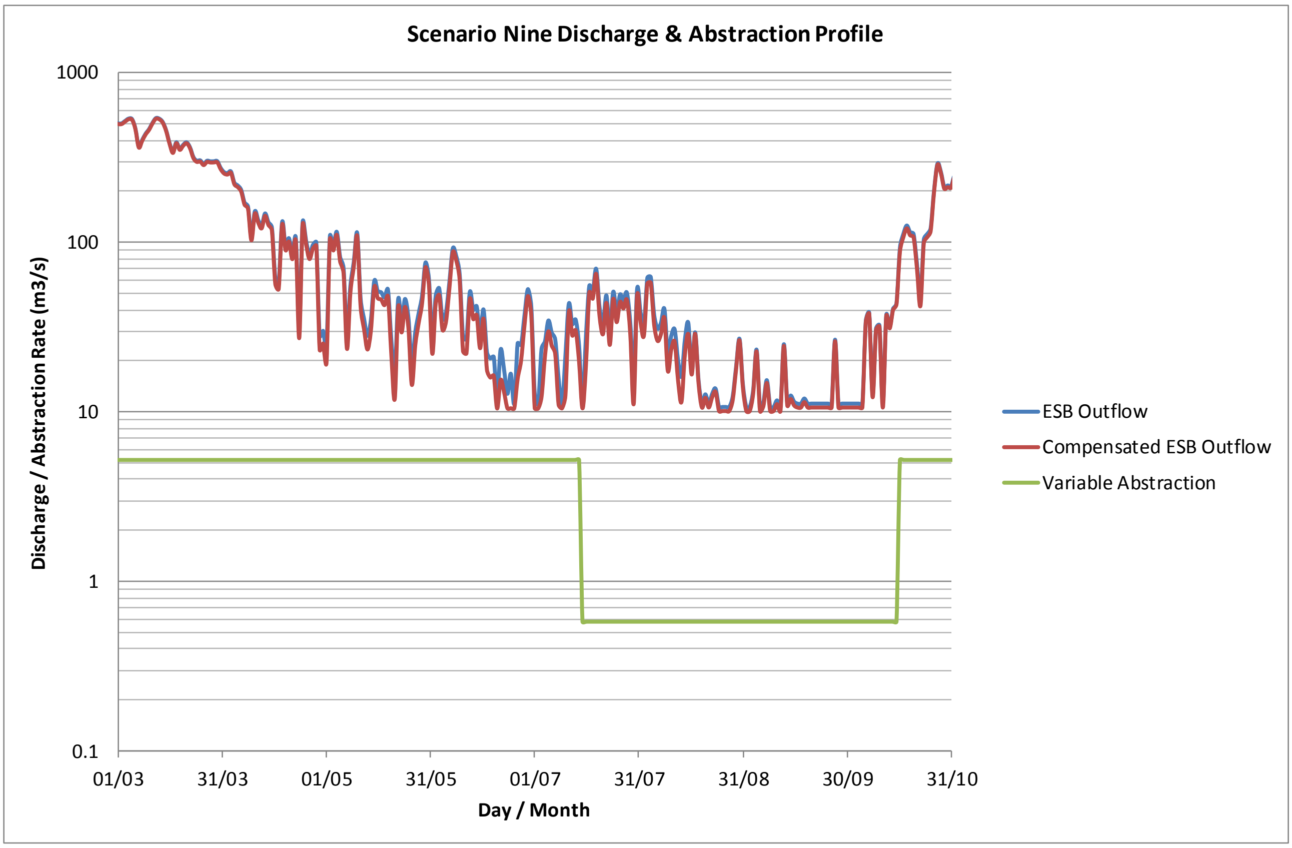


Figure 18: Scenario Nine - ESB Discharge Profiles and Abstraction Profile

5.6. Summary of Scenarios

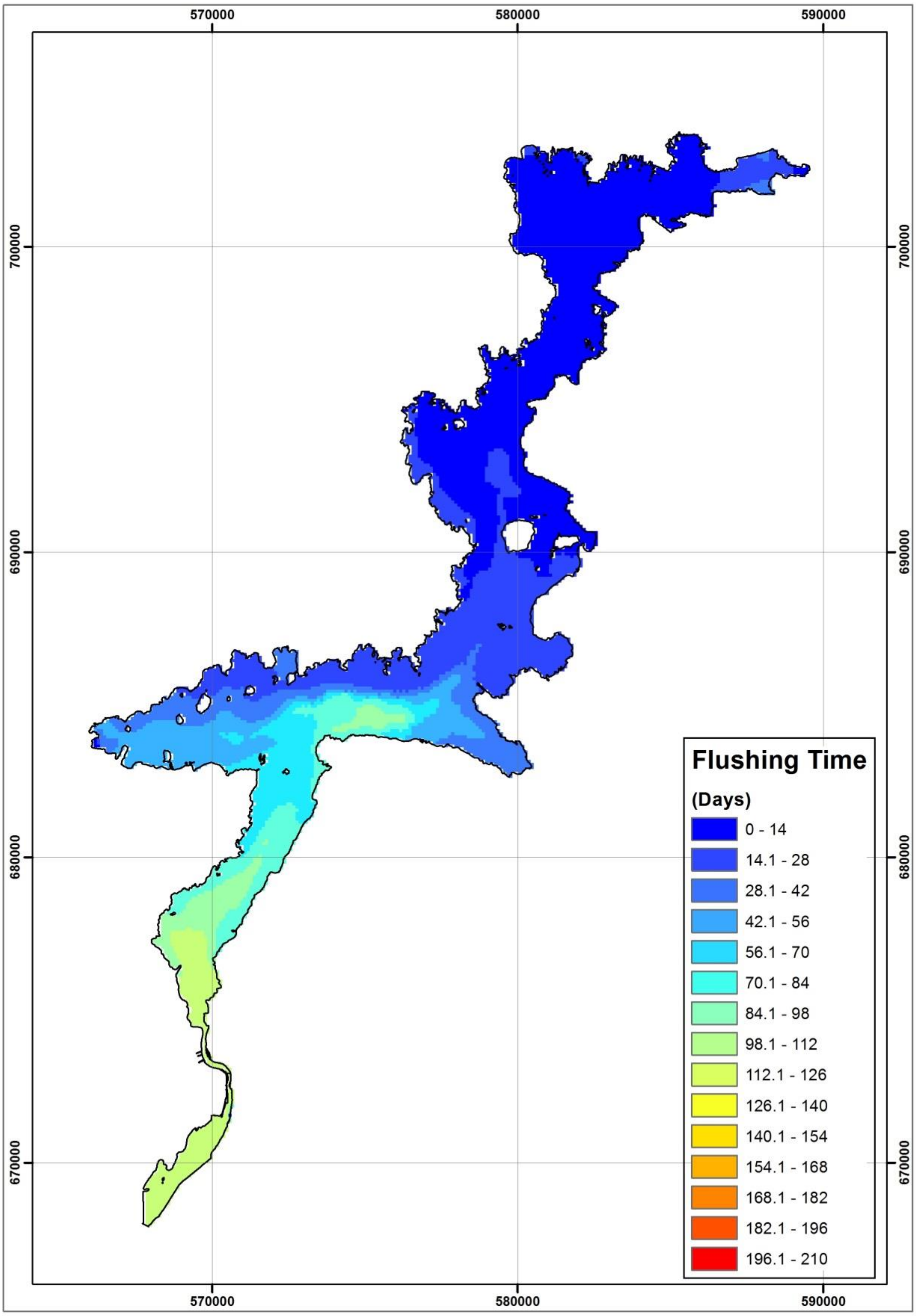
The above scenarios are summarised in the table below.

Scenario	Abstraction		Season	Spin-up Period	Simulation Period
	Location	Rate			
5	n/a	n/a	Summer	01/03/95 – 01/04/95	01/04/95 – 31/10/95
6	Northeast	350 Ml/d			
7	Northeast	410 : 50 Ml/d			
8	Parteen	350 Ml/d			
9	Northeast	450 : 50 Ml/d			

6. MODEL RESULTS

The results from the eight model scenarios are presented in this section. The results presented are the spatially varying flushing times as calculated for each scenario, along with a table defining the parameters of the scenario.

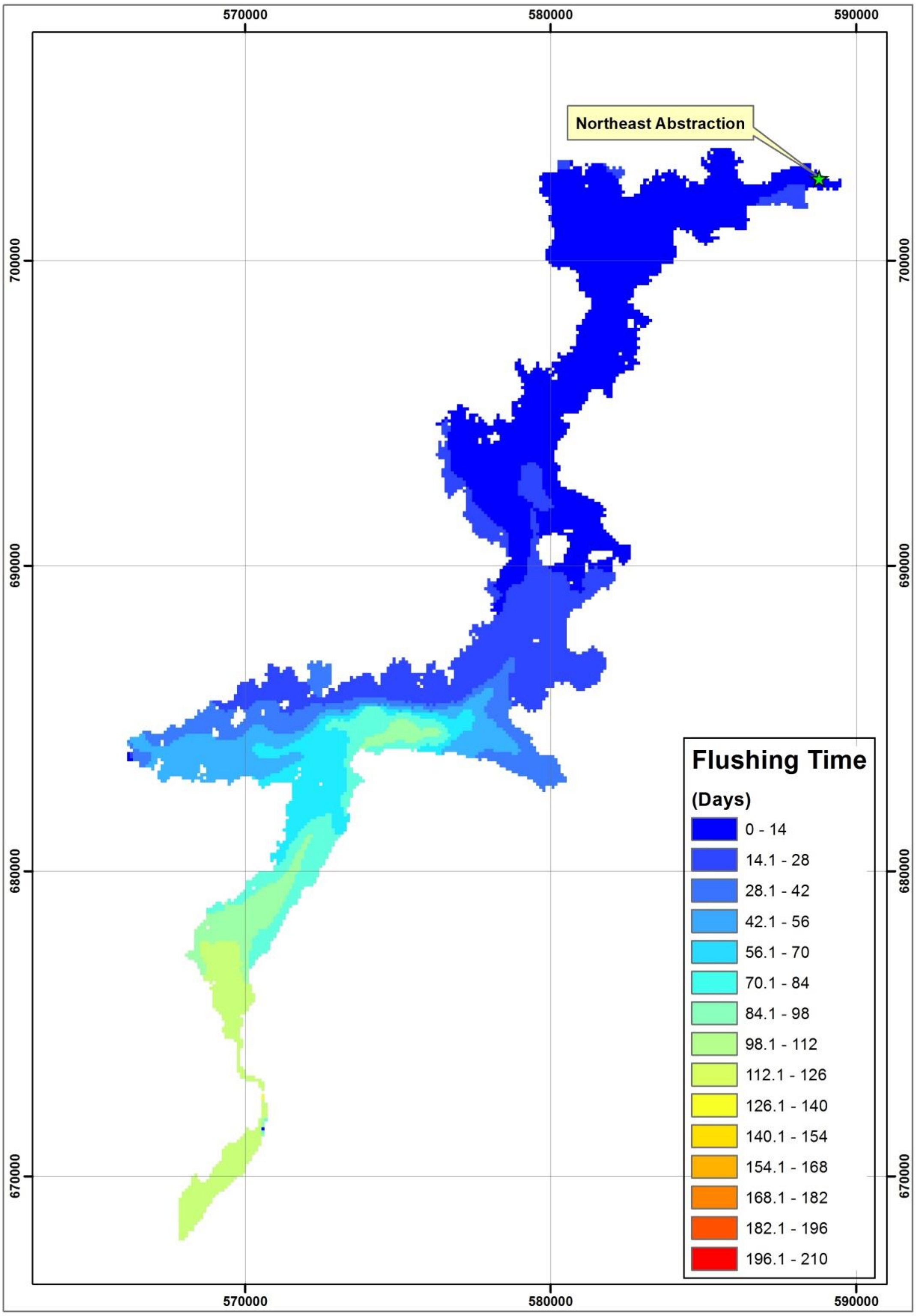
6.1. Scenario Five: Summer - baseline (no abstraction)



Scenario	Abstraction Location	Rate	Season	Spin-up Period	Simulation Period
5	n/a	n/a	Summer	01/03/95 – 01/04/95	01/04/95 – 31/10/95

Figure 19: Scenario Five: Flushing Time

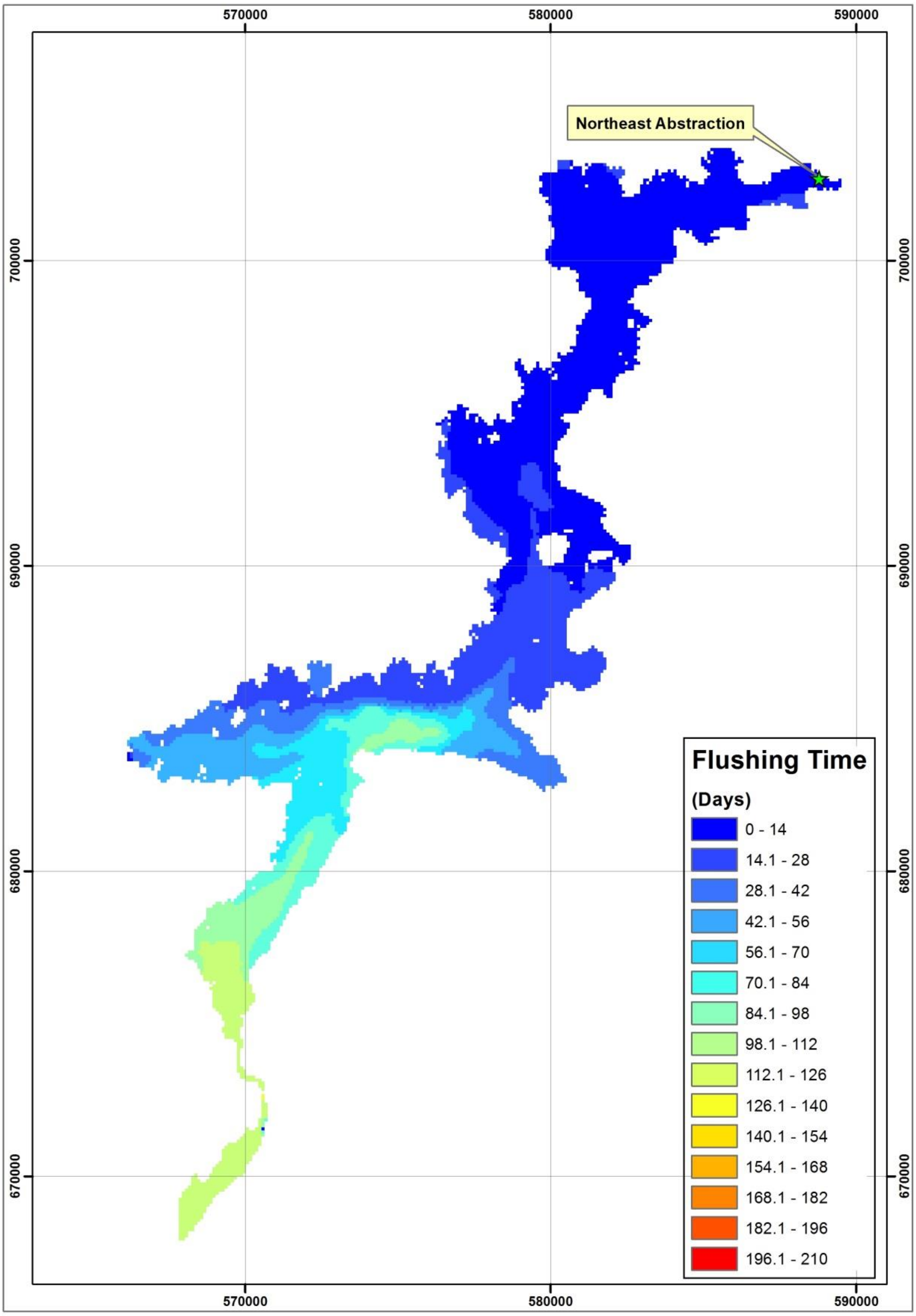
6.2. Scenario Six: Summer - constant abstraction in northeast Lough Derg



Scenario	Abstraction		Season	Spin-up Period	Simulation Period
	Location	Rate			
6	Northeast	350 Ml/d	Summer	01/03/95 – 01/04/95	01/04/95 – 31/10/95

Figure 20: Scenario Six: Flushing Time

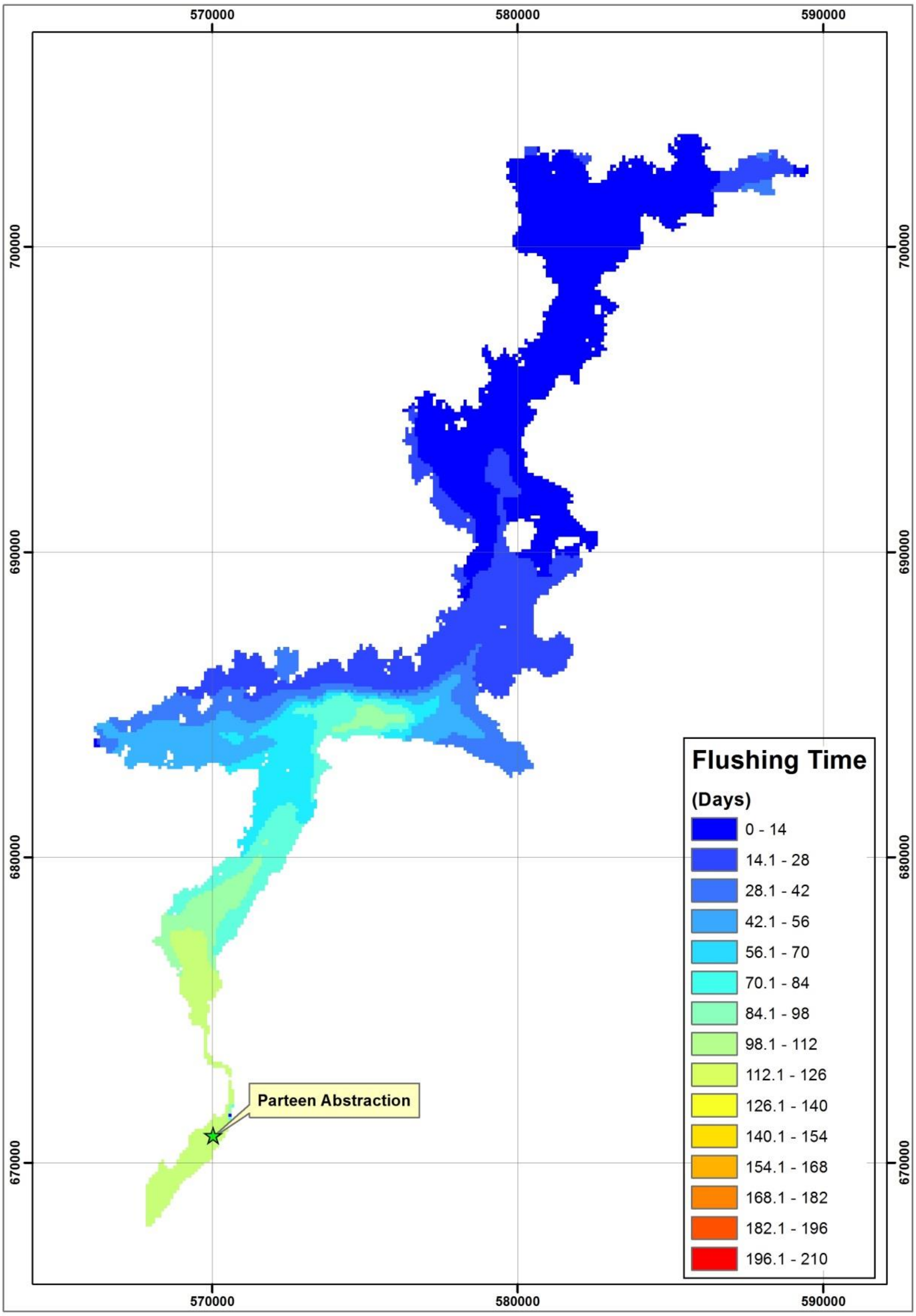
6.3. Scenario Seven: Summer - variable abstraction in northeast Lough Derg



Scenario	Abstraction Location	Rate	Season	Spin-up Period	Simulation Period
7	Northeast	410:50 Ml/d	Summer	01/03/95 – 01/04/95	01/04/95 – 31/10/95

Figure 21: Scenario Seven: Flushing Time

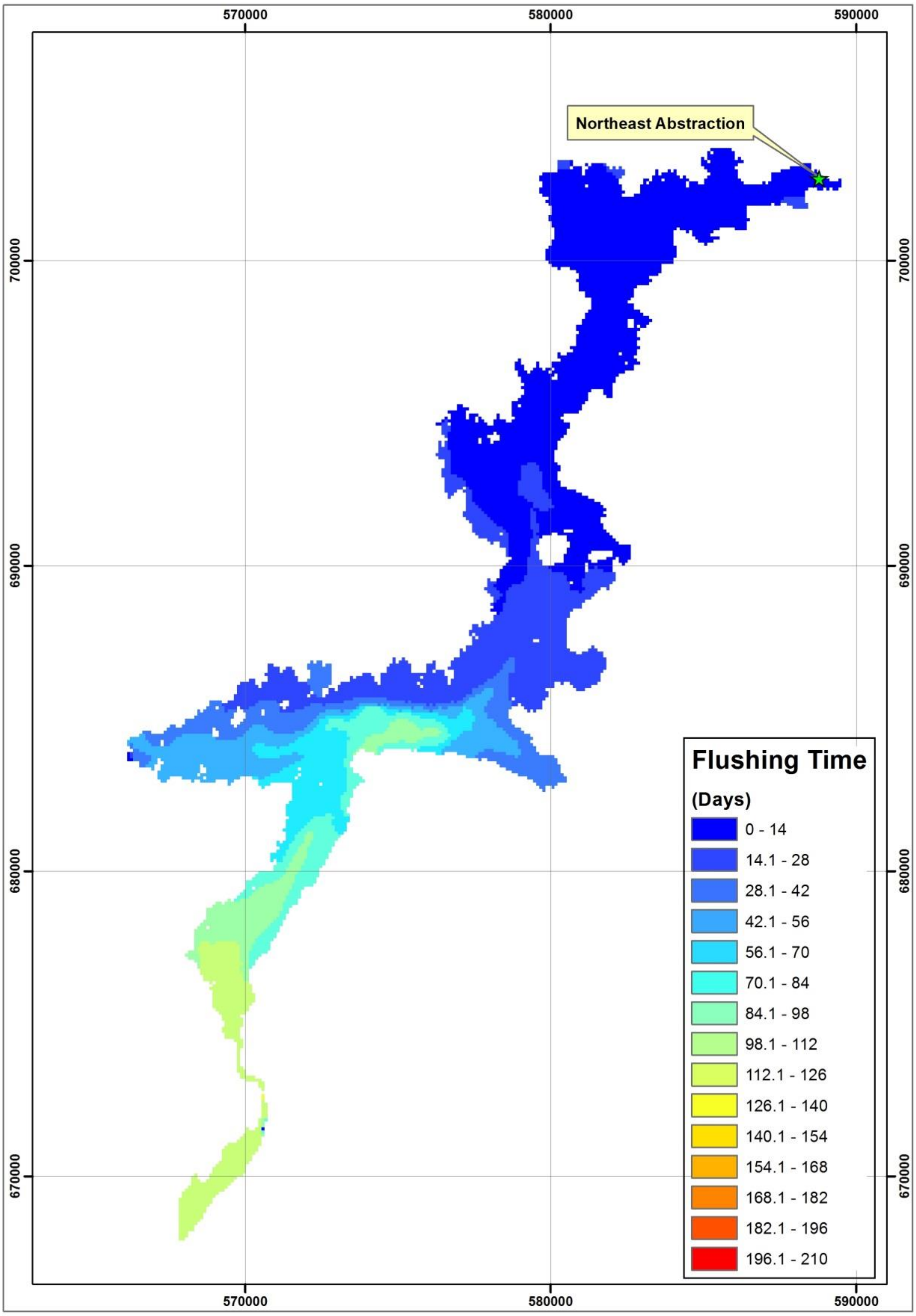
6.4. Scenario Eight: Summer - constant abstraction in Parteen Basin



Scenario	Abstraction Location	Rate	Season	Spin-up Period	Simulation Period
8	Parteen	350 Ml/d	Summer	01/03/95 – 01/04/95	01/04/95 – 31/10/95

Figure 22: Scenario Eight: Flushing Time

6.5. Scenario Nine: Summer – 450:50 variable abstraction in NE Lough Derg



Scenario	Abstraction Location	Rate	Season	Spin-up Period	Simulation Period
9	Northeast	450:50 Ml/d	Summer	01/03/95 – 01/04/95	01/04/95 – 31/10/95

Figure 23: Scenario Nine Flushing Time

7. ANALYSIS

Visual inspection of the above figures showed that there were significant spatial differences in flushing times throughout the Lough Derg and Parteen Basin waterbody for summer periods. Longest flushing time during summer months were approximately 120 days.

The locations featuring the shorter values of flushing time presented in the above figures are predicted to be faster to respond to changes in pollutant concentrations from the principal riverine input, namely the River Shannon. The corollary is that the areas with the longest flushing times were predicted to be the slowest to respond to changing pollutant loadings, and thus susceptible to excess nutrient accumulations.

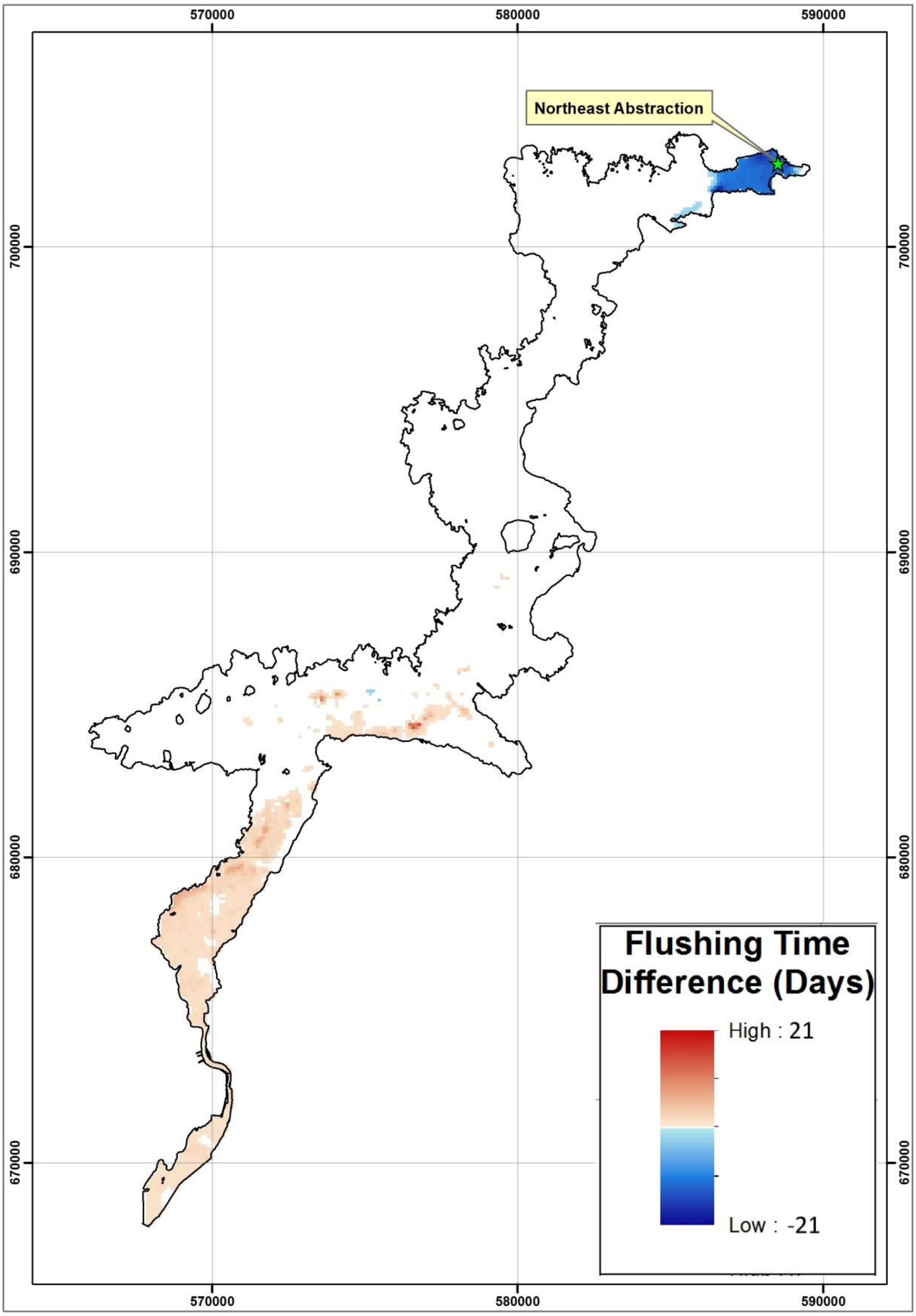
To determine if any of the modelled abstraction options resulted in significant changes to the flushing characteristics of the waterbody the following method was adopted; the calculated flushing time distributions for each modelled abstraction option were subtracted from the calculated baseline (no-abstraction) flushing times.

The resulting difference in flushing time was then plotted throughout the waterbody to determine the potential effects on flushing times above normal baseline conditions due to the various abstraction options. In all analyses, any small change in flushing time (+/-1 day) was blanked out.

The abstraction scenarios outlined in the table below are presented in the figures following.

Scenario	Abstraction Location	Rate	Season	Spin-up Period	Simulation Period
6	Northeast	350 Ml/d	Summer	01/03/95 – 01/04/95	01/04/95 – 31/10/95
7	Northeast	410 : 50 Ml/d			
8	Parteen	350 Ml/d			
9	Northeast	450 : 50 Ml/d			

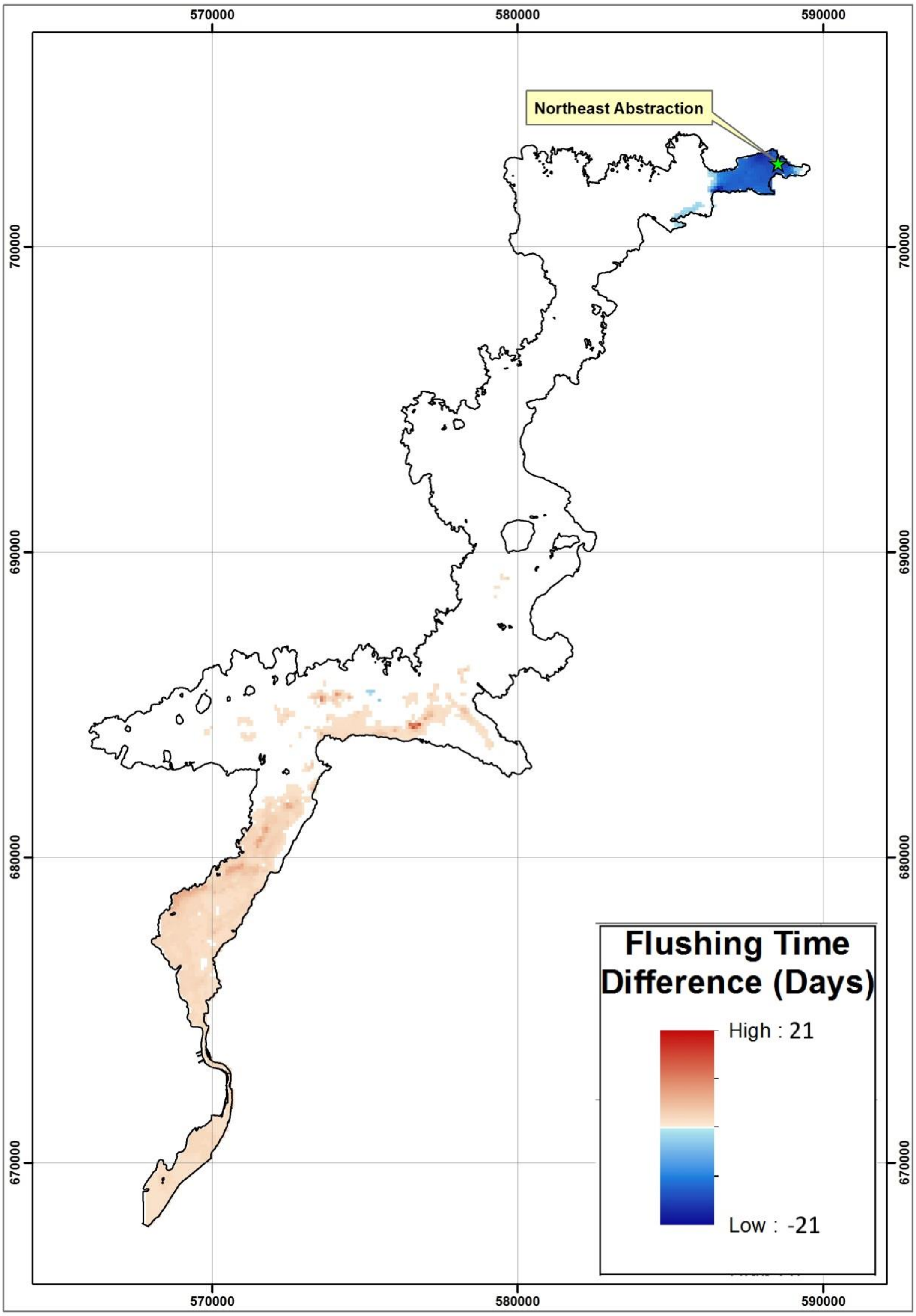
Scenario Six: Summer - constant abstraction in northeast Lough Derg



Scenario	Abstraction Location	Rate	Season	Spin-up Period	Simulation Period
6	Northeast	350 Ml/d	Summer	01/03/95 – 01/04/95	01/04/95 – 31/10/95

Figure 24: Scenario Six impact on Flushing Time

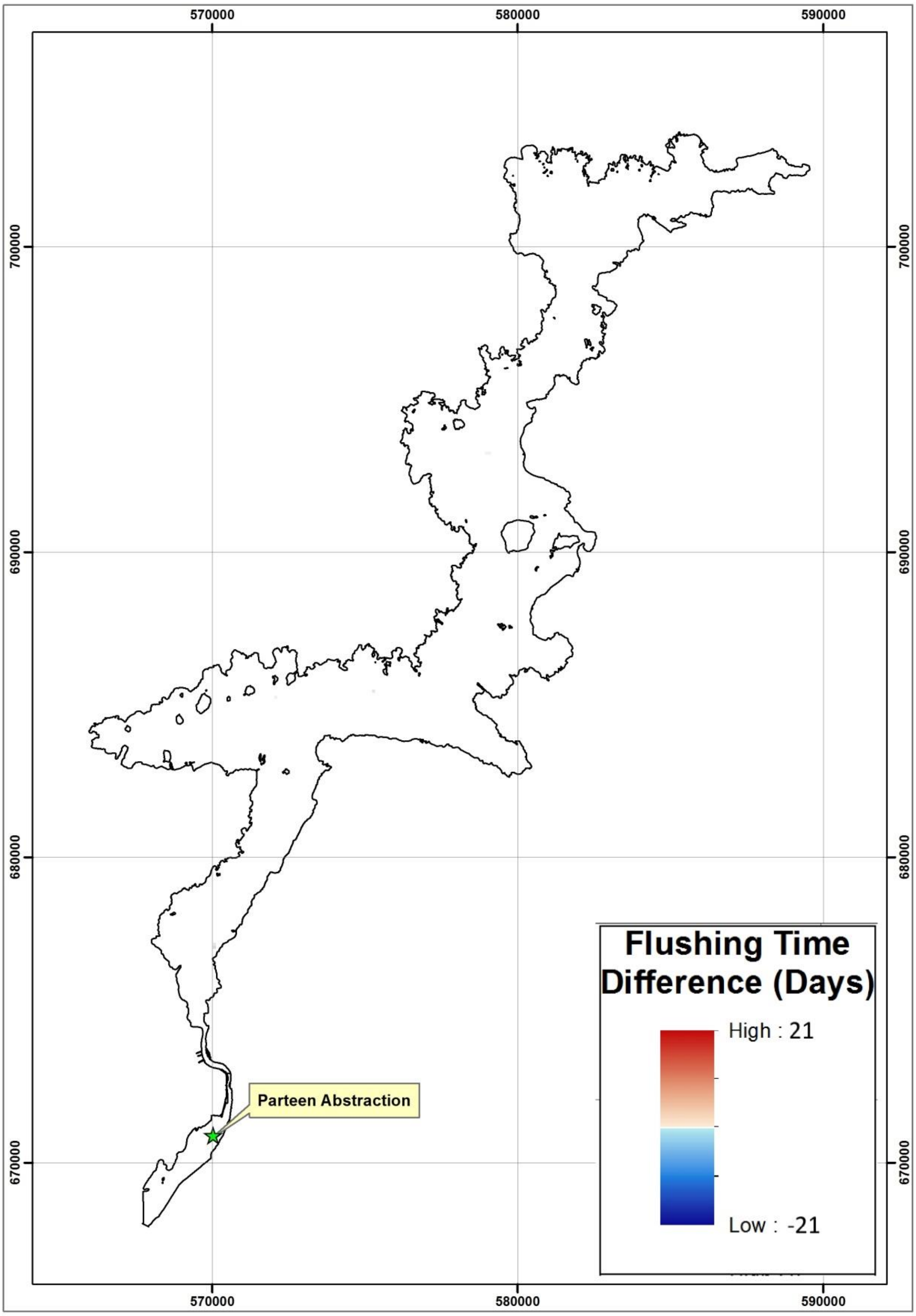
Scenario Seven: Summer – 410:50 variable abstraction in northeast Lough Derg



Scenario	Abstraction Location	Rate	Season	Spin-up Period	Simulation Period
7	Northeast	410:50 Ml/d	Summer	01/03/95 – 01/04/95	01/04/95 – 31/10/95

Figure 25: Scenario Seven impact on Flushing Time

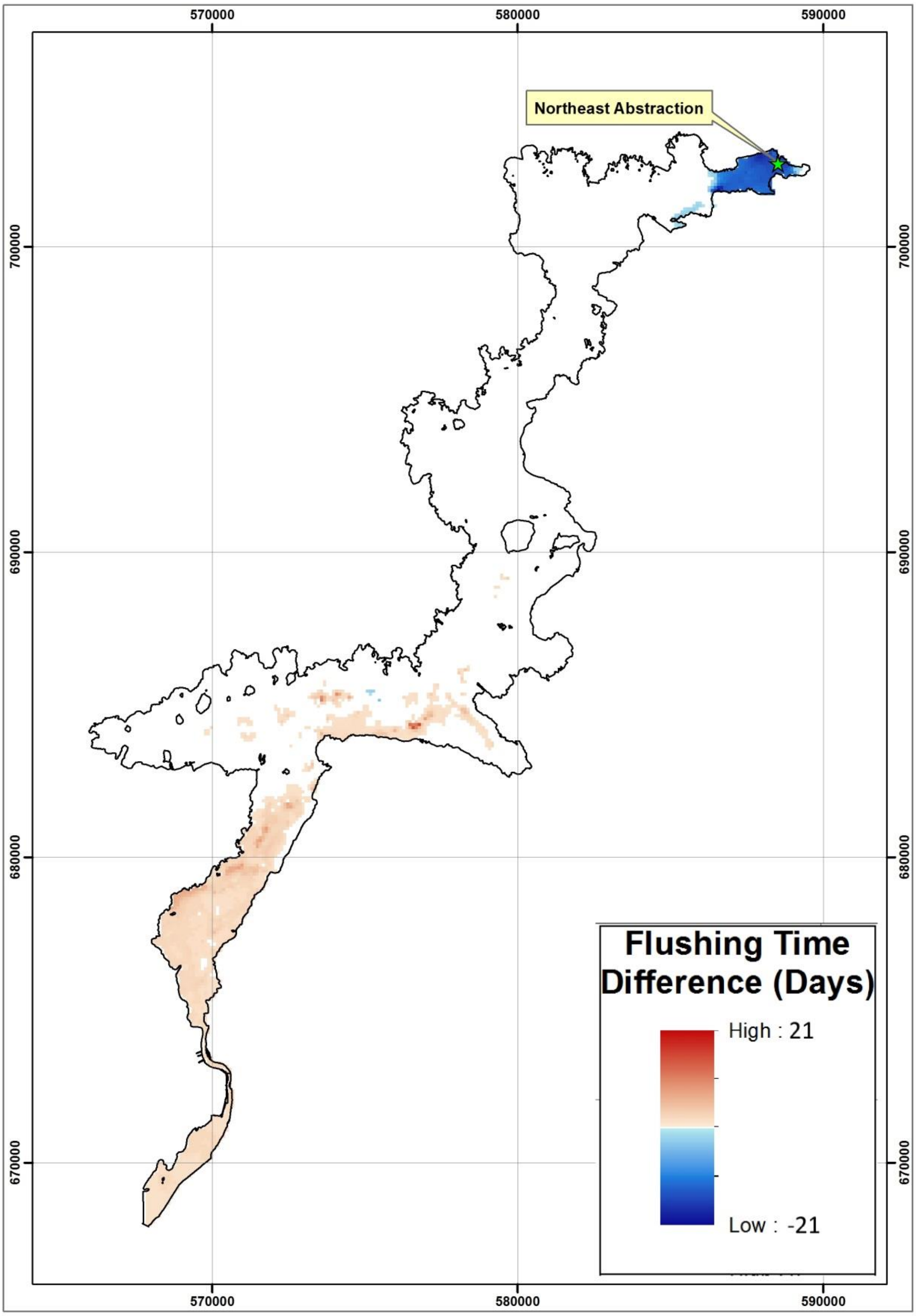
Scenario Eight: Summer - constant abstraction in Parteen Basin



Scenario	Abstraction Location	Rate	Season	Spin-up Period	Simulation Period
8	Parteen	350 Ml/d	Summer	01/03/95 – 01/04/95	01/04/95 – 31/10/95

Figure 26: Scenario Eight impact on Flushing Time

Scenario Nine: Summer – 450:50 variable abstraction in northeast Lough Derg



Scenario	Abstraction Location	Rate	Season	Spin-up Period	Simulation Period
9	Northeast	450:50 Ml/d	Summer	01/03/95 – 01/04/95	01/04/95 – 31/10/95

Figure 27: Scenario Nine impact on Flushing Time

8. DISCUSSION

Figure 24 to Figure 27 showing the effects of abstracting from Lough Derg / Parteen Basin during summer (low flow) conditions indicate that there were significant changes in flushing times in Lough Derg / Parteen Basin when abstracting from the northeast of Lough Derg versus abstracting from Parteen Basin.

8.1. Northeast abstraction

Scenarios involving an abstraction from northeast of Lough Derg at either constant or variable rates exhibit a reduction in the flushing time in Slevoir Bay, local to the abstraction location, and a corresponding increase in flushing time to the east of the abstraction point (Figure 24, Figure 25 and Figure 27). This is due to the abstraction's effect on the hydraulic flows, diverting water from the main flow in the Shannon into Slevoir Bay, thus increasing the water flow rate and rate of exchange of material.

Scenarios involving an abstraction from the northeast of Lough Derg at either constant or variable rates during summer low flow conditions exhibit an increase (maximum +16 days) in flushing times in the southern portions of Lough Derg when compared with the baseline conditions (Figure 24, Figure 25 & Figure 27).

The differences between the Summer baseline (scenario five) and constant 350 Ml/day abstraction (scenario six) were analysed. The mean increase in flushing time in the southern portion of Lough Derg / Parteen Basin was +1.91 days, with a maximum increase in flushing time at any one location of +16 days.

The differences between the Summer baseline (scenario five) and variable 410:50 Ml/day abstraction (scenario seven) were analysed. The mean increase in flushing time in the southern portion of Lough Derg / Parteen Basin was +2.05 days, with a maximum increase in flushing times at any one location of +16 days.

The differences between the Summer baseline (scenario five) and variable 450:50 Ml/day abstraction (scenario nine) were analysed. The mean increase in flushing time in the southern portion of Lough Derg / Parteen Basin was +2.13 days, with a maximum increase in flushing times at any one location of +16 days.

The reason for the increase in flushing times in the southern portion of Lough Derg / Parteen Basin was that the flows through the system for the period of simulation (01/04/1995 – 31/10/1995) were in general very low.

For constant and variable rates, the abstraction represented a very high percentage of that flow at the northeastern abstraction location. This resulted in a much reduced volume of water passing on through the system. The constant and variable abstraction regimes from the northeast of Lough Derg show increases in flushing times (+16 days increase) in the southern regions of the waterbody.

The difference in impacts of the three abstraction regimes is indiscernible spatially when comparing Figure 24, Figure 25 and Figure 27 against each other. The gross statistics describing the changes to flushing times for each abstraction regime are also very similar. This would indicate that there would be no noticeable differences in impacts on flushing times in Lough Derg between a constant abstraction and any of the proposed variable abstraction regimes.

The constant, 410:50 variable, and 450:50 abstraction regimes from the northeast of Lough Derg show increases in flushing times (maximum 16 days increase) in the southern regions of the waterbody. The difference in impacts of the three abstraction regimes is visually indiscernible spatially.

8.2. Parteen Basin abstraction

The scenario involving abstraction from Parteen Basin at a constant rate during summer low flow conditions show no change to flushing time characteristics in any region of Lough Derg and Parteen Basin when compared with the baseline conditions.

The reason the Parteen Basin abstraction did not cause any increase in the flushing time of Lough Derg was that the flow of water had already passed through the lake prior to encountering the abstraction point in Parteen Basin.

In the case of waterbodies, such as Lough Derg and Parteen Basin, that are not well-mixed horizontally (as evidenced from Figure 19), knowledge of the spatial detail in the distribution of flushing times may prove crucial when assessing its impact on water quality.

Due to higher exchange rates, water masses characterized by a short flushing time value experience more frequent changes in water quality parameters than those with long flushing times, in response to changes in water quality of ambient waters. It should be noted that the methodology adopted for this study was not pollutant specific and depicted only the general physical mixing processes in the system.

The reason for the large increase in flushing times in the southern portion of Lough Derg / Parteen Basin was that the flows through the system for the period of simulation (01/04/1995 – 31/10/1995) were in general very low. The proposed constant and variable abstraction regimes represented a very high percentage of that flow at the northeastern abstraction location. This resulted in a much reduced volume of water passing on through the system.

All abstraction profiles (constant, 410:50 variable, and 450:50 variable) from the northeast of Lough Derg show significant increases in flushing times (maximum 16 days increase) in southern regions of the waterbody. The difference in impacts of the three abstraction regimes is visually indiscernible spatially.

9. CONCLUSIONS

The modelling exercise was undertaken to determine whether any changes in flushing characteristics of Lough Derg / Parteen Basin could be ascertained due to a number of potential abstraction locations and abstraction regimes.

Based on the results from the model it has been found that changes in flushing time characteristics arise during low flow summer time conditions.

The most significant changes in flushing time in Lough Derg were for an abstraction located at the northeast of Lough Derg. There was little to no discernible difference to changes in flushing times due to one abstraction profile over another (constant v variable) at that location. There was no change in flushing time in Lough Derg for an abstraction located in Parteen Basin.

The predicted flushing time results presented above for the 1995 period can be considered to approximate a worst case scenario, occurring as they did during one of the longest recorded periods of drought flows in the River Shannon system.

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