

SECTION F – EXISTING ENVIRONMENT & IMPACT OF THE DISCHARGE(S)

Attachment F1: Assessment of Impact on Receiving Surface or Ground Water

- **Hydrodynamic Dispersion Model**
- **Water Matters - Full Report for Waterbody Southwestern Irish Sea – Killiney Bay (HA10)**
- **Shanganagh Sewerage Scheme – Marine Outfall Modelling Study Addendum 2010**

5.1.3 Stormwater Overflows

The Department of the Environment has given guidance on the control of wastewater from the urban sewer network in "Storm Water Overflows", 1993. This document does not represent legislation but is rather a representation of government policy. The critical parameters for the design of wastewater collection systems is that a maximum of three (3) sewer overflows per bathing season (May to October) are permitted unless it can be shown that overflows do not cause an adverse impact more than 98.2% of the time.

5.2 DISPERSION MODEL DEVELOPMENT

Irish Hydrodata were commissioned by M.C. O'Sullivan to model the existing and future wastewater discharges from the Bray and the Shanganagh outfalls. They have previously modelled the discharges from Ringsend and from Greystones and thus already had a good understanding of the area and were able to integrate data from these previous models.

5.2.1 Receiving Water Data

There was a reasonable amount of data available for the Bray outfall from current monitoring, drogue and dye releases. However, there was insufficient data available for the Shanganagh outfall, so Irish Hydrodata conducted additional dye and drogue releases between 5 and 7 November 1999. The sources of the input data are summarised below:

- 1999 Shanganagh Dye Release
- 1999 Shanganagh Drogue Release
- 1983 Bray Dye Release
- 1983 Bray Drogue Release
- 1974 Shanganagh Drogue Release

5.2.2 Model Combinations

There is an endless combination of wind, tide, wave and discharge conditions so some judgement on choosing the most relevant groupings for modelling is required.

Typically, the highest plume concentrations will occur under calm conditions but the plume will be relatively localised. Moderate on-shore wind conditions will normally result in the highest bacteriological concentrations on a shoreline. Very strong winds with large wave heights tend to accentuate mixing and so reduce the bacteriological concentrations. The on-shore wind speed chosen for modelling is the 95 percentile speed blowing at 7m/s. Also calm conditions were modelled to represent the limited dispersion scenario. This scenario is critical for the Shanganagh outfall discharge and the concentrations at or around Dalkey Island.

Similarly spring tides will increase the mixing effect but will transport the plume a greater distance, while neap tides will typically result in higher localised bacteriological concentrations. As a result both neap and spring tides were modelled.

The peak wastewater flowrate will obviously give the highest concentrations in the receiving water but will typically be of short duration. The most extreme case, particularly for Shanganagh, is when this peak flowrate occurs at the beginning of the flood tide a large stationary plume will be transported close to shore. It is more likely that the peak flow will not occur at this discreet point in the tidal cycle, however allowing for the peak flow to occur at the beginning of the flood tide results in only a slight over-estimation in the bacteriological concentrations. There is a natural pathogen die-off in the sea dependent on temperature and exposure to sunlight; typically after 12 hours only around 10% of the original pathogens will survive. The over-estimation is about 10 to 15% over 12 hrs and around 1% over 24 hrs.

Hence rather than model several scenarios with the peak flow occurring at different times in the tidal cycle, the peak flow was assumed to occur at the start of the flood tide.

5.2.3 Existing Contamination Parameters

Average and peak wastewater flow scenarios were investigated along with typical faecal coliform counts for the wastewater. Faecal coliform concentrations are modelled because they are typically more critical than total coliforms and streptococci. The flow rates and concentrations used for untreated sewage in the development of the existing model are as follows:

Table 5.1 Existing Model Parameters

	Flow (m ³ /day)	Modelled Faecal Coliform Concentration (MPN/100ml)	Measured Faecal Coliform Concentration (MPN/100ml)
Bray Average Flow	7000	10 ⁷	2.8×10 ⁶
Shanganagh Average Flow	15000	10 ⁷	6.0×10 ⁶

The EPA does not monitor the water quality in the River Dargle; in the greater Dublin area this responsibility normally falls to the Local Authority. Bray UDC have not conducted water quality monitoring on the Dargle historically, however a brief sampling programme was completed recently with the results shown in Table 5.2. In the absence of any measured flow data the flowrate in the River Dargle was determined using The Average Flowrate Method below

$$\begin{aligned}
 Q &= \text{Area} \times (\text{Rainfall} - \text{Evapotransportation}) \\
 \text{Area} &= \text{Catchment Area (120km}^2\text{)} \\
 \text{Rainfall} &= \text{Annual Rainfall Data from Rain gauges (970mm)} \\
 \text{Evapotransportation} &= 400 \text{ mm}
 \end{aligned}$$

For the purposes of the calculation an average annual rainfall from two rain gauges (one at the coast and one in the hills) in the catchment was utilised.

Table 5.2 Data from River Dargle

Location	Flowrate (m ³ /s)	Measured Faecal Coliform Concentration (MPN/100ml)
River Dargle	2.2	4430

The dispersion model results will be discussed in the relevant sections.

5.2.4 Interpretation of Results

On Figures 5.2 to 5.9 the extent of the plumes are given with faecal coliform concentration densities. The dispersion model is dynamic and is set up to run a set of calculations every 15 minutes so through two tidal cycles there is around 250 outputs and potential plume density outputs. Hence the diagrams shown are only indicative of the extent of the plume at a discrete time step and may not match up with the tabulated concentrations.

The model is constructed of 100 x 100m square cells where the concentration in that cell is calculated every 10 minutes. To gain a representation of the concentrations at contact recreation locations a number of cells are analysed, for example a 500 m stretch of beach would contain 5 cells. A peak concentration in one cell will not be indicative of the overall water quality. The average concentration of all of these cells at any particular point in time is the most representative of the overall state of the bathing waters. In summary, the tabulated concentrations are averaged with respect to space but peak with respect to time.

5.3 BRAY EXISTING SITUATION RESULTS

5.3.1 Historical Water Quality

The Bray Beach is a popular and important holiday destination and is popular for swimming in the height of summer. However it has, until recently, been unable to satisfy the water quality criteria required for Blue Flag status. No recent capital or operational improvements to the system have occurred so it is questionable for how long the status can be retained under present conditions.

The water quality data from 1995 to 1999 has been analysed and is available in Appendix G. There was non-compliance from the South Bray promenade in 1997, 1998 and 1999 with non-compliance from the North Bray promenade in 1996. The most notable exceedance was for faecal coliform concentrations which were exceeded 17%, 25%, 40% and 22% of the time for those four years; where Blue Flag Regulations allow a 15% exceedance.

The average measured concentration of faecal coliforms over this period at the South and North promenades were 184 and 53/100 ml respectively.

5.3.2 Dispersion Model Results

The dispersion model of the existing situation predicts that the most severe contamination of Bray Promenade due to the effects of the foul outfall under average flow conditions would be a faecal coliform count of 97/100 ml, well below the mandatory levels but just within the guideline level of 100/100ml. This concentration is derived from allowing:

- On-shore wind conditions
- spring tide conditions
- peak plume concentration

The predicted concentration at the promenade under calm conditions is zero.

Fig. 5.2 shows an indicative representation of the wastewater dispersion under average flow but adverse dispersion conditions. The contamination of the Bray promenade is likely to be accentuated by other factors such as:

- Periodic storm overflows from the pump station
- Contaminated storm water run-off
- Contamination in the River Dargle

The existing dry weather flow rate at the Bray pump station is around 4200 m³/ day. The Bray Pump station can convey 12 times the existing dry weather flow through the existing foul outfall. However, the capacity of the pumps are typically exceeded over 20 times each bathing season which leads to overflow through the storm outfall. This may be partly due to sea water overtopping the promenade during a storm, the incidence of which has been greatly reduced by coastal protection works.

The dispersion model predicts a relatively low level of bacterial contamination under average flow conditions. The overflows during storm conditions may contribute to the bacterial contamination of the sea and recorded exceedances of the bathing water parameters adjacent to the Bray promenade.

Another significant source of contamination is likely to be the River Dargle for which quality monitoring was recently conducted, as referred to in Table 5.2 above. The Dargle flow was also included in the model to estimate the effect on the water quality. Under average flow and on-shore conditions it would increase the Faecal Coliform (FC) concentration on the foreshore from 97/100ml to around 210/100 ml, which would cause exceedance of the Blue Flag limit of 100/100 ml.




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 M.B.C. Eng.
 Town Engineer (A)

MCOS
COWI

**Shanganagh and
 Bray Main
 Drainage Scheme**

**Monitoring
 Locations**

**Fig
 5.1**

Cuan Bhaile
Atha Cliath



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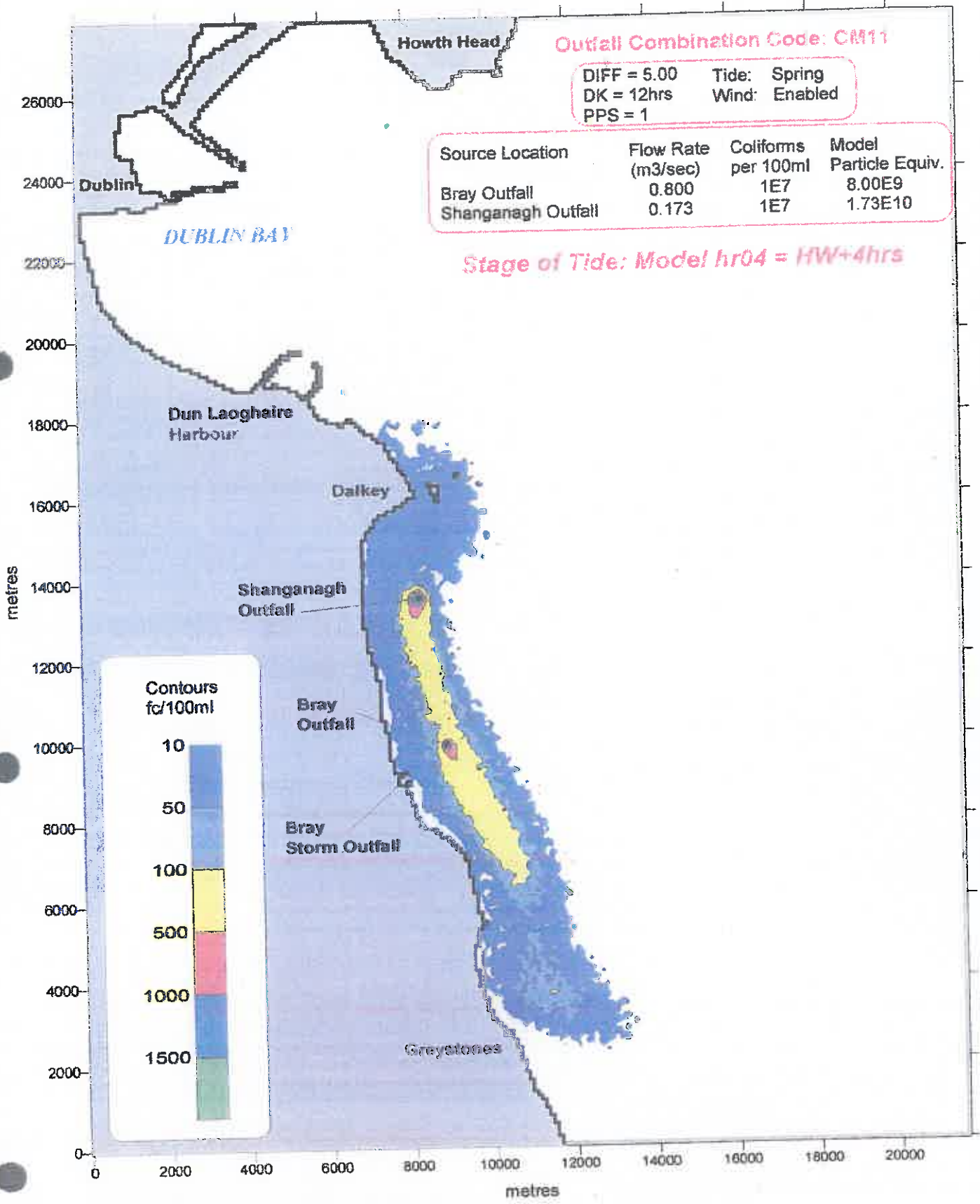
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SHANGANAGH AND BRAY OUTFALLS

PERFORMANCE EVALUATION STUDIES (Nov. 1999)



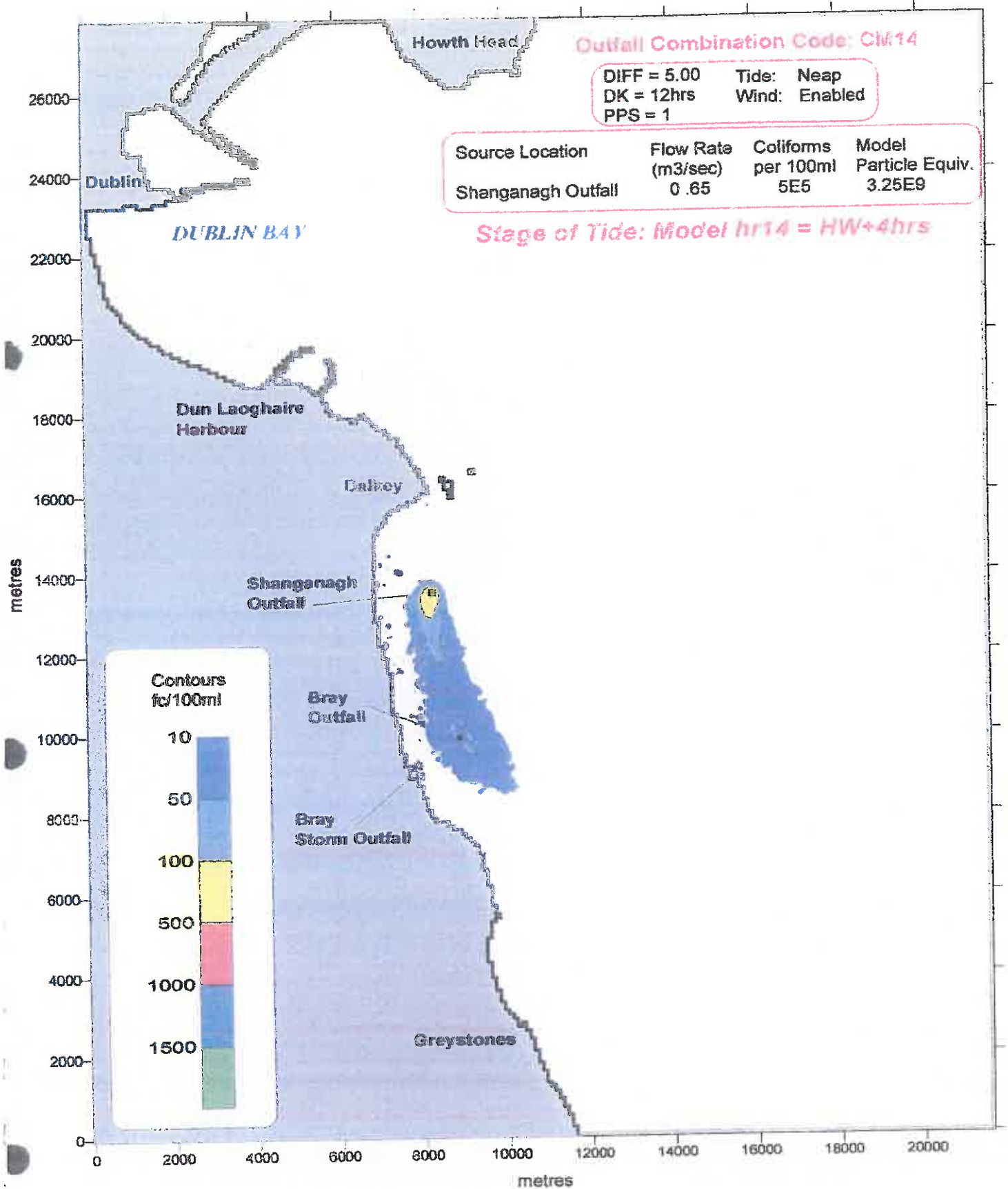
Shanganagh and Bray Main Drainage Scheme

Bray Existing Situation (Average Flow)

Fig 5.2

SHANGANAGH AND BRAY OUTFALLS

PERFORMANCE EVALUATION STUDIES (Nov. 1999)



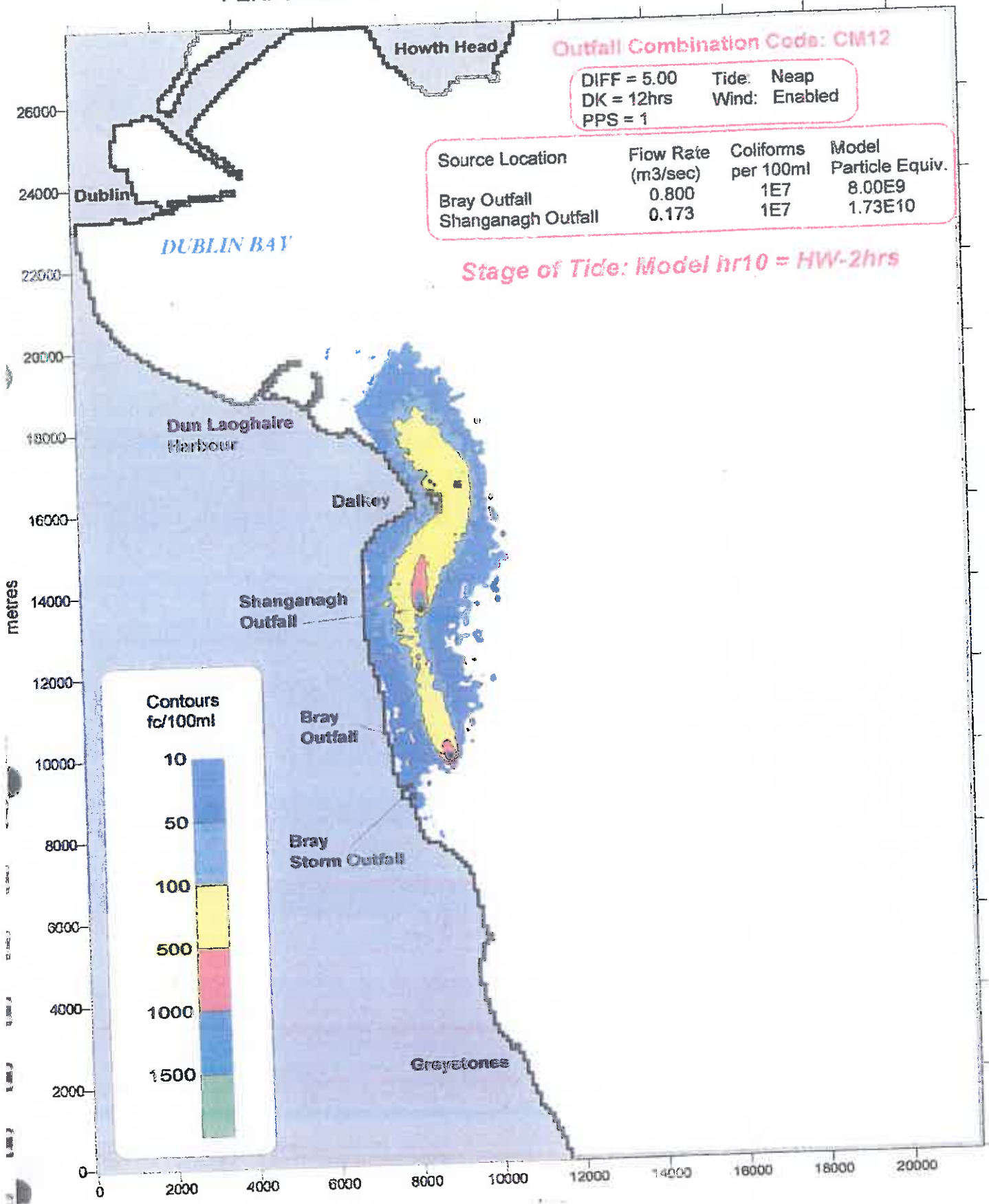
Shanganagh and Bray Main Drainage Scheme

Bray Existing Situation (Average Flow)

Fig 5.3

SHANGANAGH AND BRAY OUTFALLS

PERFORMANCE EVALUATION STUDIES (Nov. 1999)



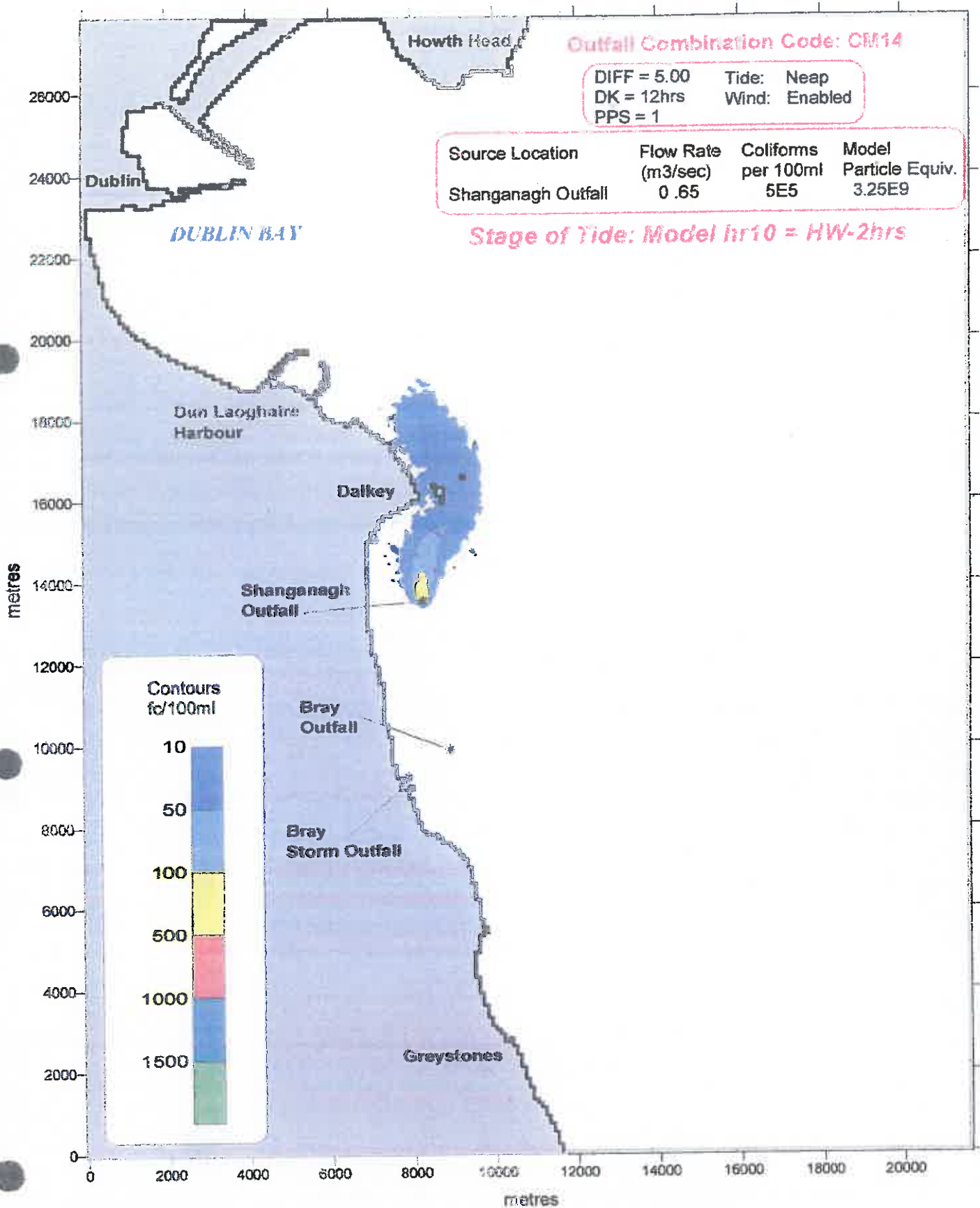
Shanganagh and Bray Main Drainage Scheme

Shanganagh Existing Situation (Average Flow)

Fig 5.4

SHANGANAGH AND BRAY OUTFALLS

PERFORMANCE EVALUATION STUDIES (Nov. 1999)



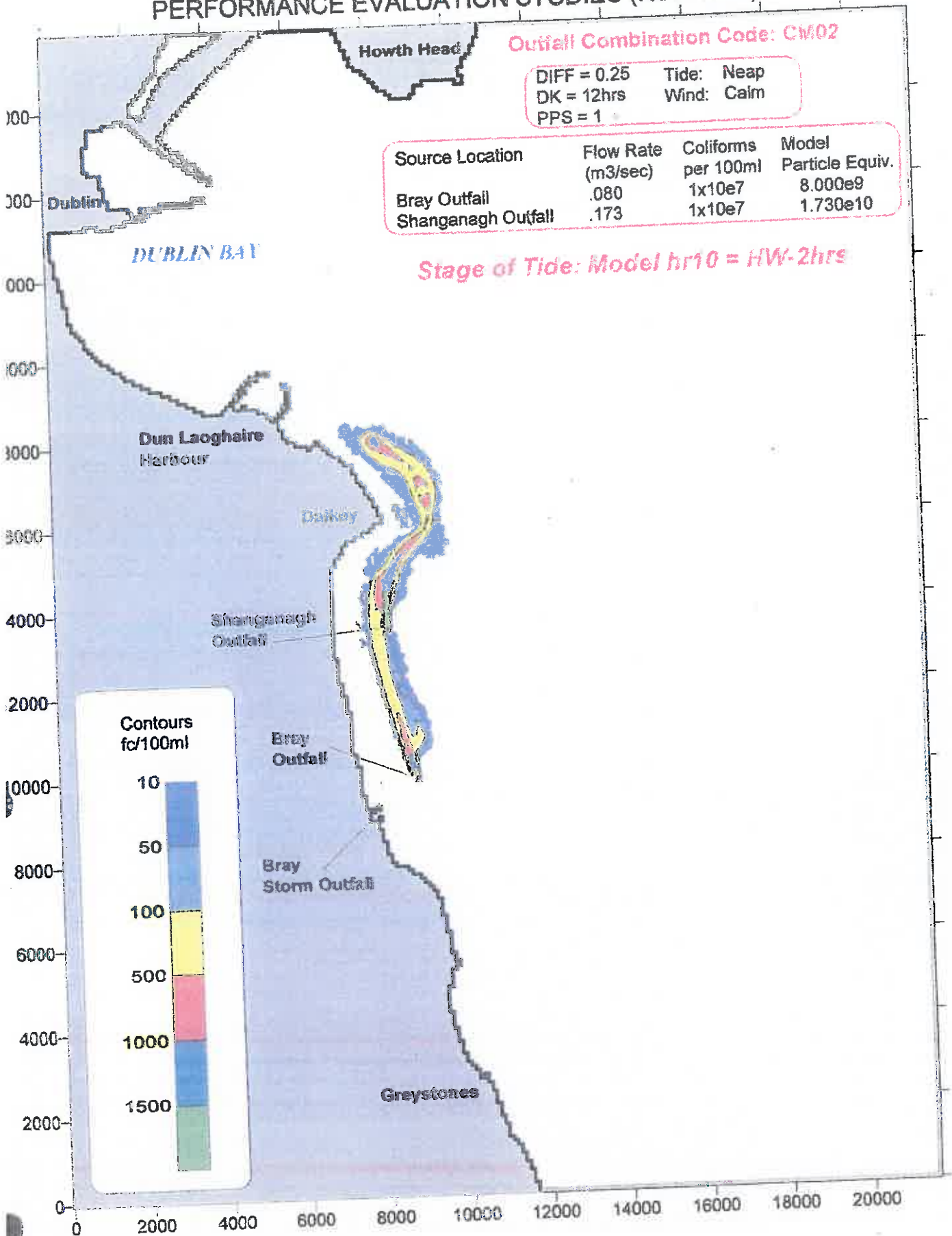
Shanganagh and Bray Main Drainage Scheme

Shanganagh Future Situation (Average Flow)

Fig 5.5

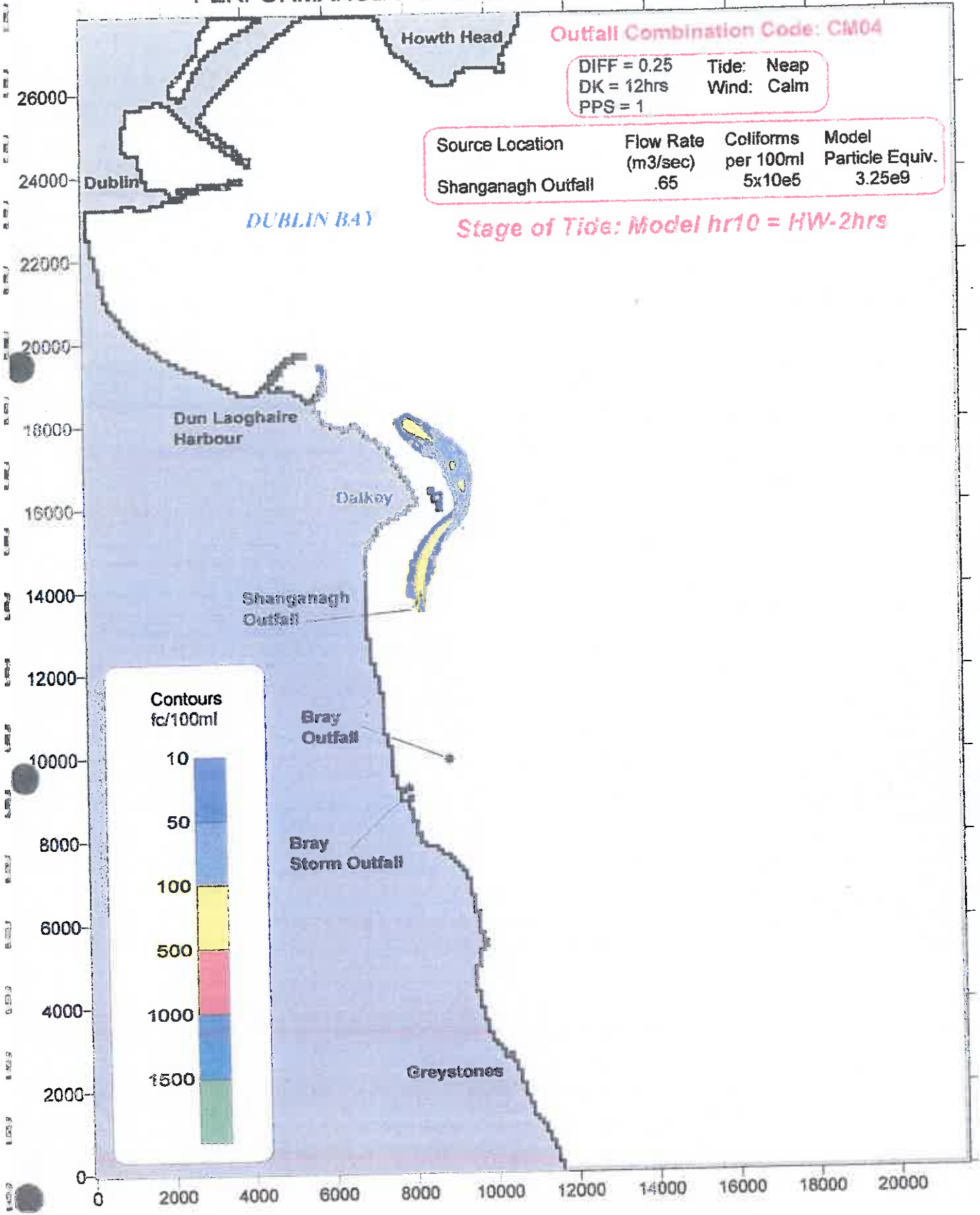
SHANGANAGH AND BRAY OUTFALLS

PERFORMANCE EVALUATION STUDIES (Nov. 1999)



SHANGANAGH AND BRAY OUTFALLS

PERFORMANCE EVALUATION STUDIES (Nov. 1999)



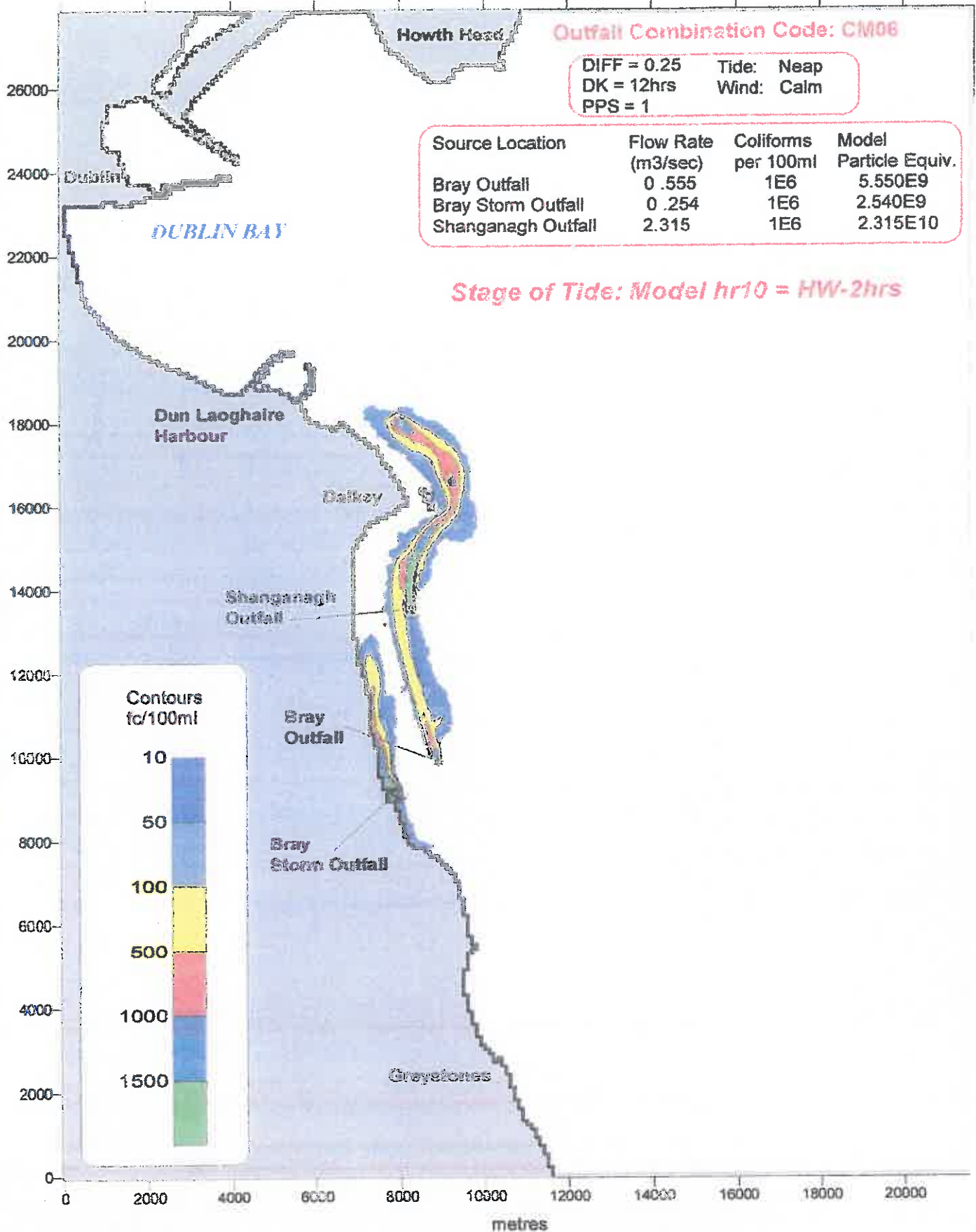
Shanganagh and Bray Main Drainage Scheme

Dalkey Future Situation (Average Flow)

Fig 5.7

SHANGANAGH AND BRAY OUTFALLS

PERFORMANCE EVALUATION STUDIES (Nov. 1999)



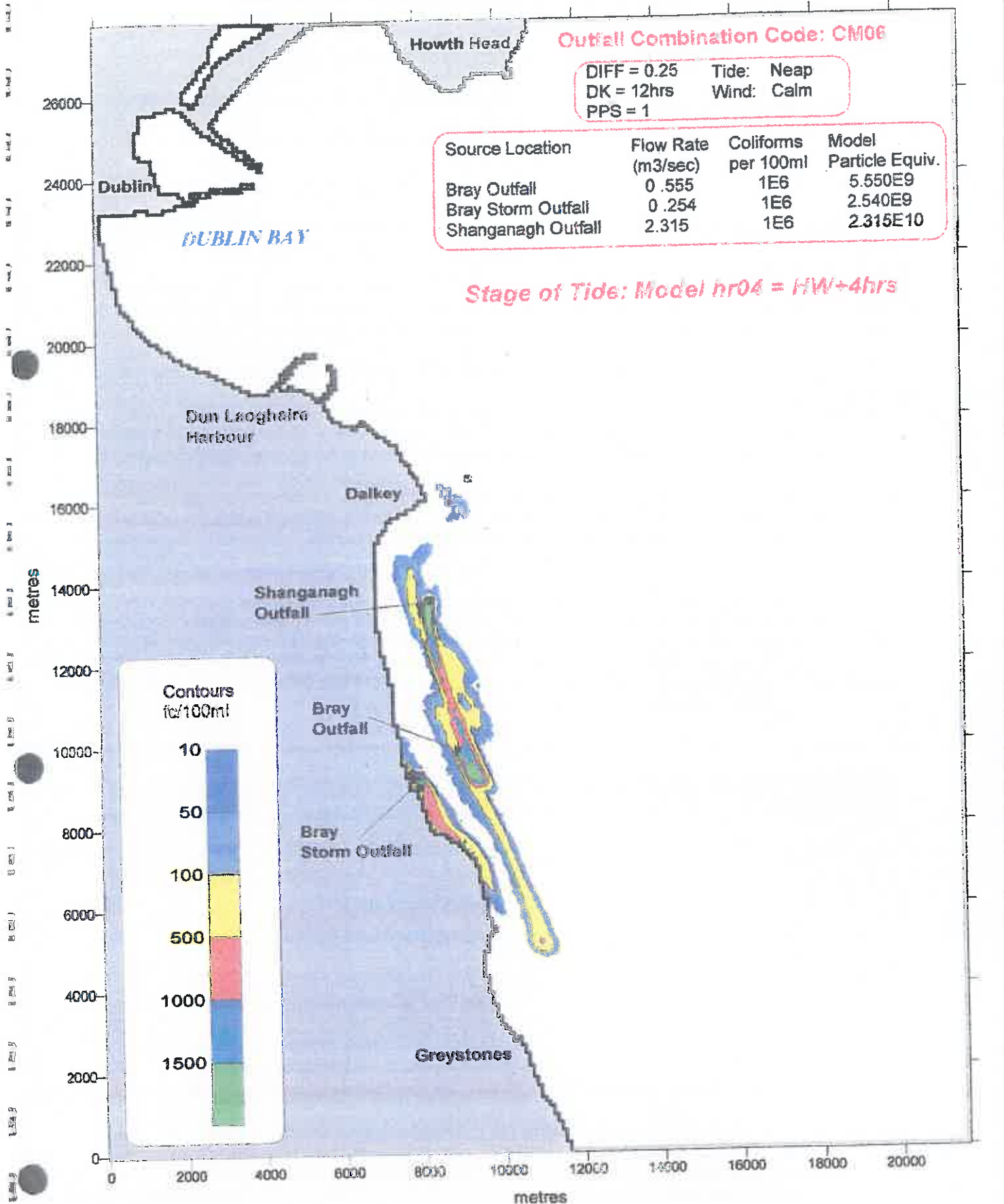
Shanganagh and Bray Main Drainage Scheme

Dalkey Future Situation (Peak Flow)

Fig 5.8

SHANGANAGH AND BRAY OUTFALLS

PERFORMANCE EVALUATION STUDIES (Nov. 1999)



Shanganagh and Bray Main Drainage Scheme

Bray Future Situation (Peak Flow)

Fig 5.9

This contamination under average flow conditions is likely to come from the prolific bird life in summer and the Enniskerry Wastewater Treatment Works. It should be possible to collect the effluent from the Enniskerry Works and convey to Bray for eventual discharge at Shanganagh.

In general, the performance of the long sea outfall appears satisfactory, based on the model.

5.4 SHANGANAGH EXISTING SITUATION

5.4.1 Historical Water Quality

The main bathing location adjacent to the outfall is Killiney Beach. However, the outfall would also impact on Bullock Harbour, and around Dalkey Head.

Killiney Beach consistently complies with the Bathing Water Directive guideline figures and has generally attained Blue-Flag status. However during 1996 there was a number of failures of the standards with 30% of faecal coliform concentrations above 100/100ml. The overall average concentration is 98/100 ml, however this average is distorted on the high side because many of the test results are un-specific with quoted figures of <100/100ml.

Monitoring results for Bullock Harbour are not available. However, this area would historically have been affected by a local outfall now being intercepted through the provision of a new pumping station linking the Bullock Harbour area to the main Dun Laoghaire catchment.

Dalkey Sound and Island are not strictly used for bathing, although it is a popular location for scuba diving and snorkelling and hence should be considered in relation to the standards. City Analysts Limited took samples at three locations, refer to **Figure 5.1** for a plan showing test locations.

The sampling was carried out on ten occasions between the 8th of May and the 13th of June 2000. Sampling was carried out at around 1 hour after the flood tide began to coincide with the peak concentration of bacteria. Seven of the test days were sunny and calm on the other three days the sea was rough and there were intermittent rain showers. Samples were tested for numbers of coliforms, E.coli (which can be equated numerically to faecal coliforms) and Faecal streptococci. The median of the faecal coliform count is given in **Table 5.3** below.

Table 5.3 Median Faecal Coliform Concentrations

Location	Faecal Coliform/100ml (Median Value)
Between the shore and Dalkey Island - 1	1
At the south face of Dalkey Island - 2	50
Close to the Muglin Islands - 3	160

5.4.2 Dispersion Model Results

The dispersion model predicts that the most severe contamination of Killiney Beach from the effects of the foul outfall under average flow conditions will be a faecal coliform count of 48/100 ml. This concentration is derived from allowing:

- on-shore wind conditions
- neap tide conditions
- average plume concentration

Fig 5.4 shows an indicative representation of the wastewater dispersion under average flow and adverse dispersion conditions at less than 100/100ml along the coastline. The concentration, therefore, is well below the mandatory number of 1000/100ml and satisfies the guideline figure of 100/100ml.

The model predicts significantly higher concentrations of 698/100 ml on the seaward side of Dalkey Island under average flows. The concentration is significantly lower on the inland side of the island at 93/100 ml which is compliant with the Blue Flag Status. **Figure 5.6** shows an indicative representation of the wastewater dispersion under average flow and adverse dispersion conditions. These concentrations are derived from allowing:

- calm conditions
- neap tide conditions
- average plume concentration

The predicted modelled concentrations at Dalkey Island and Sound are significantly higher than the measured concentrations. This may be due to unknown local current effects around the islands and a limited number of samples.

The Shanganagh Pump station has capacity for 17 times the existing dry weather flow through the existing foul outfall although pumping is not required as even storm flows can discharge under gravity. Storm overflows do not appear to have occurred from the pump station since commissioning, so bathing water contamination from overflows should not occur. Overflows from the collection network may however occur and are currently being investigated.

The dispersion model predicts moderate levels of contamination at Shanganagh Beach below the mandatory limits even during adverse environmental conditions (on-shore wind and incoming tide) and this is borne out by actual receiving water sampling.

There will be no interaction with the proposed Ringsend discharge even from high wastewater flows and adverse weather conditions.

5.5 FUTURE SITUATION – FLOWRATES AND CONCENTRATIONS

To comply with the Urban Wastewater Directive, secondary treatment will have to be installed to attain a 25:35 mg/l (BOD₅:Suspended Solids) standard. Secondary treatment would typically reduce the pathogen count of wastewater by between 15 to 30 fold. Because of the anticipated short retention time of the proposed treatment system a reduction of 20 fold is assumed. This would reduce the average flow wastewater total coliform concentration from 1×10^7 to 5×10^5 . This assumption is conservative for a well-run plant and is also intended to give a conservative result.

The wastewater under storm conditions is assumed on average to have a dilution factor of ten so that the faecal coliform count reaching the pumping stations is reduced to 1×10^6 .

The flowrates used in the model runs are given in Table 5.4:

Table 5.4: Future Model effluent discharge Parameters at Bray and Shanganagh

	MODEL SCENARIO	Flow Rate m ³ /day	Coliforms fc/100ml
1	Existing Situation		
	Bray Outfall	7000	10 ⁷
	Shanganagh Outfall	15000	10 ⁷
2	WWTW Shanganagh- Average Flow		
	Shanganagh Outfall	56250	5 x 10 ⁵
3	WWTW Shanganagh- Peak Flow		
	Bray Outfall	48000	10 ⁶
	Bray Storm	22000	10 ⁶
	Shanganagh Outfall	200000	10 ⁶
4	WWTW Shanganagh & Bray - Average Flow		
	Bray Outfall	12500	5 x 10 ⁵
	Shanganagh Outfall	43750	5 x 10 ⁵
5	WWTW Shanganagh & Bray - Peak Flow		
	Bray Outfall	48000	10 ⁶
	Bray Storm	52000	10 ⁶
	Shanganagh Outfall	200000	10 ⁶
6	WWTW Shanganagh (extended outfall) Average Flow		
	Shanganagh Outfall	56250	5 x 10 ⁵
7	WWTW Shanganagh (extended outfall) & Bray - Peak Flow		
	Bray Outfall	48000	10 ⁶
	Bray Storm	52000	10 ⁶
	Shanganagh Outfall	200000	10 ⁶
8	WWTW Shanganagh (extended outfall) & Bray - Average Flow		
	Bray Outfall	12500	5 x 10 ⁵
	Shanganagh Outfall	43750	5 x 10 ⁵
	Dargle River	190,000	1.1 x 10 ⁴

The Shanganagh flow rate used is an extreme value used to set the upper boundary of expected concentrations in the receiving waters. This approach has been taken because there is limited data on the flow to the Shanganagh pump station. It is also worthwhile looking at the extreme case because if the effects from this scenario are acceptable, then less extreme situations will also be acceptable. It is therefore used to define a worst case scenario for the discharge.

5.6 FUTURE SITUATION RESULTS

The combined effect of transferring the Bray wastewater to Shanganagh, reducing the faecal coliform effluent concentration and increasing the total wastewater flowrate results in a lowering of the average flow contamination. The following table indicates the change in worst case bathing water concentrations predictions:

Table 5.5: Future Model Results (faecal coliforms/100ml)

Model Scenario	Bray Prom	Shanganagh Beach	Muglins / Dalkey I	Dalkey Sound
Existing (1)	97	48	698	93
2	13	10	131	17
3	1396	62	934	125
4	13	7	102	14
5	3308	77	934	125
6	0	11	33	8
7	1396	33	234	58
8	133	4	27	6

Note: All concentrations are average with respect to space and peak with respect to time (refer Section 5.2.4 for an explanation)

The effect of reducing the concentration resulting from secondary treatment is a significant improvement in the estimated water quality at average flow conditions despite the increase in wastewater flowrate.

5.6.1 Bray

The most notable improvement in water quality is observed at Bray, which is expected, because the Bray wastewater will be discharged through the Shanganagh Outfall. Representations of the average flow effects before and after treatment are given on Figures 5.2 and 5.3 respectively.

The Bray discharge has been modelled with no storage facilities, hence all of the flow is discharged either through the foul outfall or the storm outfall. The flowrates used are quite high and probably err on the conservative side. However it is clear that discharging through the storm outfall has a significant negative effect on the water quality at Bray Promenade with concentrations up to 3300/100 ml. A representation of this peak flow effect is given on Figure 5.9. Given this impact, storage will be required to meet the DOELG spill frequency guidelines for Bathing Waters.

5.6.2 Shanganagh

The worst case concentration at Shanganagh Beach occurs during on-shore conditions coinciding with a neap tide, when tidal currents give the lowest dispersion. The anticipated concentration at the beach is 77/100 ml which is very acceptable, especially considering the infrequency of these discharge conditions.

5.6.3 Dalkey Island/ Muglins Island

The worst case concentration from the existing outfall at Dalkey Island occurs during calm conditions coinciding with a flood neap tide.

During peak storm flow the anticipated concentration is 934/100 ml which marginally complies with the mandatory NLV figure of 1000/100 ml for recognised Bathing Waters. Fig 5.9 is a graphical representation of the discharge condition, with contours showing the coliform concentrations. Extension of the outfall by 500 m would further reduce this concentration to 141/100 ml under these extreme conditions. However, peak flow storm conditions will normally be associated with wind to assist in dispersion which would result in a concentration of 497/100 ml without outfall extension and 234/100 ml with extension. Note that with extension the critical condition would be on-shore wind conditions to give a higher concentration. However, these situations arise only at maximum storm flow conditions and are of very low frequency.

During times of average flow and calm conditions the concentration falls to 131/100ml, which of course would be a very common event during the bathing season, which is loosely associated with scuba diving and snorkelling activity. Therefore, the seaward side of Dalkey Island would marginally not comply with Blue Flag requirements but easily comply with the National Limit Values. Given the relatively limited number of people using these waters and the fact that Blue Flag status is not specifically required, then the situation should be acceptable.

However, it is considered prudent to conduct on-going monitoring and allowance has been made for possible future installation of Ultra Violet (UV) disinfection.

5.7 OVERFLOWS AND STORAGE - BRAY

Determination of the overflow and storage requirements requires confirmation of the existing and future flow scenarios to the pump station. Confirmation of these flow scenarios can only be obtained when the collection network surveys and models are completed. However it is possible to gain an initial understanding of storage and overflow requirements by looking at historical flow records.

Storage will be more critical at Bray, considering the number of overflows that have occurred at the pump station based on the pump-run records. The DOE Spill Frequency Guidelines for Bathing Waters allow for only three spills per bathing season. Thus, when existing data was analysed to determine future storage provisions at Bray Pumping Station the fourth largest spill was looked at in each case.

During 1998, the fourth largest spill event during the bathing season was 7,776 m³ recorded on July 22. Pump records show that the spill occurred over 19 minutes, this is the length of time that 6 storm and 3 foul pumps were operating simultaneously. Based on pump duty flow rates, this would indicate that all the pumps operating together were yielding 6 m³/s. Allowing a future forward pumping capacity to treatment at Shanganagh of 0.38 m³/s (2.2DWF - Dry Weather Flow) results in a storm tankage requirement estimate of 6400m³. This equates to the estimated maximum flow-rate, less the forward flow to treatment, over the recorded spill duration (19 minutes). An allowance has been made for additional storm flows in the catchment.

During 1999, the fourth largest spill event during the bathing season was 14,000 m³ recorded on 22nd July. Pump records show that the spill occurred over 31 minutes, this is the length of time that 5 storm and 3 foul pumps were operating simultaneously. Based on pump duty flow rates, this would indicate that all the pumps operating together were yielding 4.9 m³/s. Allowing a future forward pumping capacity to treatment at Shanganagh of 0.38 m³/s (2.2DWF) results in a storm tankage requirement estimate of 8800 m³.

It is not possible to establish the extent of seawater inflows, if any, which may be associated with this flow. As has been mentioned the construction of the revetments at Bray Promenade has lowered the incidences of seawater inflow. The assumed future forward pumping rate to Shanganagh is quite high and is discussed later in this report. However for storage volume estimation, the effect of altering this value is relatively small considering the high peak flow rate of around 6.0m³/s. The volume of storage tank required is thus assumed to be of the order of 5,000 m³ which is significant given that space is limited at the Bray Pump Station. It should be noted that this estimate will be evaluated further in the catchment studies report.

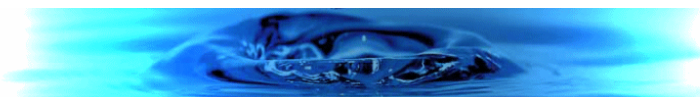
5.8 OVERFLOWS AND STORAGE - SHANGANAGH

At present there does not seem to be a bacterial contamination problem due to the Shanganagh outfall, with the possible exception of Dalkey Sound, where the model predicts an exceedance of the bacterial standard under worst case conditions. Following installation of secondary treatment, the concentrations at Dalkey Sound would cause exceedance of the standard only during storm flow conditions. If it can be shown under storm conditions that exceedances do not have an adverse impact on bacterial standards at Killiney and Dalkey Sound for 98.2% of the time as outlined in the DOELG Guidance Document "Storm Water Overflow"; 1993 then it would be acceptable to overflow screened wastewater to the long sea outfall without secondary treatment or storage during storm flow events while carrying forward 3 x DWF to treatment.

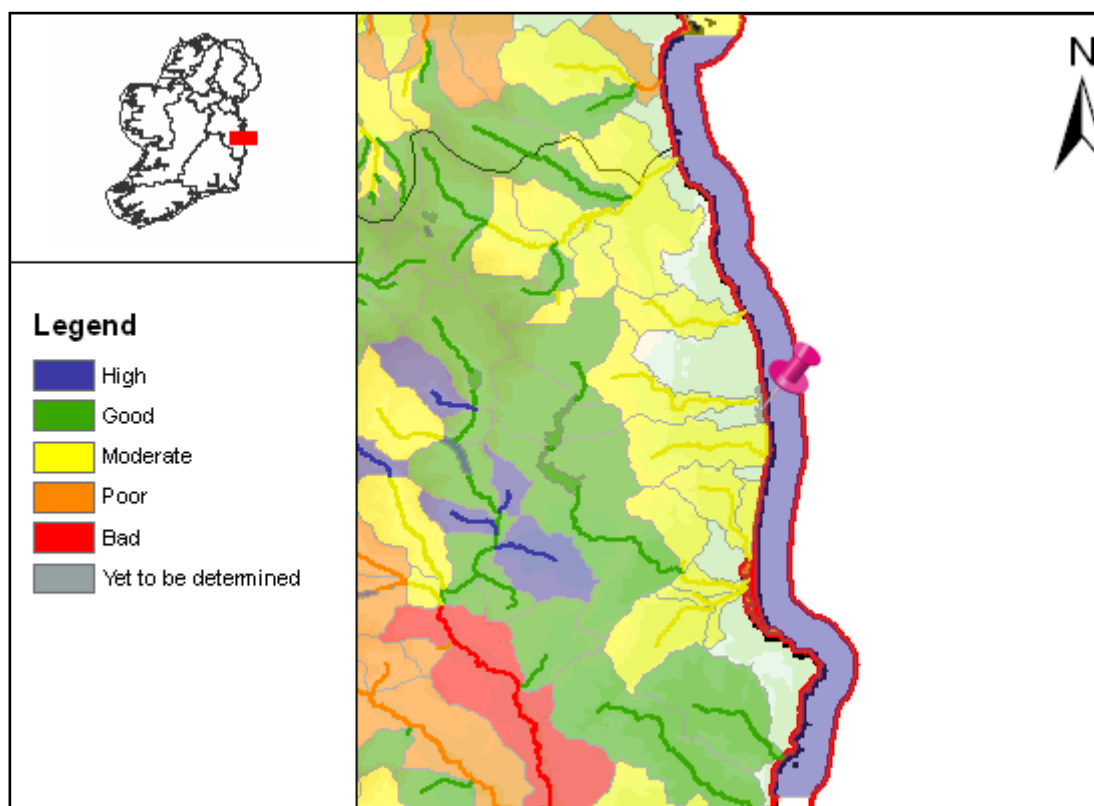
However, until catchment modelling is complete it would be prudent to include for some storage in the proposed Wastewater Treatment Works (WWTW) layout.

The storm flow scenario that was modelled above is an extreme event that will probably occur only once or twice a year. This assumption will be confirmed once catchment and rainfall data become available. In these circumstances, the level of exceedance of the standards at Dalkey Sound would be acceptable from a compliance point of view. The improvement compared with the existing situation should also be noted.

2.5 DWF?



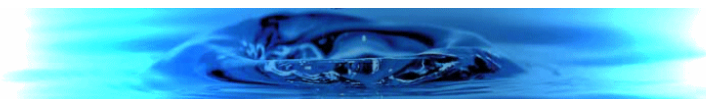
Full Report for Waterbody Southwestern Irish Sea - Killiney Bay (HA10)



River Basin Management Plans (RBMPs) have been published for all River Basin Districts in Ireland in accordance with the requirements of the Water Framework Directive. The WaterMaps viewer is an integral part of the River Basin Management Plan and provides access to information at individual waterbody level and at Water Management Unit level for all the River Basin Districts in Ireland.

The following report provides summary plan information about the selected waterbody (indicated by the pin in the map above) relating to its status, risks, objectives, and measures proposed to retain status where this is adequate, or improve it where necessary. Waterbodies can relate to surface waters (these include rivers, lakes, estuaries [transitional waters], and coastal waters), or to groundwaters. Other relevant information not included in this report can be viewed using the WaterMaps viewer, including areas listed in the Register of Protected Areas.

You will find brief notes at the bottom of some of the individual report sheets that will help you in interpreting the information presented. More detailed information can be obtained in relation to all aspects of the RBMPs at www.wfdireland.ie.



Summary Information:

Water Management Unit: N/A

WaterBody Category: Coastal Waterbody

WaterBody Name: Southwestern Irish Sea - Killiney Bay (HA10)

WaterBody Code: IE_EA_100_0000

Overall Status: High

Overall Objective: Protect

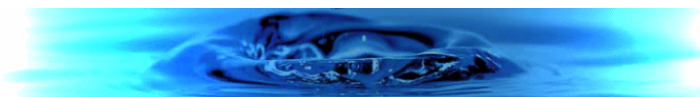
Overall Risk: 1a At Risk

Heavily Modified: No



Report data based upon final RBMP, 2009-2015.

The information provided above is a summary of the principal findings related to the selected waterbody. Further details and explanation of individual elements of the report are outlined in the following pages.

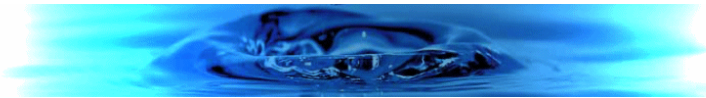


Status Report

Water Management Unit: N/A
WaterBody Category: Coastal Waterbody
WaterBody Name: Southwestern Irish Sea - Killiney Bay (HA10)
WaterBody Code: IE_EA_100_0000
Overall Status Result: High
Heavily Modified: No



Status Element Description		Result
Status information		
DIN	Dissolved Inorganic Nitrogen status	N/A
MRP	Molybdate Reactive Phosphorus status	N/A
DO	Dissolved oxygen as per cent saturation status	N/A
BOD	Biochemical Oxygen Demand (5-days) status	N/A
PHY	Macroalgae - phytobiomass status	N/A
OPP	Macroalgae - opportunistic algae status	N/A
RSL	Macroalgae - reduced species list status	N/A
ANG	Angiosperms - Seagrass and Saltmarsh status	N/A
BIN	Benthic Invertebrates status	N/A
FIS	Fish status	N/A
HYD	Hydrology status	N/A
MOR	Morphology status	N/A
SP	Specific Pollutant Status	N/A
PAS	Overall protected area status	N/A
ES	Ecological Status	High
CS	Chemical Status	N/A
SWS	Surface Water Status	N/A
EXT	Extrapolated status	N/A
DON	Donor water bodies	N/A

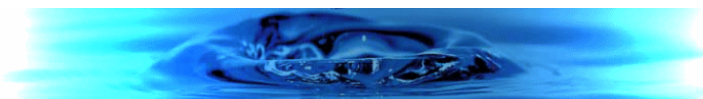


n/a - not assessed

Status

By 'Status' we mean the condition of the water in the waterbody. It is defined by its chemical status and its ecological status, whichever is worse. Waters are ranked in one of 5 status classes: High, Good, Moderate, Poor, Bad. However, not all waterbodies have been monitored, and in such cases the status of a similar nearby waterbody has been used (extrapolated) to assign status. If this has been done the first line of the status report shows the code of the waterbody used to extrapolate.

You can read more about status and how it is measured in our RBMP Document Library at www.wfdireland.ie (Directory 15 Status).

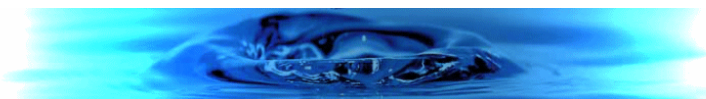


Risk Report

Water Management Unit: N/A
WaterBody Category: Coastal Waterbody
WaterBody Name: Southwestern Irish Sea - Killiney Bay (HA10)
WaterBody Code: IE_EA_100_0000
Overall Risk Result: 1a At Risk
Heavily Modified: No



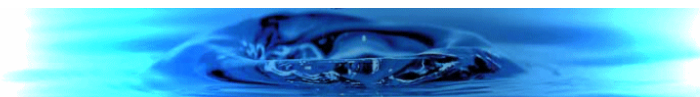
Risk Test Description	Risk
Marine Direct Impacts	
MDI1 Dangerous Substances	N/A
MDI2 OSPAR	N/A
MDI3 UWWT Regs Designations	N/A
MDIO Marine Direct Impacts Overall - Worst Case	N/A
Morphological Risk Sources	
CM1 Dredging	N/A
CM2 Deposition	N/A
CM3 Coastal Defences	N/A
CM4a Built Structures - Port Tonnage	N/A
CM4b Built Structures - Industrial/Urban Shoreline	N/A
CM4c Built Structures - Industrial Intakes	N/A
CM5 Intensive Landuse (Coastal Lagoons)	N/A
MOR Overall Morphological Risk - Worst Case	2b Not At Risk
MOR Overall (MIMAS) Morphological Risk - Worst Case (2008)	N/A
Overall Risk	
CP Worst case of Point and Marine Direct Impacts Overall (2008)	1a At Risk
RA Coastal Risk Overall - Worst case (2008)	1a At Risk
Point Risk Sources	
CP1 WWTPs (2008)	1a At Risk
CP2 CSOs	2b Not At Risk
CP3 IPPCs (2008)	2b Not At Risk
CP4 Section 4s (2008)	2b Not At Risk
CP5 WTPs/Mines/Quarries/Landfills	N/A
CPO Overall Risk from Point Sources - Worst Case (2008)	2b Not At Risk



Risk

By 'risk' we mean the risk that a waterbody will not achieve good ecological or good chemical status/potential at least by 2015. To examine risk the various pressures acting on the waterbody were identified along with any evidence of impact on water status. Depending on the extent of the pressure and its potential for impact, and the amount of information available, the risk to the water body was placed in one of four categories: 1a at risk; 1b probably at risk; 2a probably not at risk; 2b not at risk. Note that '2008' after the risk category means that the risk assessment was revised in 2008. All other risks were determined as part of an earlier risk assessment in 2005.

You can read more about risk assessment in our 'WFD Risk Assessment Update' document in the RBMP document library, and other documents at www.wfdireland.ie (Directory 31 Risk Assessments).



Objectives Report	
Water Management Unit:	N/A
WaterBody Category:	Coastal Waterbody
WaterBody Name:	Southwestern Irish Sea - Killiney Bay (HA10)
WaterBody Code:	IE_EA_100_0000
Overall Objective:	Protect
Heavily Modified:	No



	Objectives Description	Result
	Objectives information	
OB1	Prevent deterioration objective	No Status
OB2	Restore at least good status objective	No Status
OB3	Reduce chemical pollution objective	No Status
OB4	Protected areas objective	Protect
OBO	Overall objectives	Protect

Extended timescales

Extended timescales have been set for certain waters due to technical, economic, environmental or recovery constraints. Extended timescales are usually of one planning cycle (6 years, to 2021) but in some cases are two planning cycles (to 2027).

Objectives

In general, we are required to ensure that our waters achieve at least good status/potential by 2015, and that their status does not deteriorate. Having identified the status of waters (this is given earlier in this report), the next stage is to set objectives for waters. Objectives consider waters that require protection from deterioration as well as waters that require restoration and the timescales needed for recovery. Four default objectives have been set initially:-

- Prevent Deterioration*
- Restore Good Status*
- Reduce Chemical Pollution*
- Achieve Protected Areas Objectives*

These objectives have been refined based on the measures available to achieve them, the latter's likely effectiveness, and consideration of cost-effective combinations of measures. Where it is considered necessary extended deadlines have been set for achieving objectives in 2021 or 2027.

SHANGANAGH SEWERAGE SCHEME

Marine Outfall Modelling Study

Addendum 2010

FINAL REPORT



Prepared by:-

IRISH HYDRODATA LIMITED,
Rathmacullig West,
Ballygarvan,
Co. Cork.

November 2010

SHANGANAGH SEWERAGE SCHEME
MARINE OUTFALL MODELLING STUDY
Addendum 2010

Prepared for:

Dun Laoghaire-Rathdown County Council

Presented to:

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Prepared by:-

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November 2010

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1. INTRODUCTION

1.1 BACKGROUND TO STUDY 2010

A marine outfall study was carried out by Irish Hydrodata Ltd. (IHD) in 1999 (report in 2000, ref.1) in order to evaluate the performance of outfalls at Shanganagh and Bray. At that time, those marine outfalls discharged untreated municipal effluent to the Irish Sea. The performance of the outfalls in terms of bacterial impacts was also examined as it was thought that the provision of treatment could mean that only one primary outfall would be required.

The study included the construction of a 2D depth-averaged hydrodynamic flow model and associated faecal coliform dispersion model.

For this present study, IHD was requested by WYG Ireland (WYG) on behalf of Dun Laoghaire-Rathdown County Council (DLRCC), to investigate the fate of dissolved inorganic nitrogen (DIN) discharging from the Shanganagh outfall, the River Dargle and the Bray storm outfall. It is a condition of the Waste Water Discharge Licence (WWDL) application that compliance with S.I. 272 of 2009 (ref. 2) for DIN is achieved. The model's results are to be compared with the S.I. allowable levels.

The 2D model originally constructed in 1999, is to be used in this current investigation. A conservative scenario is considered and the DIN is treated as a very slowly decaying contaminant akin to its actual behaviour in winter. A worst case scenario is to be expected during neap tides when ranges are reduced and water exchanges limited.

Partial extracts from the 1999 study are included in this document to give a more complete description of the 2010 study.

1.2 STUDY BRIEF 2010

The objectives of the study as defined by WYG were:

to make an assessment of the fate of DIN discharging in various combinations of flow and concentration from:

- a. Shanganagh Outfall;
- b. River Dargle;
- c. Storm Outfall at Bray;

and to predict if compliance is achieved with S.I. 272 of 2009 for DIN.

1.3 SUMMARY OF STUDY WORKS 1999

In 1999 the following study works were undertaken:

- a two dimensional flow model was set-up for the sea area stretching from Howth Head to Greystones, a distance of 30km. The model extended approx 20km offshore and was used to simulate water circulation;

- a two dimensional bacterial dispersion model of the sea area outlined above was prepared;
- field measurements, including dye, drogue and current metering in the vicinity of Shanganagh outfall, were carried out to confirm those made in earlier studies in 1969-1974.

The results of these works are described in various sections of the report of the 1999 study.

2. OCEANOGRAPHIC CHARACTERISTICS OF AREA

2.1 BATHYMETRY

During model construction, information relating to water depths and general bathymetric features of the area were obtained from Admiralty Chart Nos. 1468 & 1415. Bathymetric data from other sources was used where appropriate. The model bathymetry is shown in Figure 2.1.

2.2 TIDES AND WATER LEVEL CHANGES

The tidal regime off the coast is semidiurnal with two high waters (HW) and two low waters (LW) each day. A gradual increase in tidal amplitude is observed northward along the coast. The main tidal features are summarised in Table 2.1.

LEVEL	Greystones	Dublin Port	Kish Light
Mean High Water Spring (MLWS)	1.40	1.60	1.68
Mean High Water Neap (MLWN)	0.75	0.90	1.29
Mean Sea Level (MSL)	-0.07	-0.10	0.04
Mean Low Water Neap (MLWN)	-0.89	-1.00	-1.21
Mean Low Water Spring (MHWS)	-1.54	-1.80	-1.60

Table 2.1 - Tidal statistics (m) relative to Malin Head datum.

2.3 TIDAL STREAMS AND CURRENTS

The general circulation patterns of the western Irish Sea have been well documented through the years. Along the Dublin/Wicklow coast, Admiralty charts and tidal atlases provide a more specific indication of the current patterns.

The tidal currents off Bray and Shanganagh generally run parallel to the coast. Speeds reach maximum values of about 1.0 knot (~0.5m/s) during spring tides. In the vicinity of Dalkey Island the speeds are somewhat higher, increasing locally to more than 2 knots (~1m/s). Current meter data from various studies was assessed and incorporated into the original model construction.

Dye dispersion and drogue data for the Shanganagh outfall location were recorded as part of the 1999 study. A recording current meter was also deployed at the outfall for 24 hours and measured speed and direction data.

Extensive drogue and dye track data were also available for the Bray Outfall from previous studies. Some older data for the Shanganagh outfall was also obtained.

All of this data was used for calibration and verification of the model.

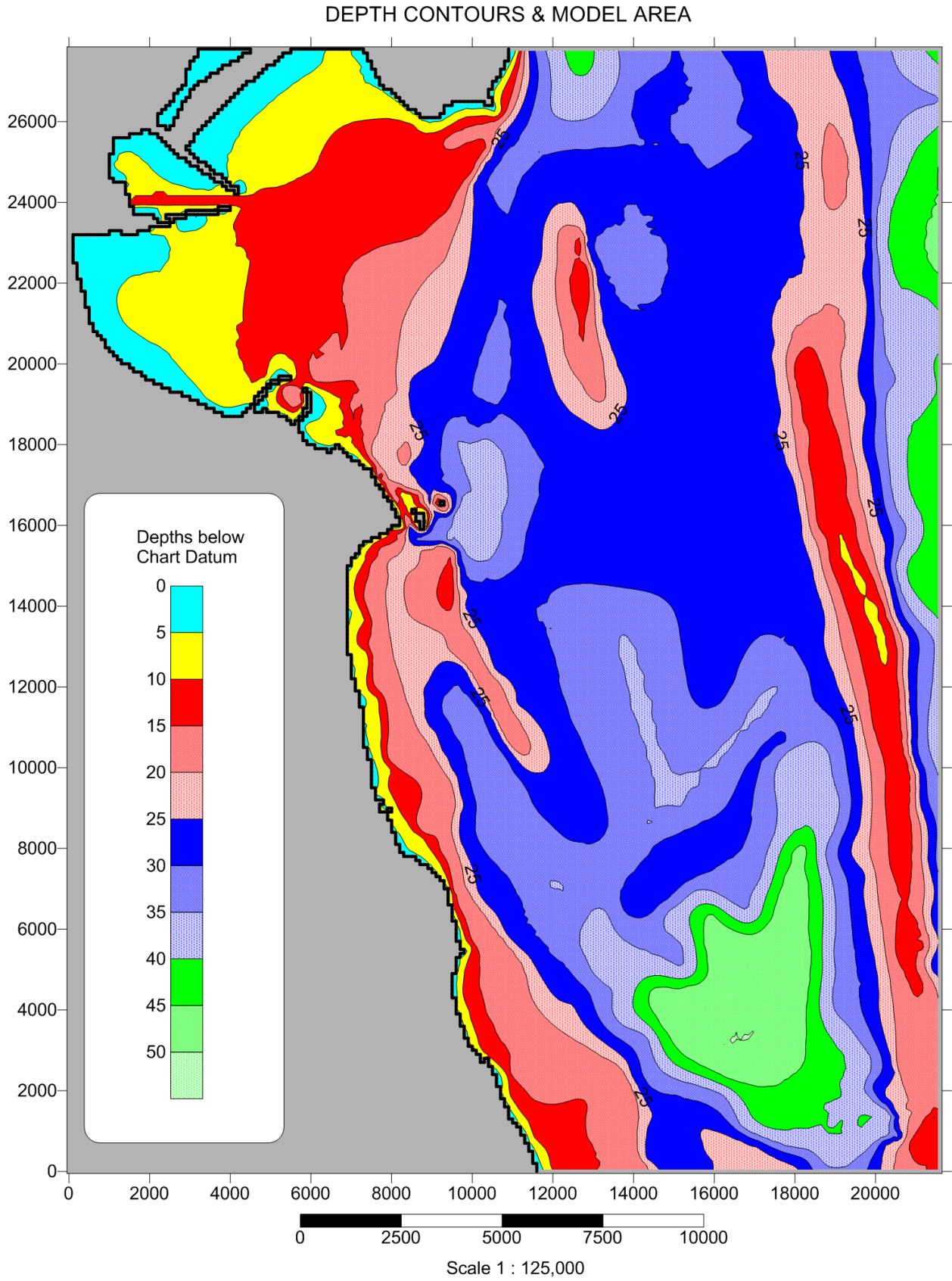


Figure 2.1

3 PREDICTIVE MODEL OF WATER QUALITY

3.1 OVERVIEW OF MODELLING APPROACH AND METHODS

Hydrodynamics

A two dimensional depth averaged flow model (M2D, ref:3) was used to simulate the tidal circulations in the study area and provide an hourly flow pattern for both the spring and neap tidal cycles. The effects of wind were included in terms of enhanced horizontal mixing along the axis of the wind vector.

Dispersion of Effluent

The model used for predicting the effluent dispersion patterns (TRACK, ref: 4) is based on the concept of particle tracking. With this technique, the continuum of dispersed contaminant is simulated by a cloud of discrete particles. The model operates on the same grid as that employed in the flow models and particles are tracked in 3-dimensional space.

3.2 2D - FLOW MODEL

Model Framework

In the 2D coastal circulation model the bathymetry was defined on a rectangular grid with cells of horizontal dimension 100m x 100m. The model extended for 200 grid cells east-west (20km), from the mainland to the far side of the Kish Bank, and for 300 grid cells north-south (30km), from Howth Head to Greystones. The model was centred on Bray and Shanganagh, (Figure 2.1). The large model area was necessitated by the tidal excursions and the need to ensure boundary effects did not impact the flows in the region of the outfalls.

Current Analysis Method

The computer model (M2D) was used to determine the current flow patterns based on the bathymetric grid described above. The model is based on a finite difference solution of the equations of motion of fluid flow and incorporates non-linear effects, wind induced currents and drying bank features. Boundary conditions are then applied in the form of tidal oscillations and the equations of motion solved for each cell at successive time steps.

Several model runs were then conducted for a range of boundary parameters to obtain simulations equivalent to mean neap and mean spring tides.

2 D - Flow Model Calibration

Calibration of the model is achieved by comparing predicted current speeds with field measurements and adjusting model coefficients as required. The method is robust in that once bathymetry and tidal elevations are specified to a reasonable accuracy and typical model coefficients employed, good predictions will be obtained without the need for specific adjustments.

A typical model output, for maximum ebb on a spring tide, is presented in Figure 3.1. Maximum flood on a spring tide is presented in Figure 3.2. The maximum neap tide ebb and flood cases are presented in Figures 3.3 and 3.4 respectively. Highest speeds occur to the south of the model area, near Greystones while the slackest ones are predicted for Dublin Bay.

3.3 2D - DISPERSION MODEL

Model Approach

Dispersion was simulated using the particle tracking model TRACK. In the model the discharge of effluent material is represented by a number of discrete particles. As the simulation progresses through time, a series of particles are released at the outfall location. During each time step the particles are moved horizontally by the current flows. In addition to these advective steps, each particle is moved by random steps along the three coordinate axes in order to simulate the effects of horizontal and vertical diffusion. The model, therefore, uses flow fields which are two dimensional in plan but tracks particles in three dimensions. This allows relatively simple representation of the currents to be used whilst enabling the processes of vertical mixing to be included.

The particle step length which simulated diffusion in the models was selected randomly in the range +/- infinity according to an appropriate Gaussian probability density function.

Dispersion Coefficients

In shallow coastal waters, dispersion results from a combination of physical mechanisms. These principally relate to the current and the manner in which it varies both vertically and laterally. The greater the 'velocity shear' the more rapid will be the dilution of the effluent. The horizontal diffusion coefficient was determined from the effective value arising from the shear dispersion caused by the vertical profile of tidal velocity.

The effect of wind is to promote more rapid mixing. This was simulated by an increased diffusion coefficient.

Decay

The process of contaminant decay was included in the model by evaluation of the probability of decay for each particle during each time step. This was expressed as a function of T_{90} where T_{90} is the time for 90 percent decay. An actual decay event occurred when a random number was less than this probability.

In the simulations produced for this study, the decay time was defined to be 10 days and so the results achieved equilibrium within 10% after one day and within 1% after twenty tides.

Model Simulations

The simulations made by the model were of twenty tidal cycles' duration using a time step of 100 seconds. Each time step, 100 particles were released giving a total of 894240 particles overall. However, due to the effects of decay ($T_{90} = 10$ days) and particle loss across the model's south and north boundaries, there were approximately 200,000 particles remaining in the model at the end of each simulation.

Calculation of Contaminant Concentrations

Concentrations of effluent were estimated by counting the number of particles in each model grid cell (100m x 100m). This produced the number of model particles in a volume of water which was determined by the horizontal cell dimensions and the water depth at that point.

Dispersion Model Calibration

Verification of the combined flow/particle track dispersion model was achieved by comparing simulated drogue tracks with field data and similarly, comparing patch releases of particles with dye track data. The agreement was good in that the excursions and patch dimensions were very similar to those recorded. The reader is referred to the original 1999 study report for more detailed information.

3.4 OUTFALL SITES AND DISCHARGE CHARACTERISTICS

Discharge Locations

In the model, effluent was discharged at a location corresponding to the existing Shanganagh outfall discharge point.

The storm outfall at Bray was simulated as a point source as it effectively discharges at the mouth of the harbour.

The River Dargle, as a source of contamination, was also simulated in this manner.

Effluent Flow Rates and Concentrations

The model simulates discharges at the WWTP at Shanganagh. This is the combined effluent from Shanganagh and Bray.

Shanganagh Outfall

A number of discharge cases were modelled as described below (the flow data was supplied by WYG):-

- The low flow scenario for the Design Year of 2018 at the Shanganagh WWTP is 1xDWF. This is the total flow from Shanganagh and Bray and is $0.377\text{m}^3/\text{sec}$.

- The average flow scenario for the Ultimate Design Year of 2031 at the Shanganagh WWTP is 1.25xDWF. This is the total flow from Shanganagh and Bray and is 0.598m³/sec.

Figures supplied by WYG indicate that *“the proposed secondary treatment plant will result in a reduction in total nitrogen in the wastewater by 20%, resulting in a typical N value of 30-35mg/l for effluent quality”*. A value of 35mg/l DIN was used in all simulations of discharge at the Shanganagh outfall.

The discharge from the Shanganagh outfall is modelled as a continuous release of particles for twenty tidal cycles. Model results of concentration are obtained at intervals of 1/12th of a tidal cycle for the last of the twenty cycles.

River Dargle

Flow data obtained from the Environmental Protection Agency (EPA) indicates a mean flow for the River Dargle of 3.4m³/s.

The DIN value of 2.6mg/l used in the model comes from the report *‘Proposed Environmental Quality Standards for General Components in Surface Waters in Ireland’* (ref. 5). Also, the EIS for the Bray Flood Defence Scheme (ref. 6) contains information on water samples collected in the Dargle catchment during 2001-2003. A median Oxidised Nitrogen value of 2.3mg/l is indicated for a location 1km upstream of Bray Bridge and a value of 3.2mg/l for a location upstream of Glencullen Bridge. These figures would indicate that a value of 2.6mg/l is reasonable.

The discharge from the River Dargle is modelled as a continuous release of particles for twenty tidal cycles. Model results of concentration are obtained at intervals of 1/12th of a tidal cycle for the last of the twenty cycles.

Bray Storm Outfall

At the Bray storm outfall, the flow value modelled was the same as used in the 1999 study, which is 0.254m³/sec.

A two-fold dilution of the effluent concentration is assumed during the overflow, leading to a value of 18mg/l DIN.

The discharge from the Bray storm outfall is modelled as a continuous release of particles for tidal cycle #15 only, i.e. for 12.5hrs. Model results of concentration are obtained at HW and LW for each of the next five tidal cycles.

The modelled flows and concentrations are summarised in Table 3.2.

Case	Model Scenario	Flow Rate m ³ /day	Flow Rate m ³ /sec	Concentration DIN (mg/l)
1	WWTW Shanganagh (Design Year 2018) Low Flow (1xDWF)	32572	0.377	35.0
2	WWTW Shanganagh (Design Year 2031) Average Flow (1.25xDWF)	51623	0.598	35.0
3	River Dargle (mean flow)	293760	3.4	2.6
4	Bray Storm Outfall	21946	0.254	18.0

Table 3.1 – Modelled Effluent Discharge Characteristics

3.5 DISPERSION MODEL RESULTS

Dispersion of Discharges

For model cases 1, 2 and 3 of Table 3.2, simulations were first conducted for both spring and neap tide ranges under calm conditions. The simulations were then repeated with increased lateral diffusion corresponding to an equivalent onshore wind of 7m/s. This was done for the continuous release scenarios at the Shanganagh outfall and the River Dargle. For the Bray Storm Outfall, the worst case scenario of neap tide range with calm conditions was modelled. In total, 13 simulations were conducted. Results are presented in graphical form in Appendices 1 and 2.

Model Output

The results from the continuous discharges from the Shanganagh outfall and the River Dargle for corresponding model runs (e.g. spring-range/calm, spring-range/wind, neap-range/calm and neap-range/wind) have been combined as indicated in Table 3.3.

Time series data of DIN concentration (Appendix 1) is generated for groups of model cells (coastal inspection strips) at selected locations along the coast. These locations are shown in Figure 3.5 and correspond to a number of bathing or water sport areas as used in the 1999 study. The plots show the average concentration at each model output time step. The average value is that computed over the number of cells in a strip within which concentrations are recorded (note that not all cells within any strip are necessarily filled).

The contour plots of DIN (Appendix 2) are based on the concentration as determined by the number of particles within each cell (100mx 100m), each particle being equivalent to a pre-defined effluent source volume.

Model Scenario	Flow Rate m ³ /sec	DIN (mg/l)	Spring/ Calm	Spring/ Wind	Neap/ Calm	Neap/ Wind
WWTW Shanganagh (Design Year 2018) Low Flow (1xDWF) + River Dargle (mean flow)	0.377 3.4	35.0 2.6	 CM40	 CM41	 CM42	 CM43
WWTW Shanganagh (Design Year 2031) Average Flow (1.25xDWF) + River Dargle (mean flow)	0.598 3.4	35.0 2.6	 CM50	 CM51	 CM52	 CM53
Bray Storm Outfall	0.254	18.0			CM62	

Table 3.2 – Model result combinations and associated model output labelling

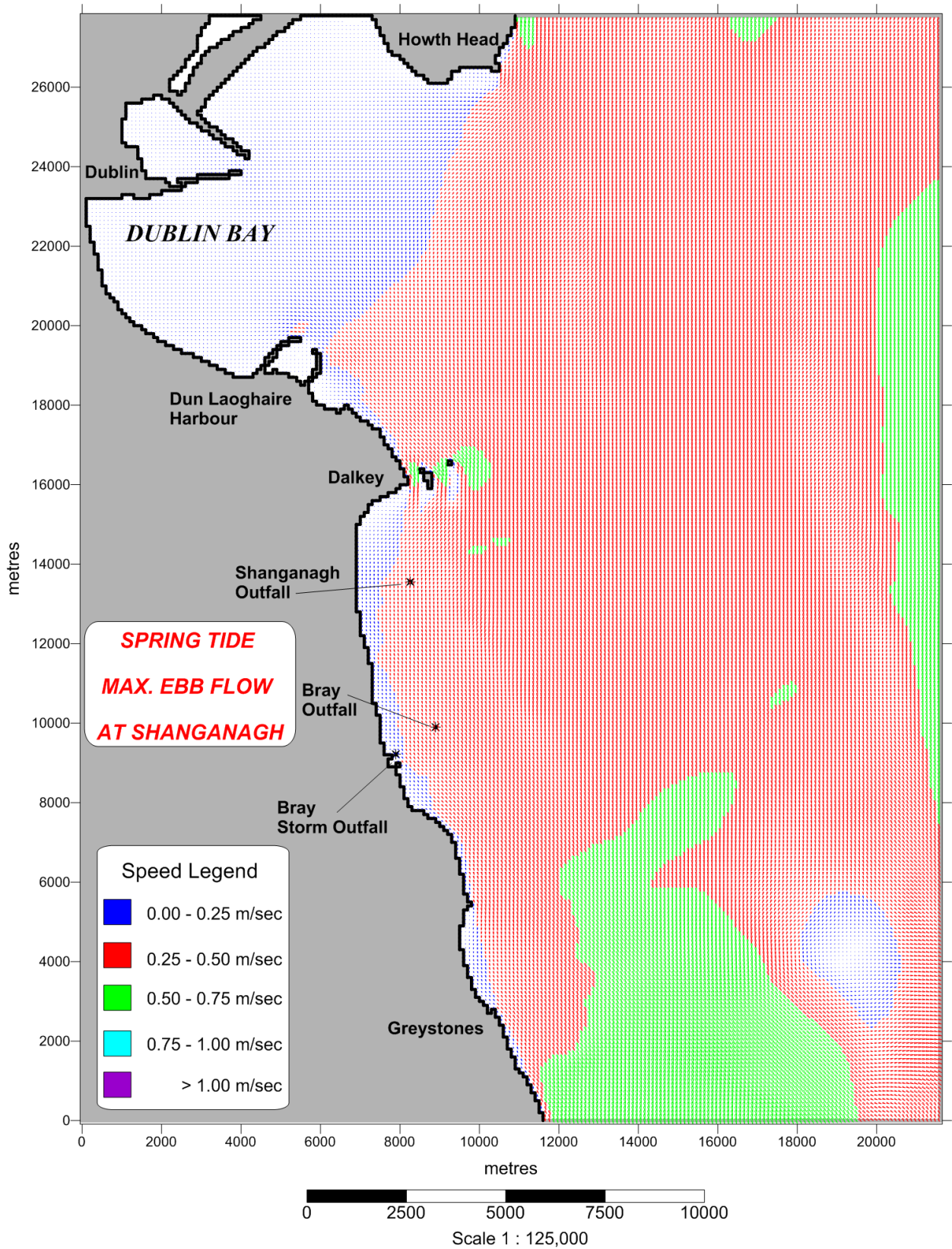


Figure 3.1

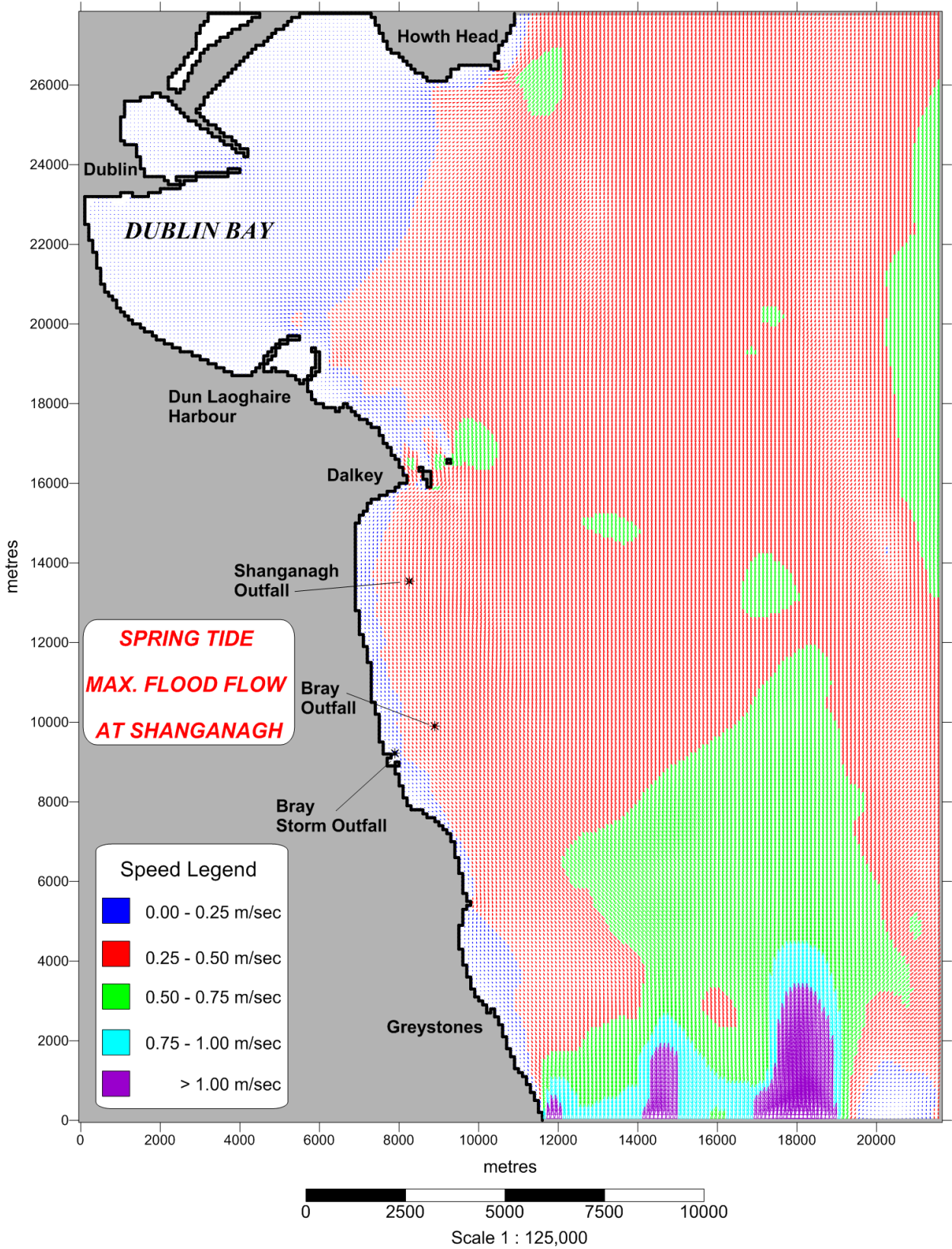


Figure 3.2

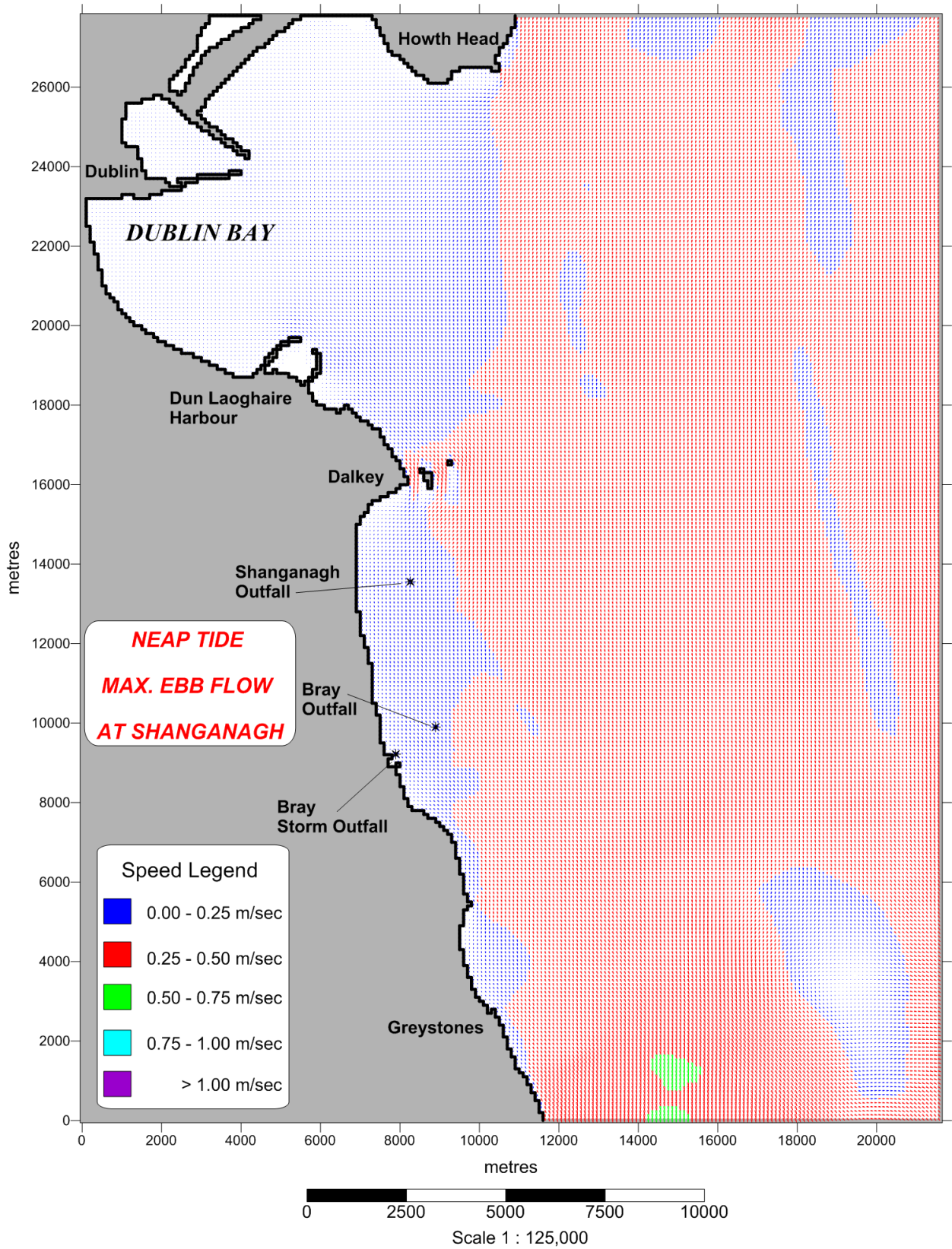


Figure 3.3

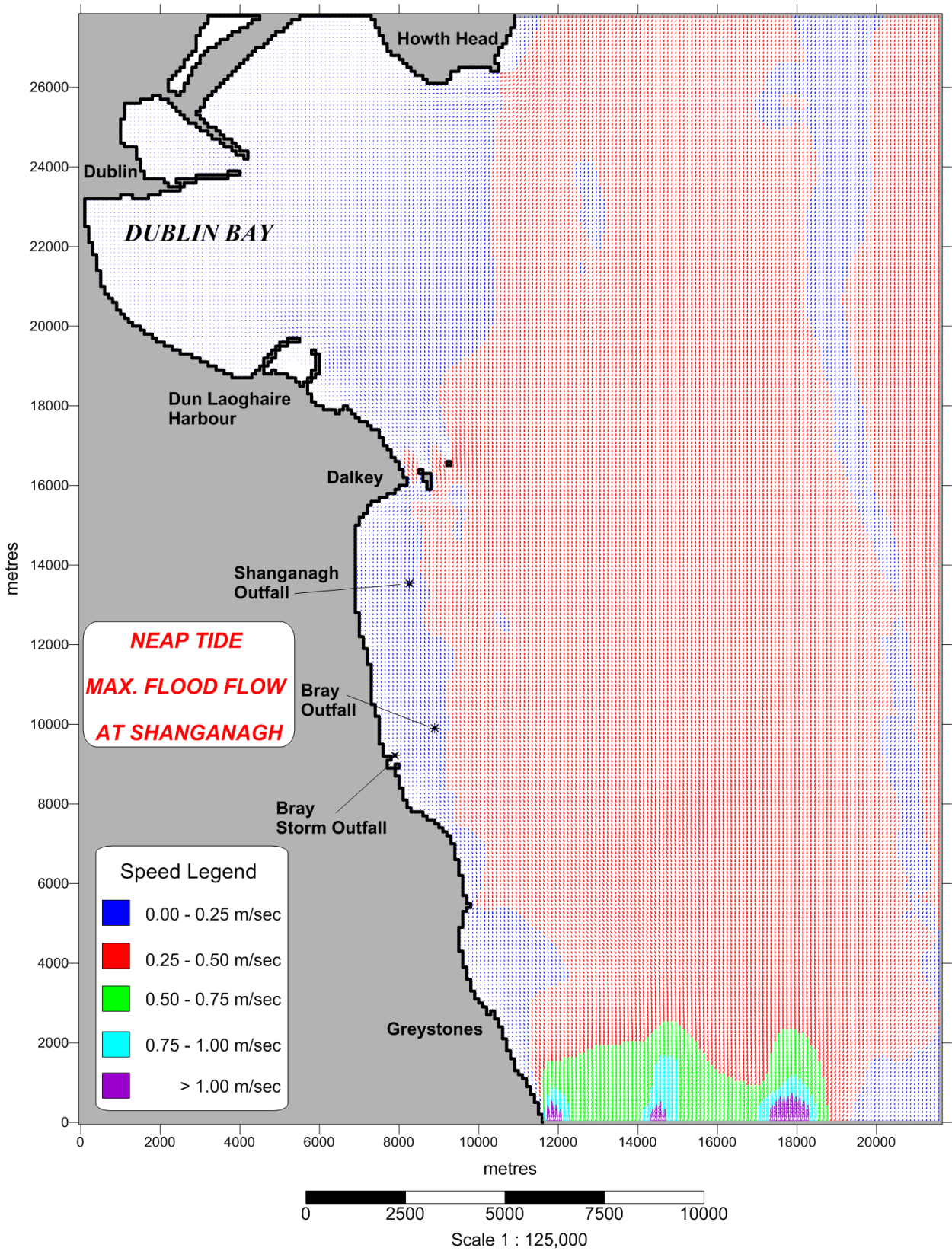


Figure 3.4

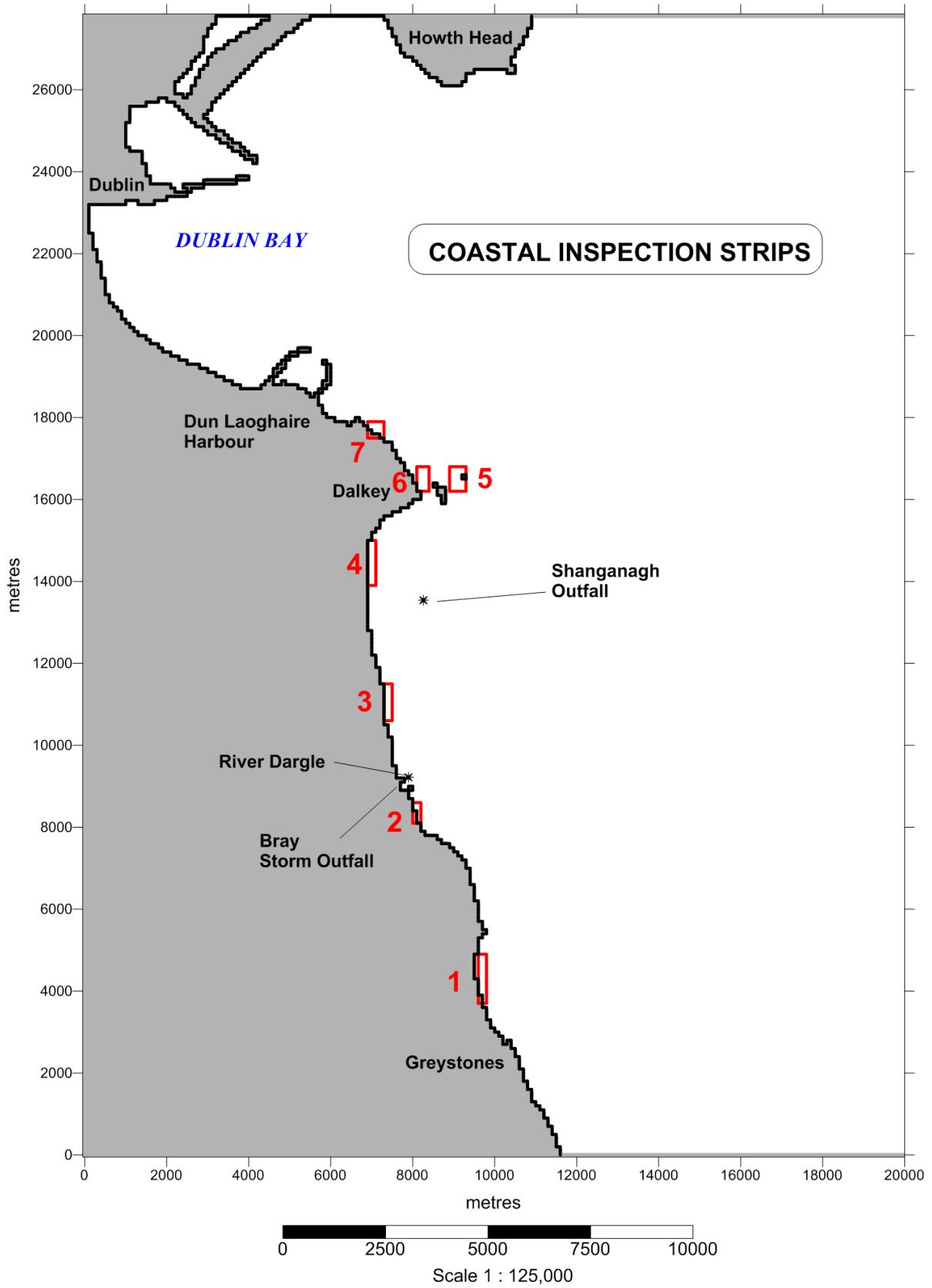


Figure 3.5

4. CLOSURE

- 4.1 This report presents the findings of a modelling study of the proposed treated waste water from the municipalities of Shanganagh and Bray, discharging from the Shanganagh outfall. The study assesses the DIN based on certain effluent characteristics. It is an objective of the study to see if the DIN levels in the receiving waters resulting from the discharges are compliant with S.I. 272 of 2009. The S.I. indicates that for coastal water bodies with salinity levels of 34.5psu, DIN values must be less than or equal to 0.25mg/l to achieve 'Good' status.
- 4.2 The general oceanography of the region is typical of open coastal sites. The tidal currents flow parallel to the shoreline with peak speeds in excess of 0.5m/s. Dispersion characteristics are good as shown by dye and drogue data. Tidal ranges in the area are approx. 3.2m on springs and 2.0m on neaps.
- 4.3 A two dimensional flow model together with a particle track dispersion model (originally constructed and used in the 1999 study) was used to simulate the discharges. Results in the form of plots of contours of DIN concentration were prepared for the simulations. The results from the Shanganagh outfall simulations were combined with those from the River Dargle for presentation purposes. The results for the Bray storm outfall simulation are presented alone. All results are presented in Appendix 2.
- 4.4 To facilitate interpretation of the different model/effluent discharge scenarios seven representative coastal water strips were examined for average DIN concentration. Time series plots of the findings for each hour of the tidal cycle are presented in Appendix 1. The maximum of the average values from this data are summarised in Table 4.1 for a number of locations. It should be noted that the results of the discharges from the Shanganagh outfall and the River Dargle are combined.

Model Combination	Bray Prom (2)	Shanganagh Beach (4)	Muglins / Dalkey Is(5)	DalkeySound (6)
CM40 (Sp – Calm)	0.095	0.044	0.014	0.015
CM41 (Sp – Wind)	0.030	0.012	0.009	0.009
CM42 (Np – Calm)	0.202	0.010	0.025	0.012
CM43 (Np – Wind)	0.041	0.013	0.013	0.009
CM50 (Sp – Calm)	0.090	0.044	0.020	0.016
CM51 (Sp – Wind)	0.030	0.013	0.012	0.011
CM52 (Np – Calm)	0.202	0.010	0.040	0.018
CM53 (Np – Wind)	0.041	0.017	0.020	0.017
CM62 (Np – Calm)	0.070	0.000	0.000	0.000

Table 4.1 - Predicted Maximum of Average DIN levels (mg/l) over a tidal cycle at Selected Locations

- 4.5 Model combinations CM40-CM43 simulate the low flow (1xDWF) case at the Shanganagh outfall for the Design Year of 2018, combined with the mean flow scenario from the River Dargle. The highest concentrations occur during neap tide range and calm wind conditions. A level of 0.202 mg/l DIN is predicted in Strip 2 (Bray Promenade) and is due to the River Dargle, whose plume hugs the coastline. Levels at a distance away from the coastline, primarily arising from the Shanganagh outfall, are generally less than 0.02 mg/l. During neap-range/calm conditions, values up to 0.05mg/l are encountered near the outfall.
- 4.6 Model combinations CM50-CM53 simulate the average flow (1.25xDWF) case at the Shanganagh outfall for the Ultimate Design Year of 2031, combined with the mean flow scenario from the River Dargle. The highest concentrations occur during neap tide and calm wind conditions. Again, a level of 0.202 mg/l DIN is predicted in Strip 2 (Bray Promenade). Levels at a distance away from the coastline primarily arise from the Shanganagh outfall and are generally less than 0.03 mg/l. During neap-range/calm conditions, values up 0.05 to 0.10mg/l are encountered near the outfall.
- 4.7 Model combination CM62 simulates an event at the Bray storm outfall. The plume hugs the coastline and exhibits maximum values of about 0.15mg/l near the discharge source.
- 4.8 The model results show:
- The River Dargle is the principal source of DIN in the area.
 - Concentrations for the discharge at the Shanganagh outfall for the Design Year of 2018 are typically <0.05mg/l near the outfall and < 0.02mg/l farther afield.
 - Concentrations for the discharge at the Shanganagh outfall for the Ultimate Design Year of 2031 are typically <0.10mg/l near the outfall and < 0.03mg/l farther afield.
 - The Bray storm outfall discharge levels adjacent to the coast are typically <0.15mg/l and persist locally for a number of tidal cycles.

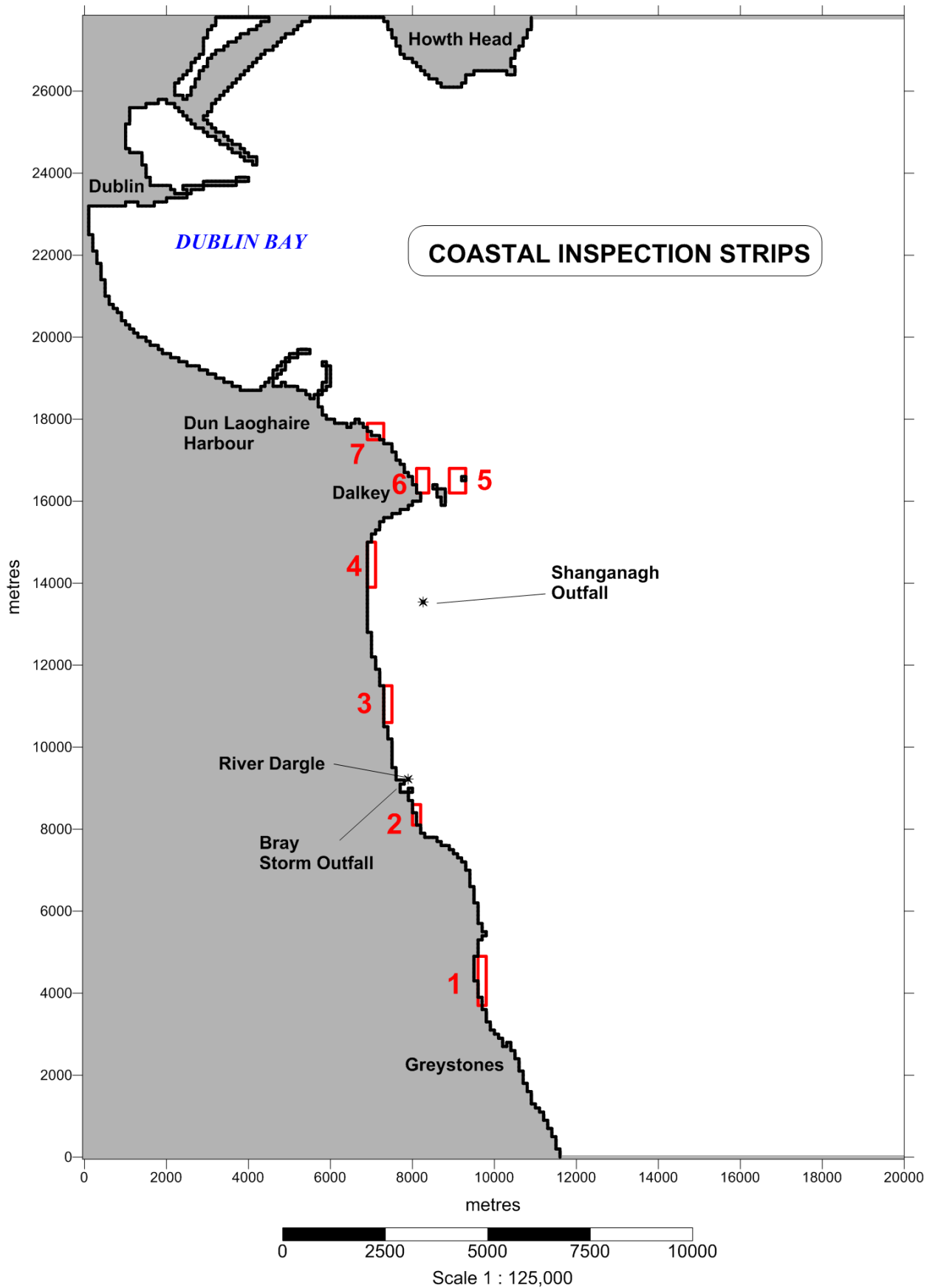
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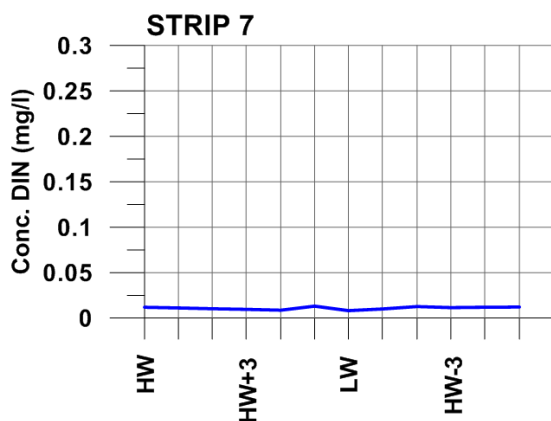
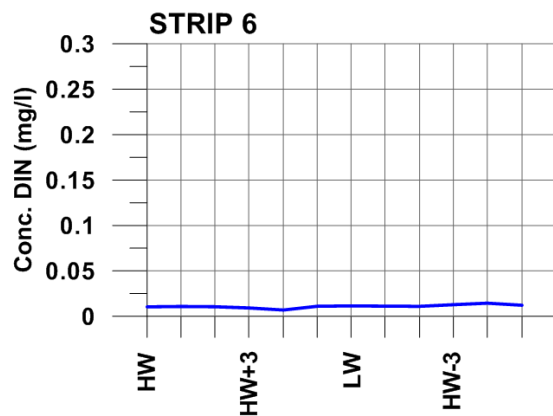
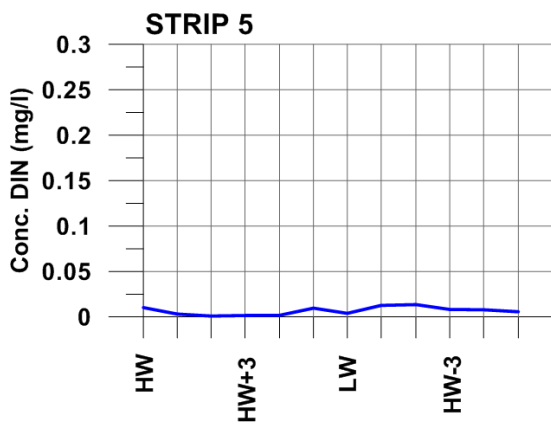
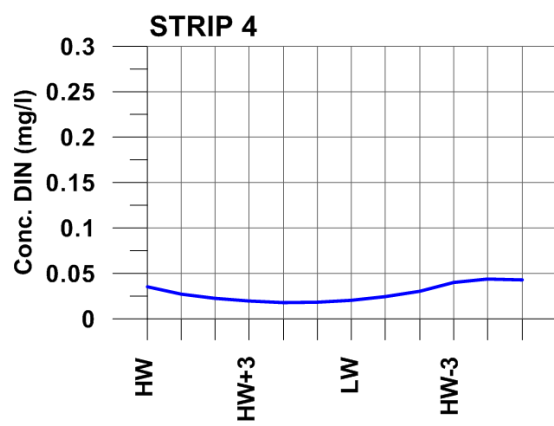
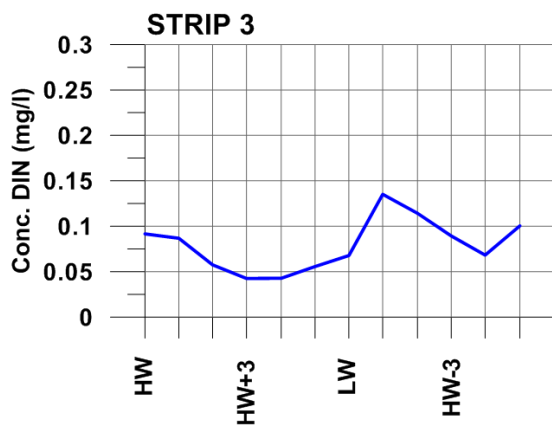
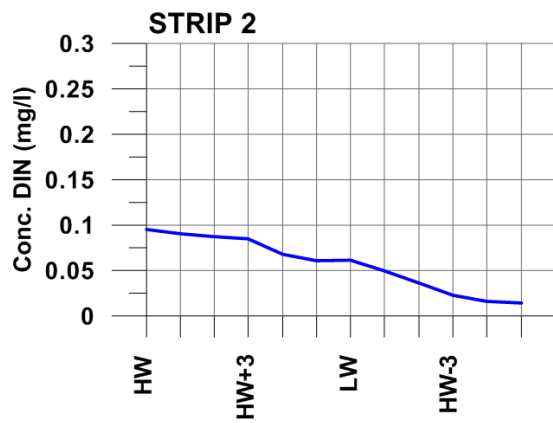
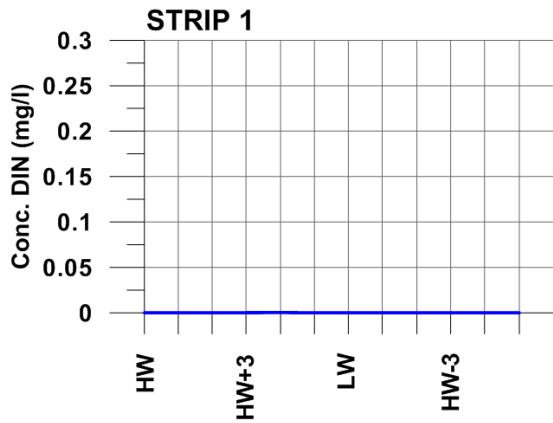
APPENDIX 1

Model Results

Time Series Plots of Concentration In Coastal Inspection Strips



Average Concentration of DIN in Coastal Inspection Strips



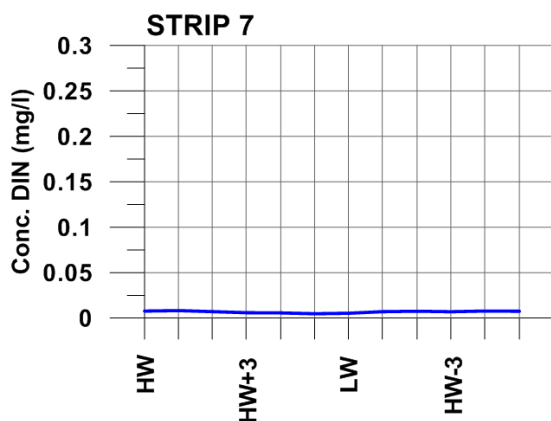
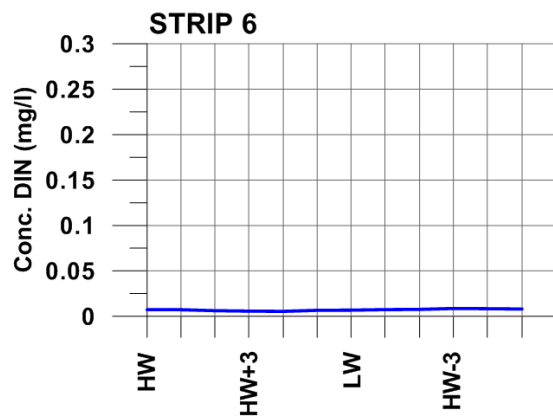
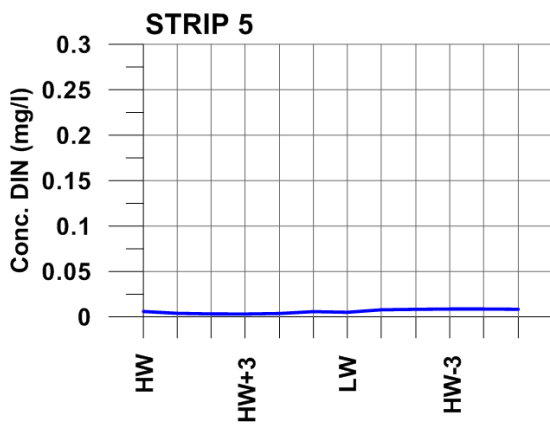
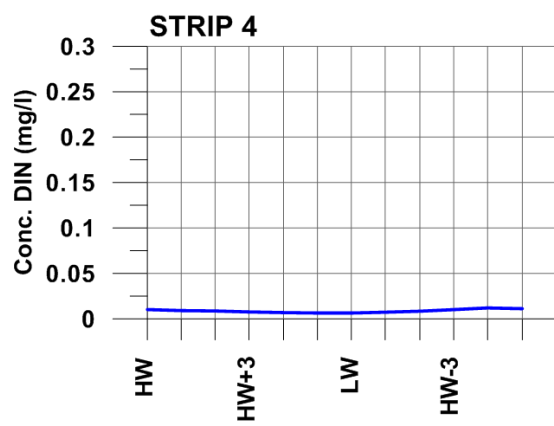
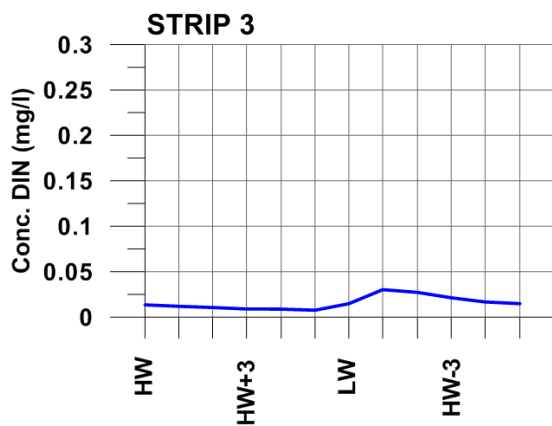
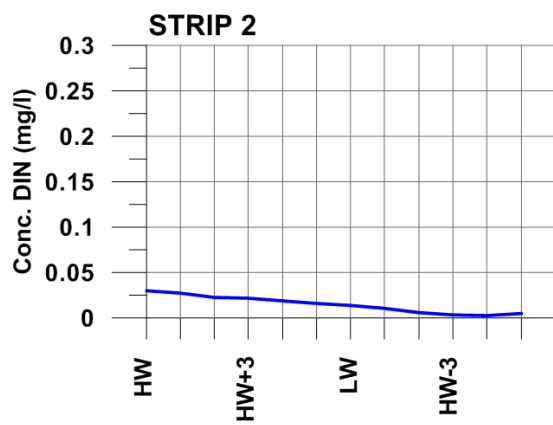
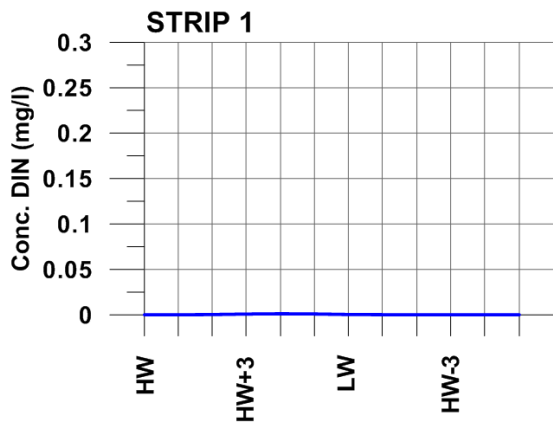
Model Case CM40

Spring Tide, Wind Calm

Shanganagh Outfall (Design year 2018):
 $Q = 1 \times DWF = 0.377 \text{ m}^3/\text{sec}$
 $C = 35 \text{ mg/l N}$

River Dargle:
 $Q = \text{Mean Flow} = 3.4 \text{ m}^3/\text{sec}$
 $C = 2.6 \text{ mg/l N}$

Average Concentration of DIN in Coastal Inspection Strips



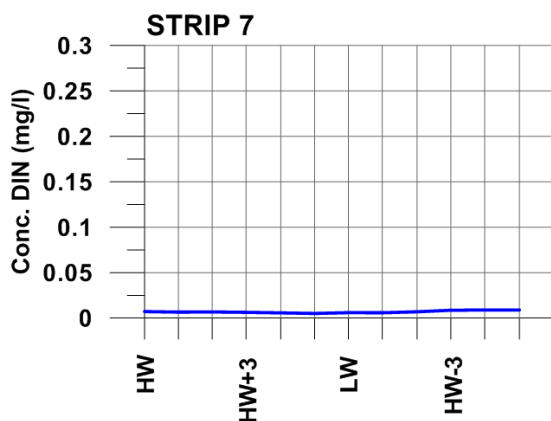
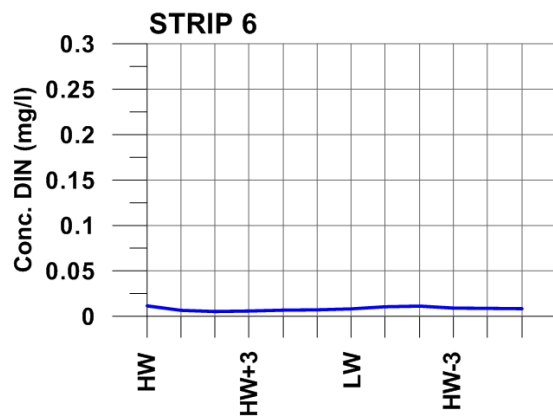
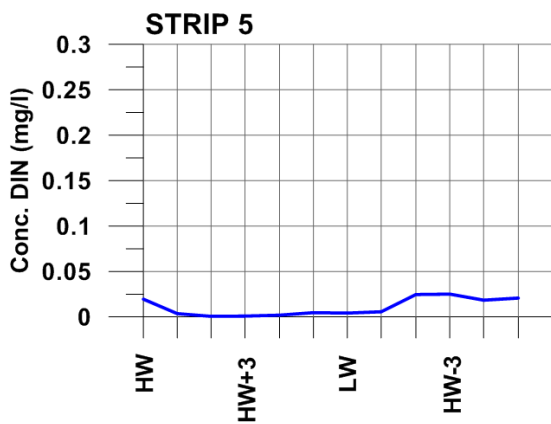
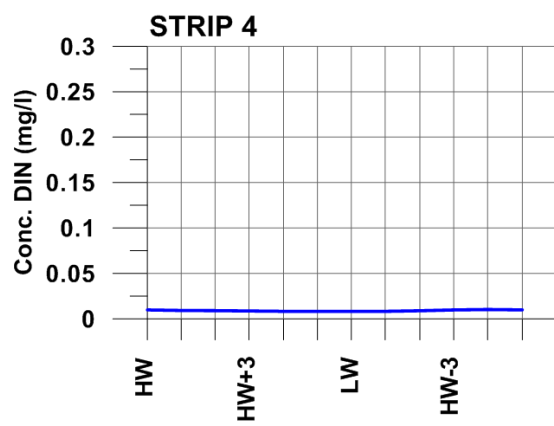
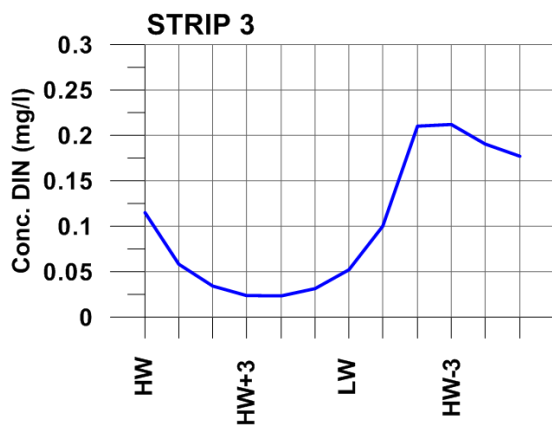
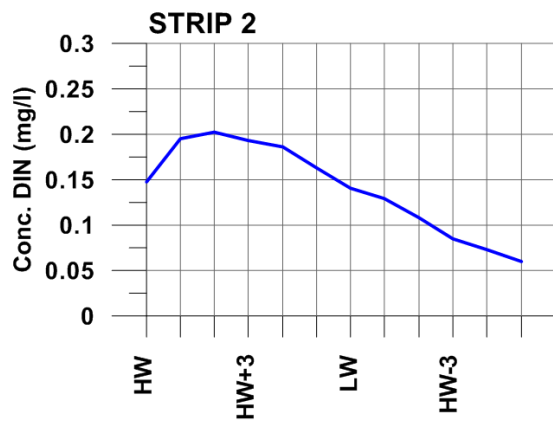
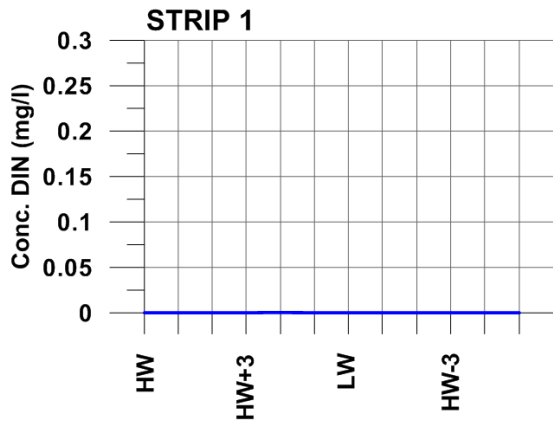
Model Case CM41

Spring Tide, Wind Enabled

Shanganagh Outfall (Design year 2018):
 Q = 1xDWF = 0.377m³/sec
 C = 35mg/l N

River Dargle:
 Q = Mean Flow = 3.4m³/sec
 C = 2.6 mg/l N

Average Concentration of DIN in Coastal Inspection Strips



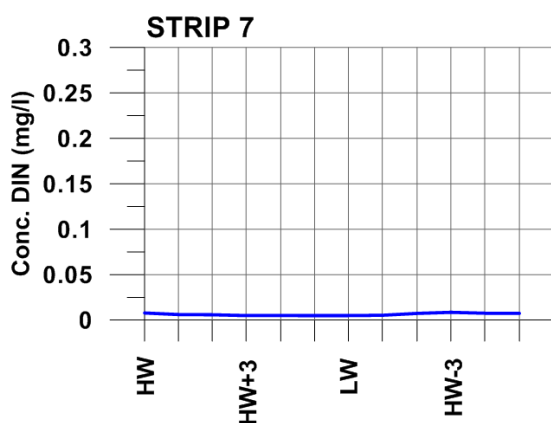
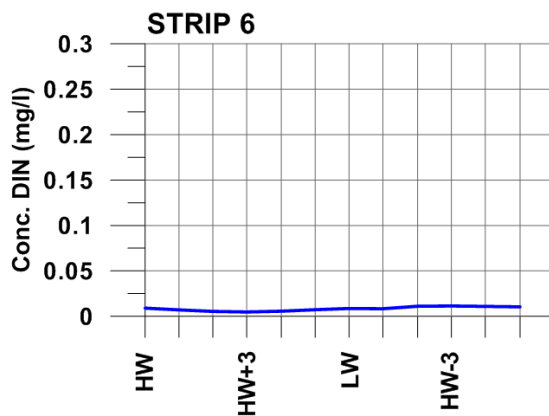
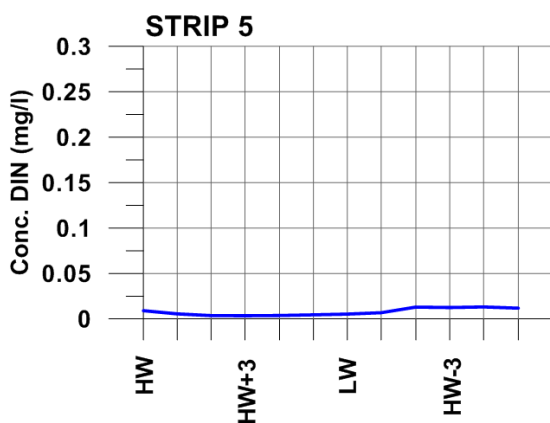
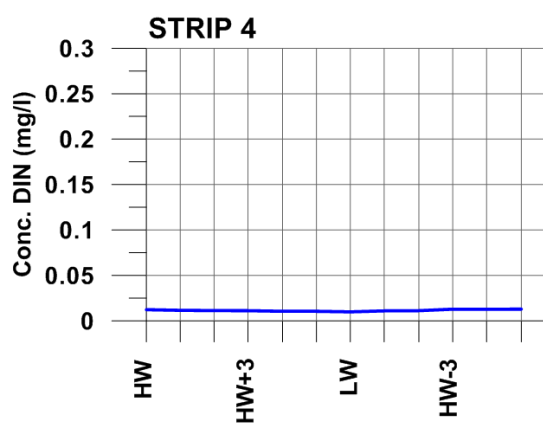
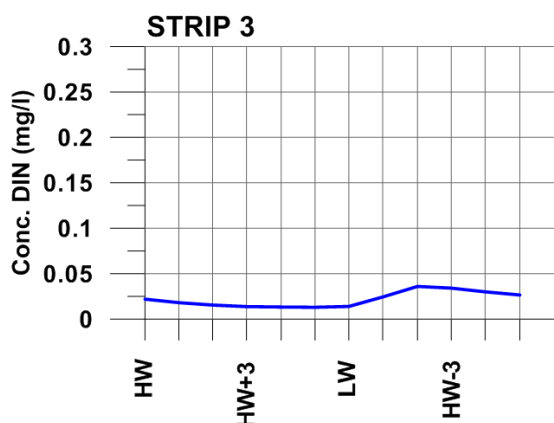
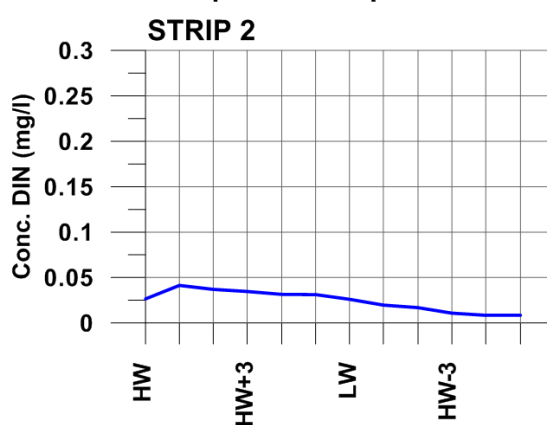
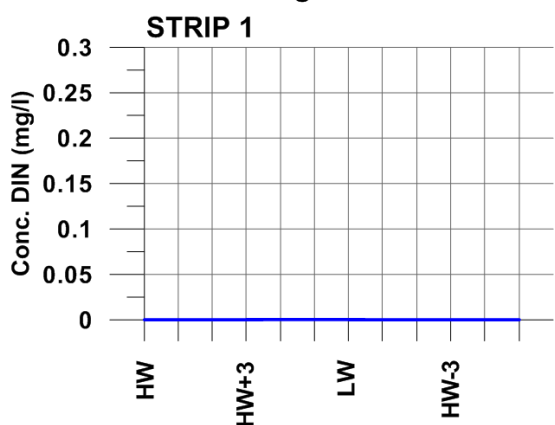
Model Case CM42

Neap Tide, Wind Calm

Shanganagh Outfall (Design year 2018):
 $Q = 1 \times DWF = 0.377 \text{ m}^3/\text{sec}$
 $C = 35 \text{ mg/l N}$

River Dargle:
 $Q = \text{Mean Flow} = 3.4 \text{ m}^3/\text{sec}$
 $C = 2.6 \text{ mg/l N}$

Average Concentration of DIN in Coastal Inspection Strips



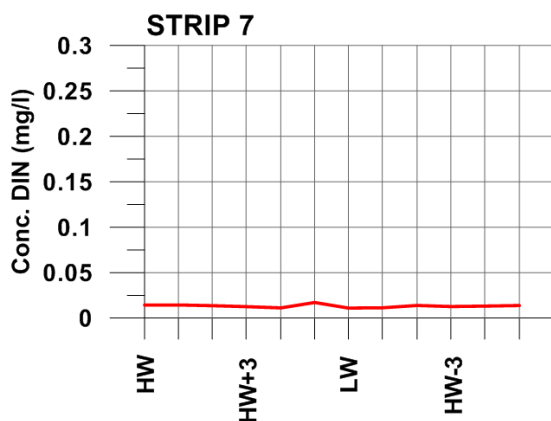
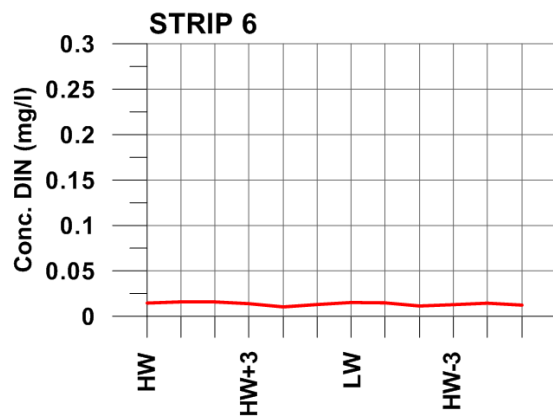
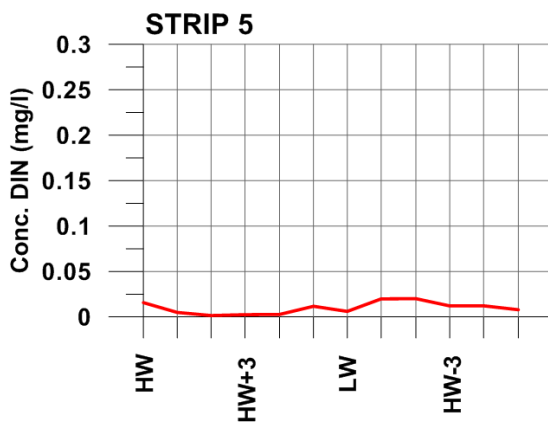
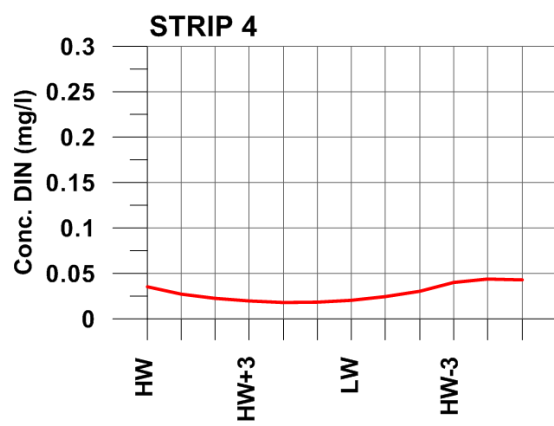
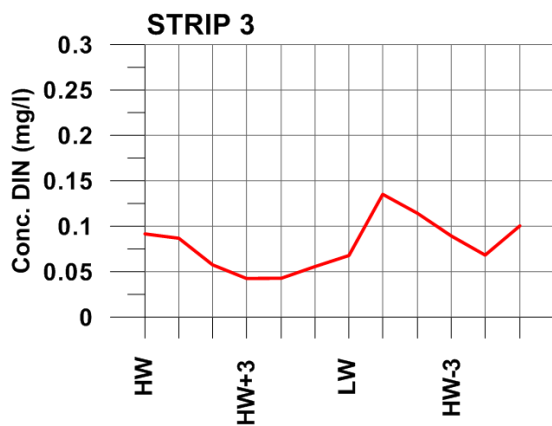
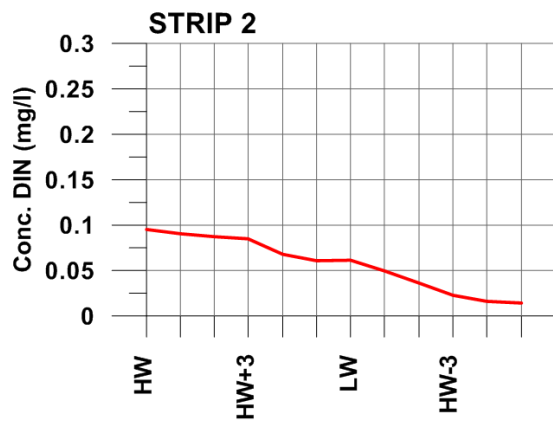
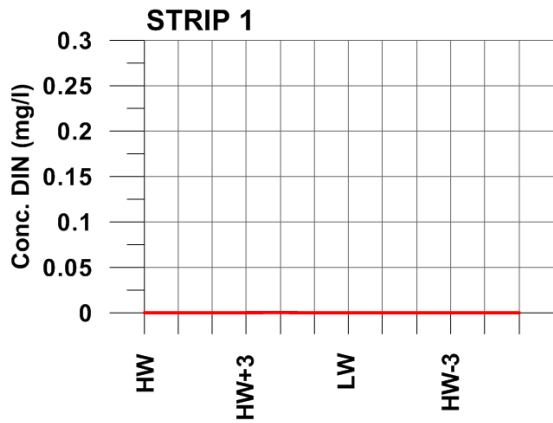
Model Case CM43

Neap Tide, Wind Enabled

Shanganagh Outfall (Design year 2018):
 Q = 1xDWF = 0.377m³/sec
 C = 35mg/l N

River Dargle:
 Q = Mean Flow = 3.4m³/sec
 C = 2.6 mg/l N

Average Concentration of DIN in Coastal Inspection Strips



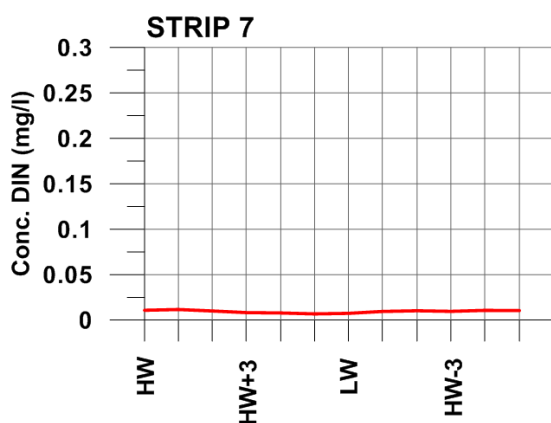
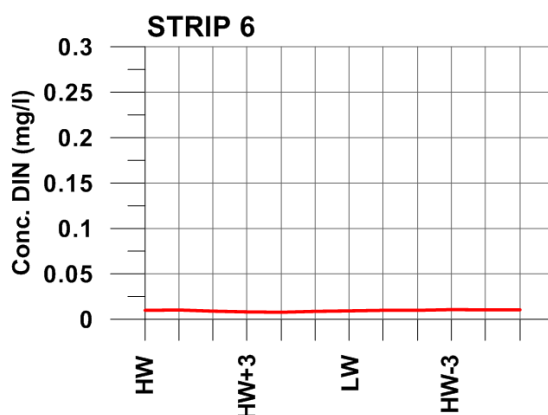
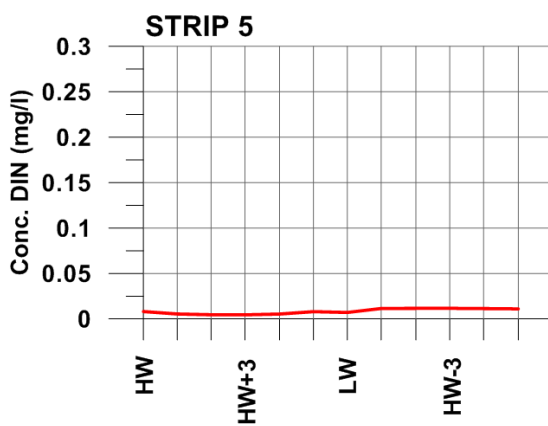
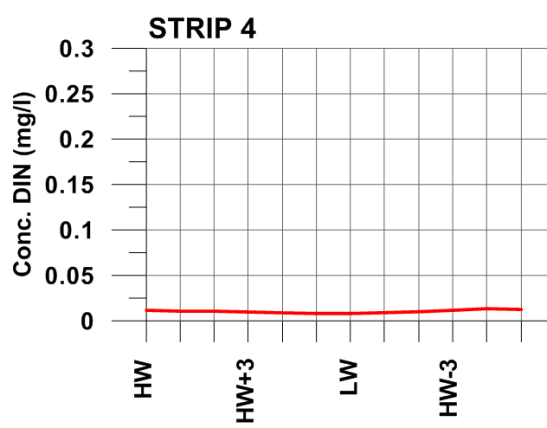
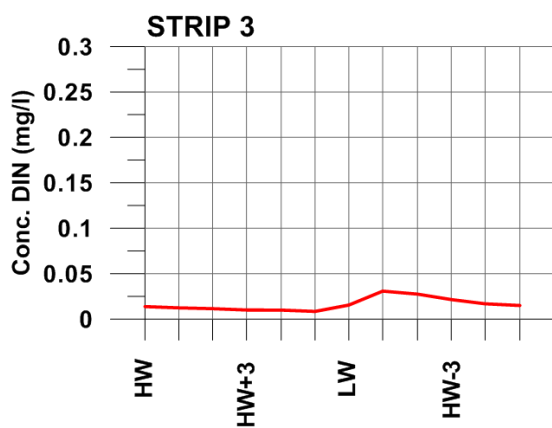
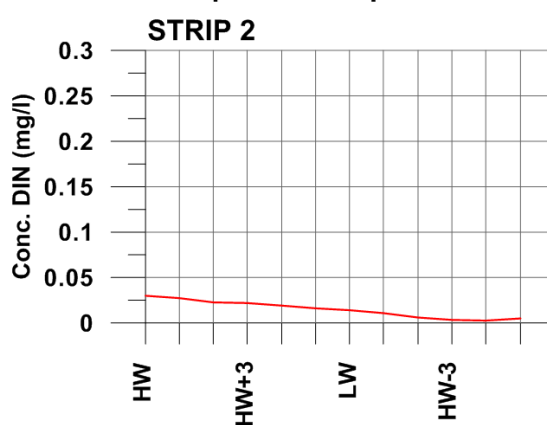
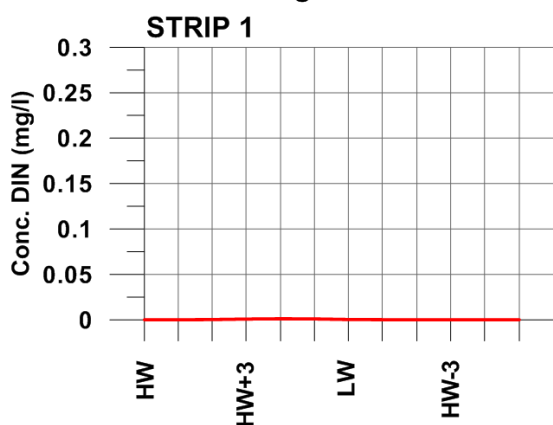
Model Case CM50

Spring Tide, Wind Calm

Shanganagh Outfall (Design year 2031):
 $Q = 1.25 \times DWF = 0.598 \text{ m}^3/\text{sec}$
 $C = 35 \text{ mg/l N}$

River Dargle:
 $Q = \text{Mean Flow} = 3.4 \text{ m}^3/\text{sec}$
 $C = 2.6 \text{ mg/l N}$

Average Concentration of DIN in Coastal Inspection Strips



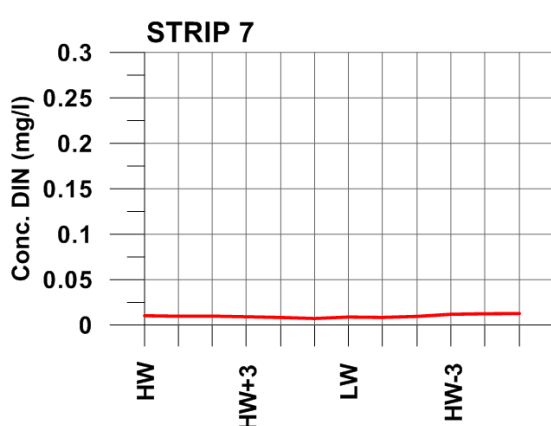
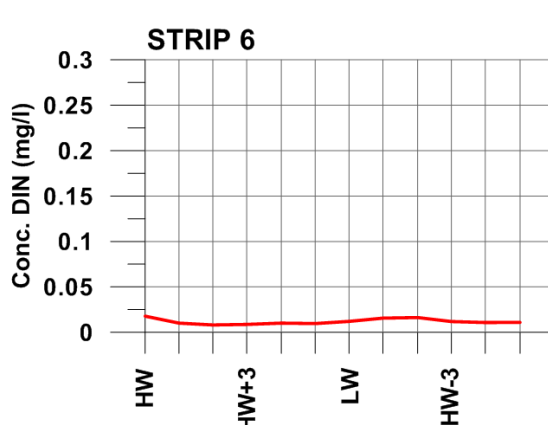
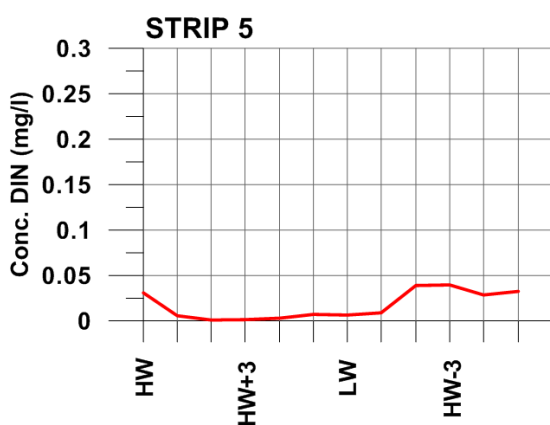
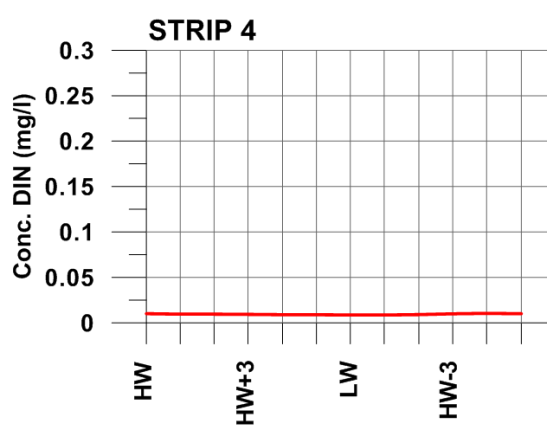
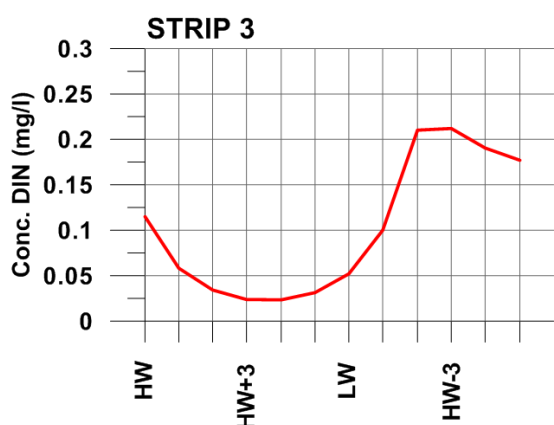
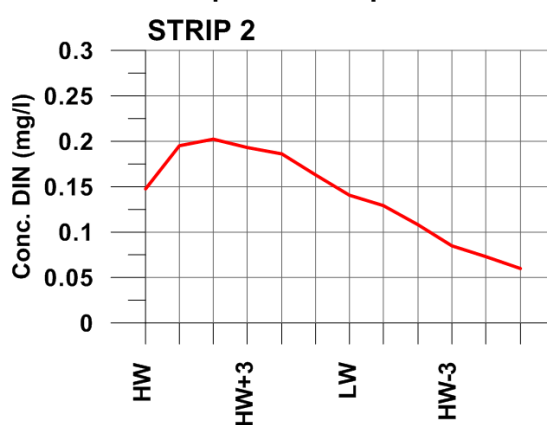
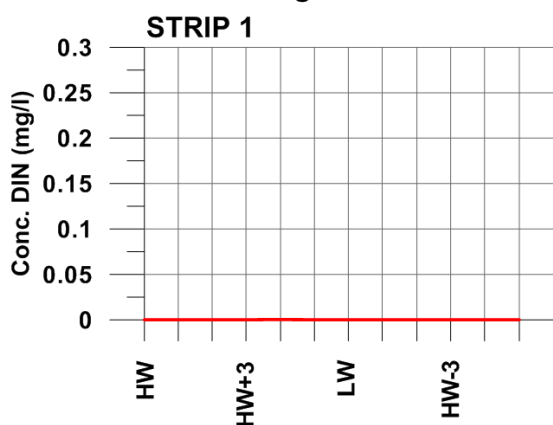
Model Case CM51

Spring Tide, Wind Enabled

Shanganagh Outfall (Design year 2031):
 $Q = 1.25 \times DWF = 0.598 \text{ m}^3/\text{sec}$
 $C = 35 \text{ mg/l N}$

River Dargle:
 $Q = \text{Mean Flow} = 3.4 \text{ m}^3/\text{sec}$
 $C = 2.6 \text{ mg/l N}$

Average Concentration of DIN in Coastal Inspection Strips



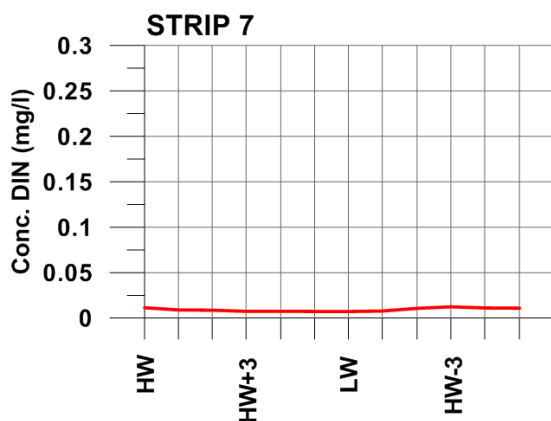
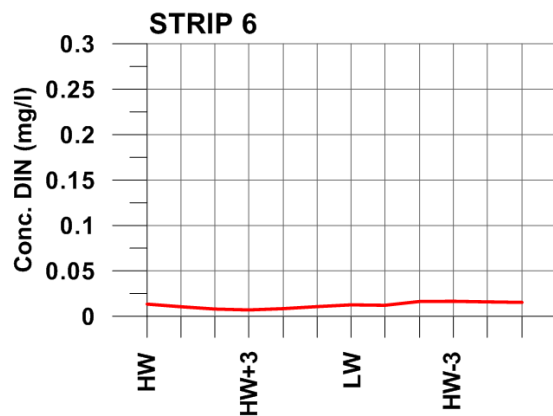
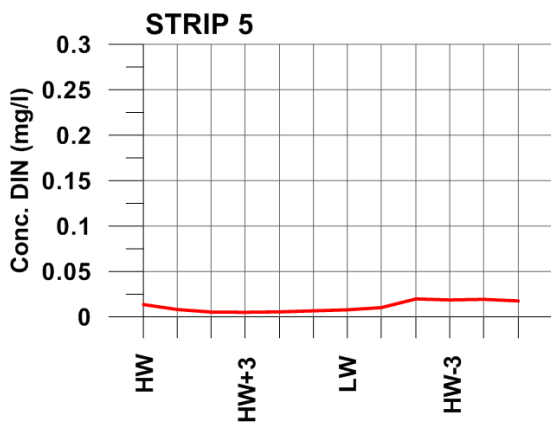
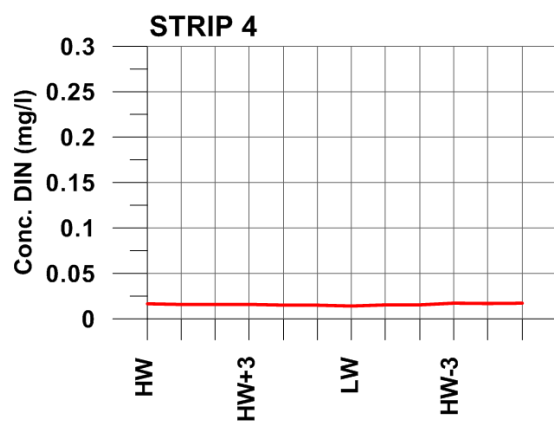
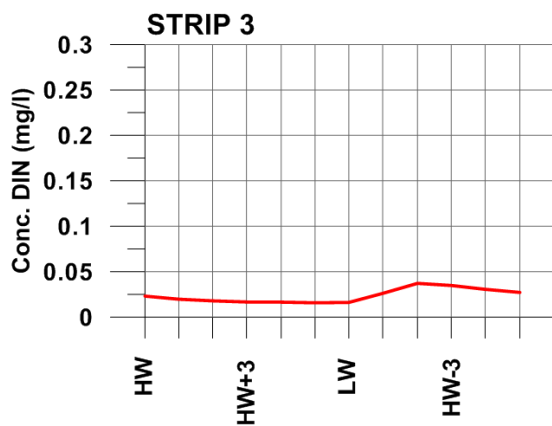
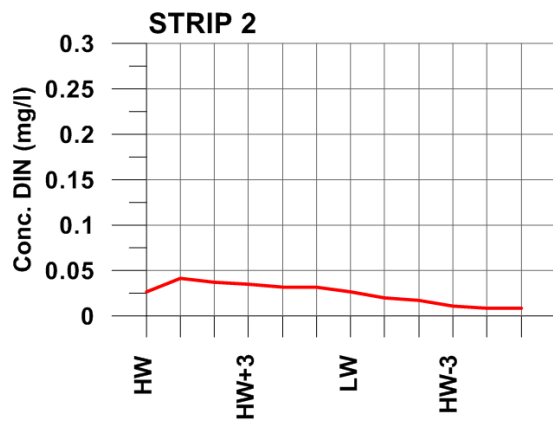
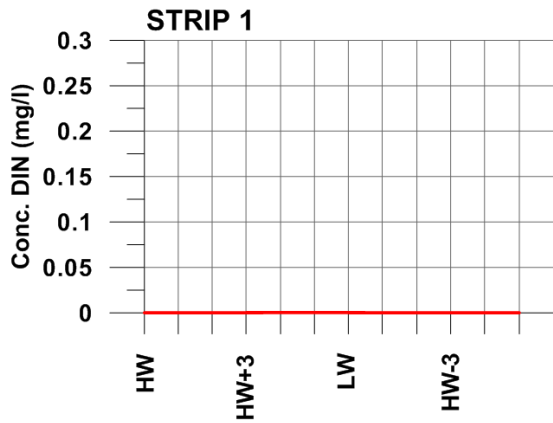
Model Case CM52

Neap Tide, Wind Calm

Shanganagh Outfall (Design year 2031):
 $Q = 1.25 \times DWF = 0.598 \text{ m}^3/\text{sec}$
 $C = 35 \text{ mg/l N}$

River Dargle:
 $Q = \text{Mean Flow} = 3.4 \text{ m}^3/\text{sec}$
 $C = 2.6 \text{ mg/l N}$

Average Concentration of DIN in Coastal Inspection Strips



Model Case CM52

Neap Tide, Wind Enabled

Shanganagh Outfall (Design year 2031):
 $Q = 1.25 \times DWF = 0.598 \text{ m}^3/\text{sec}$
 $C = 35 \text{ mg/l N}$

River Dargle:
 $Q = \text{Mean Flow} = 3.4 \text{ m}^3/\text{sec}$
 $C = 2.6 \text{ mg/l N}$

APPENDIX 2

Model Results - Contour Plots of Concentration

Shanganagh Outfall (Design Year 2018)

Flow (1xDWF) 0.377m³/sec

Concentration: 35mg/l N

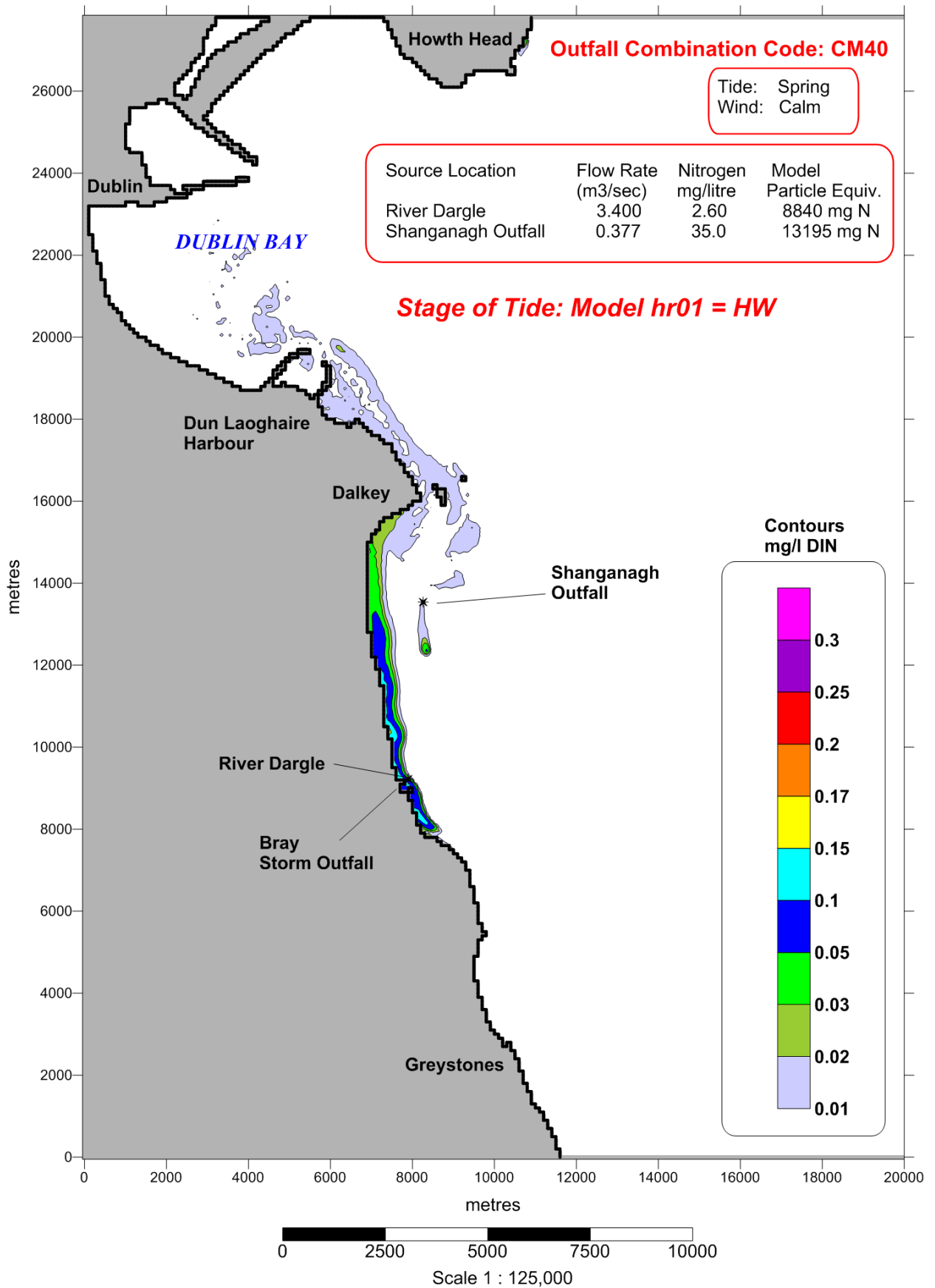
River Dargle

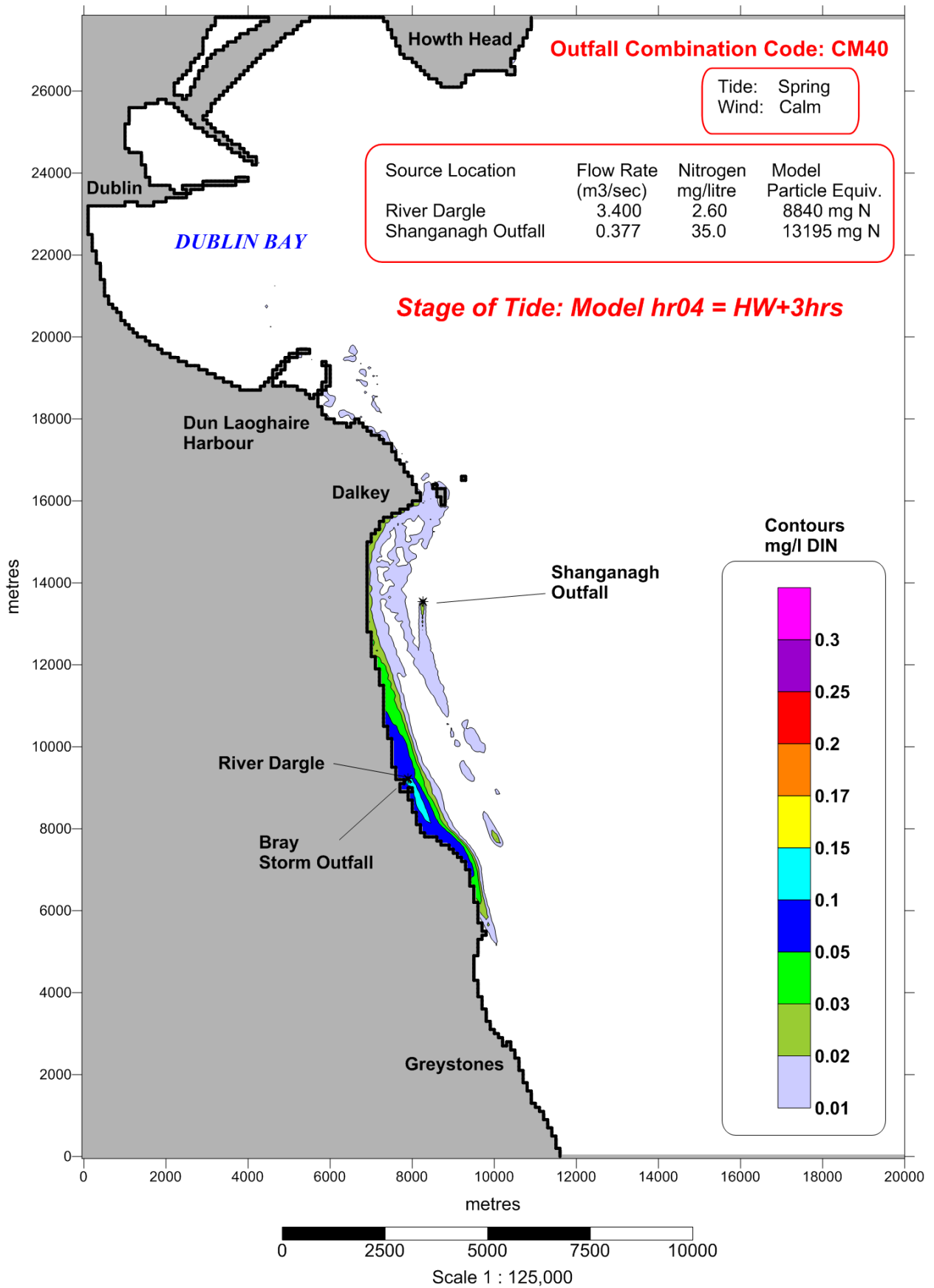
Mean Flow 3.4m³/sec

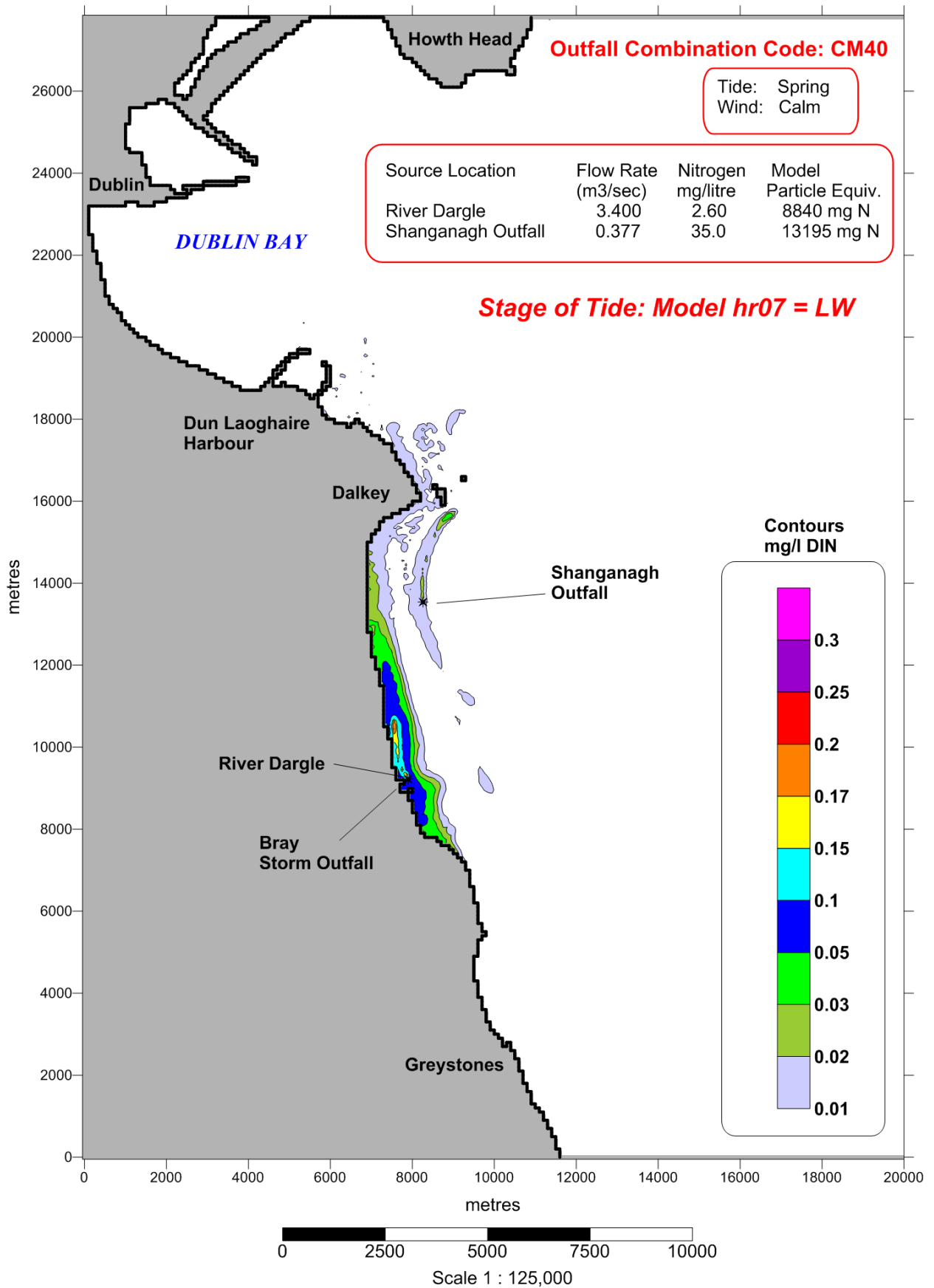
Concentration: 2.6 mg/l N

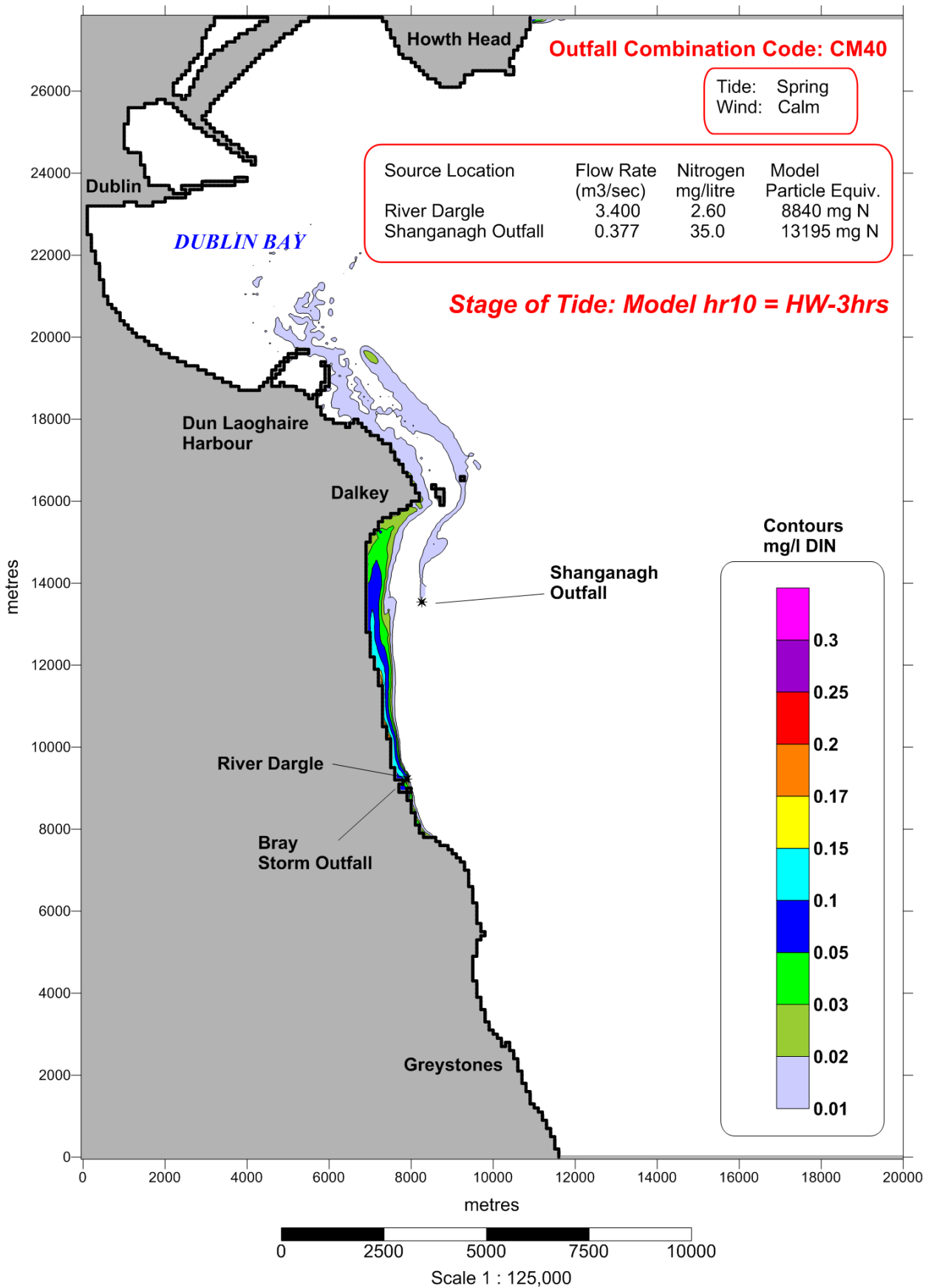
Tide: Spring

Wind: Calm

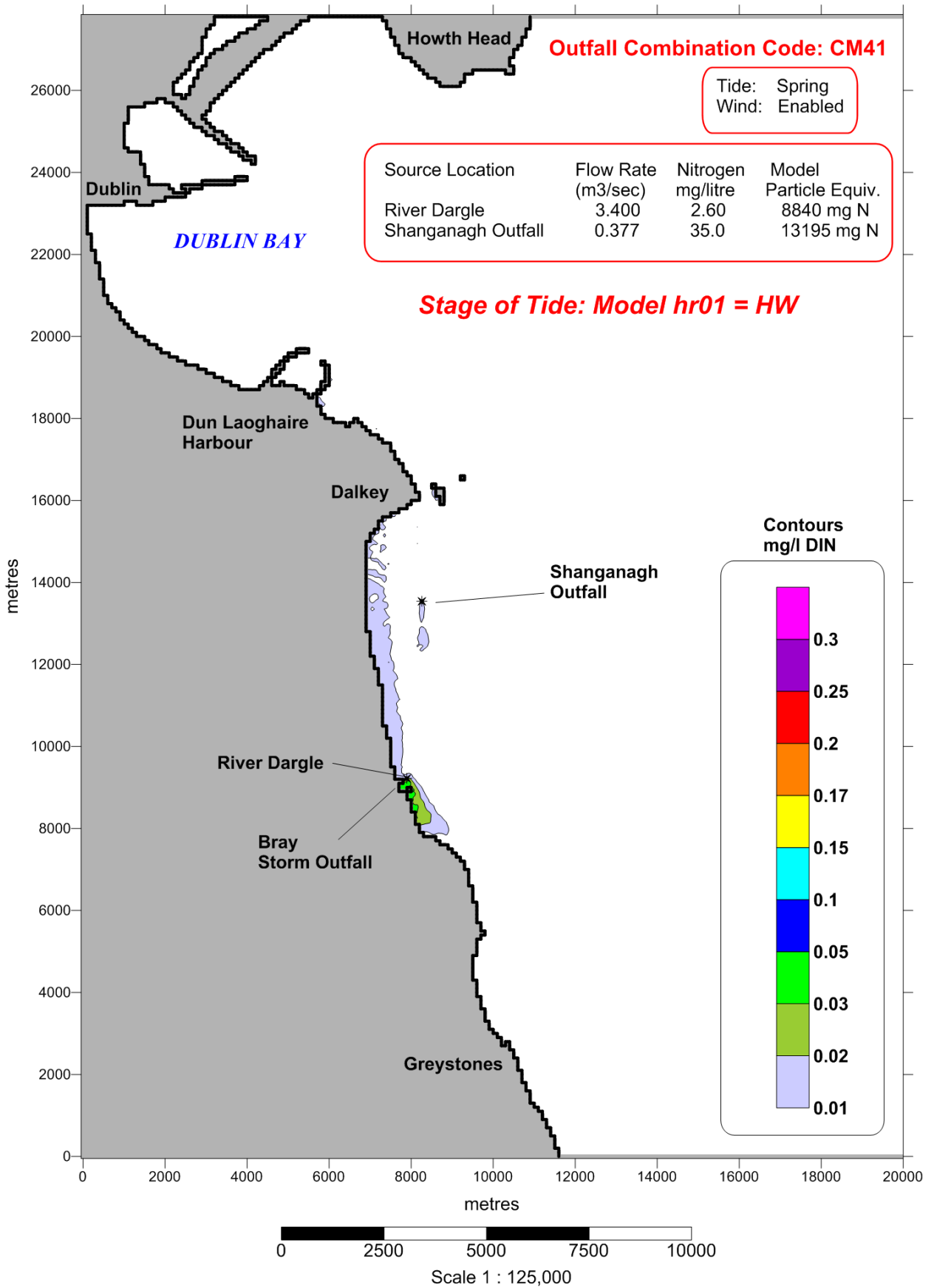


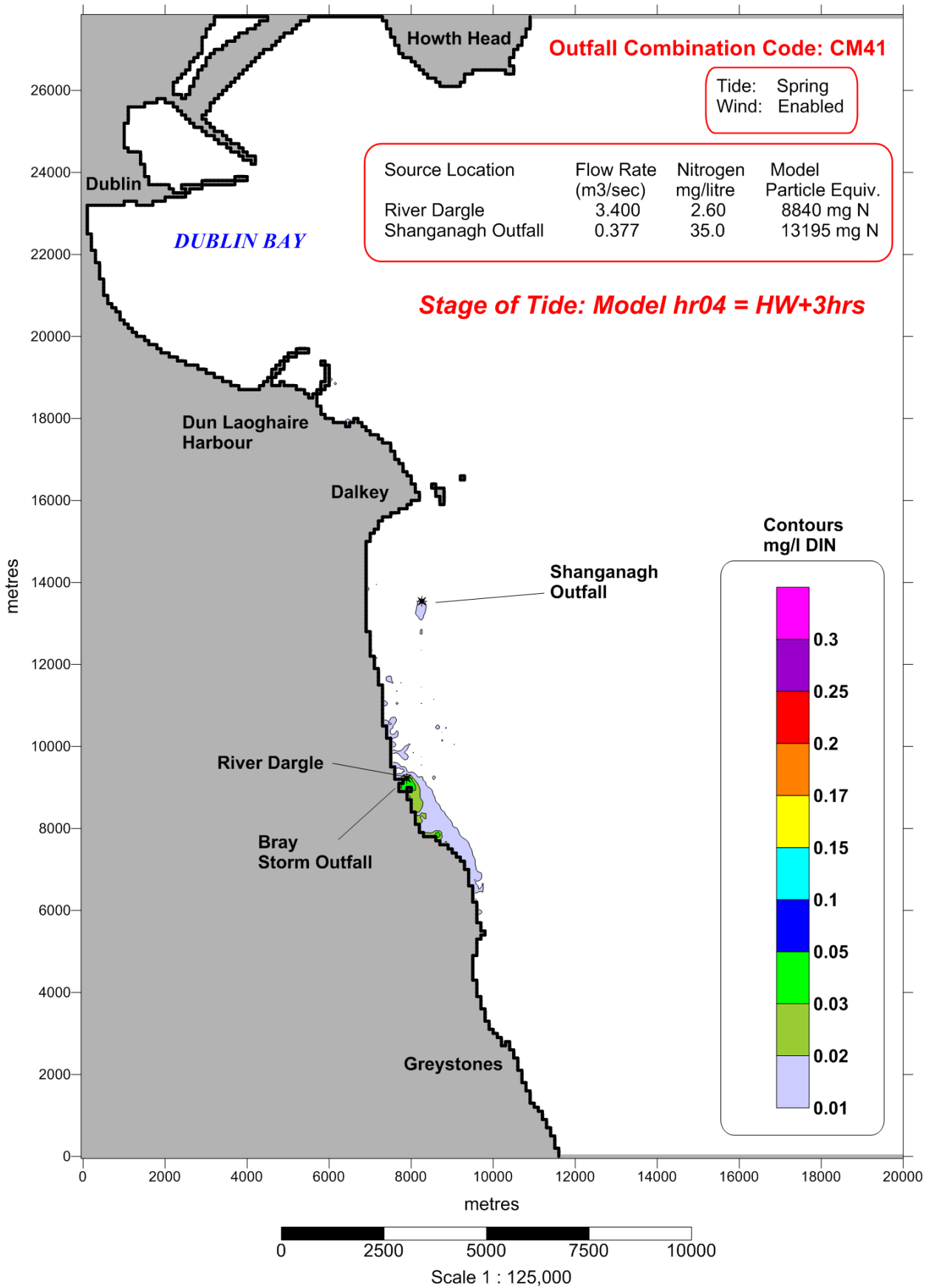


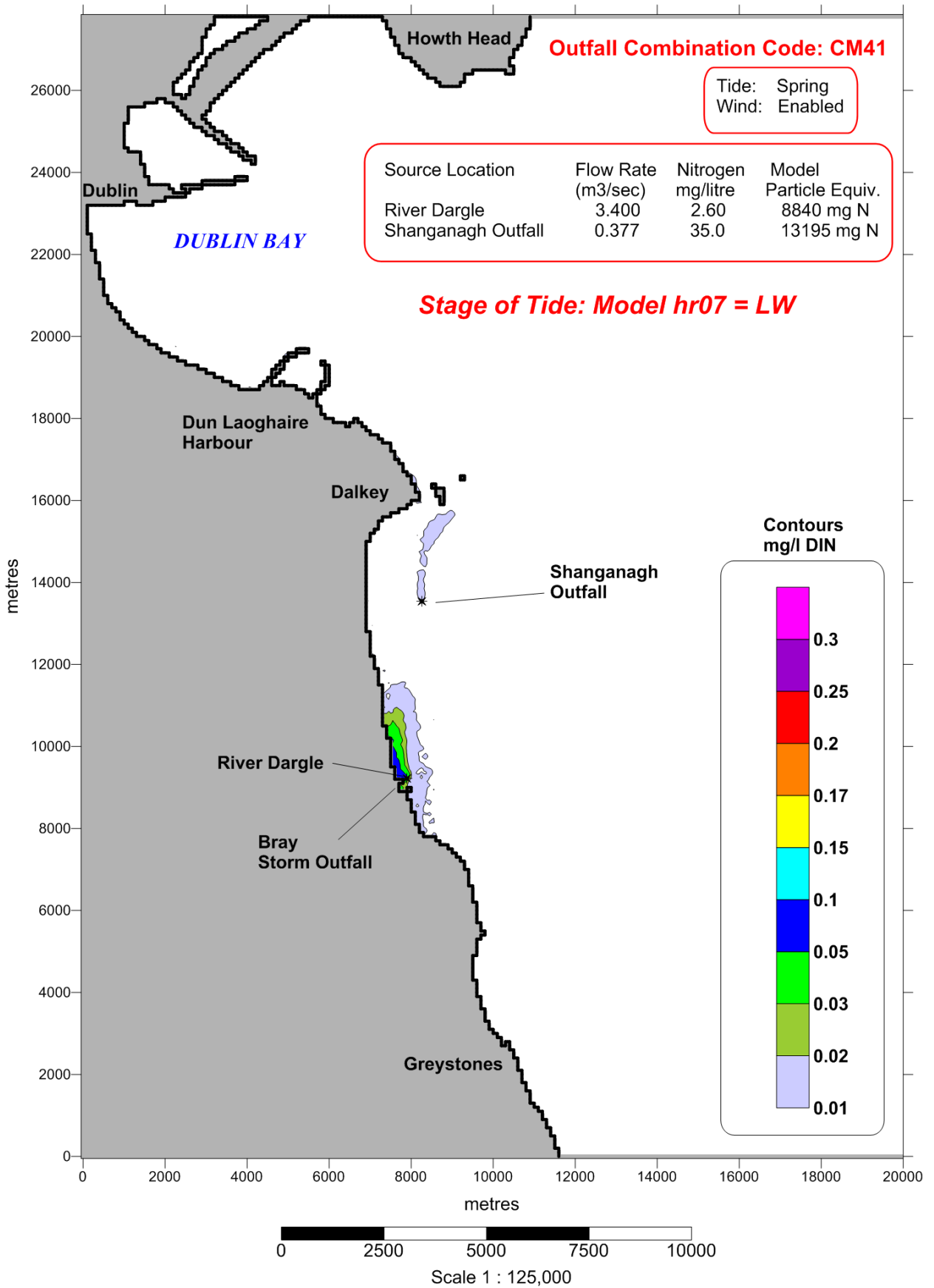


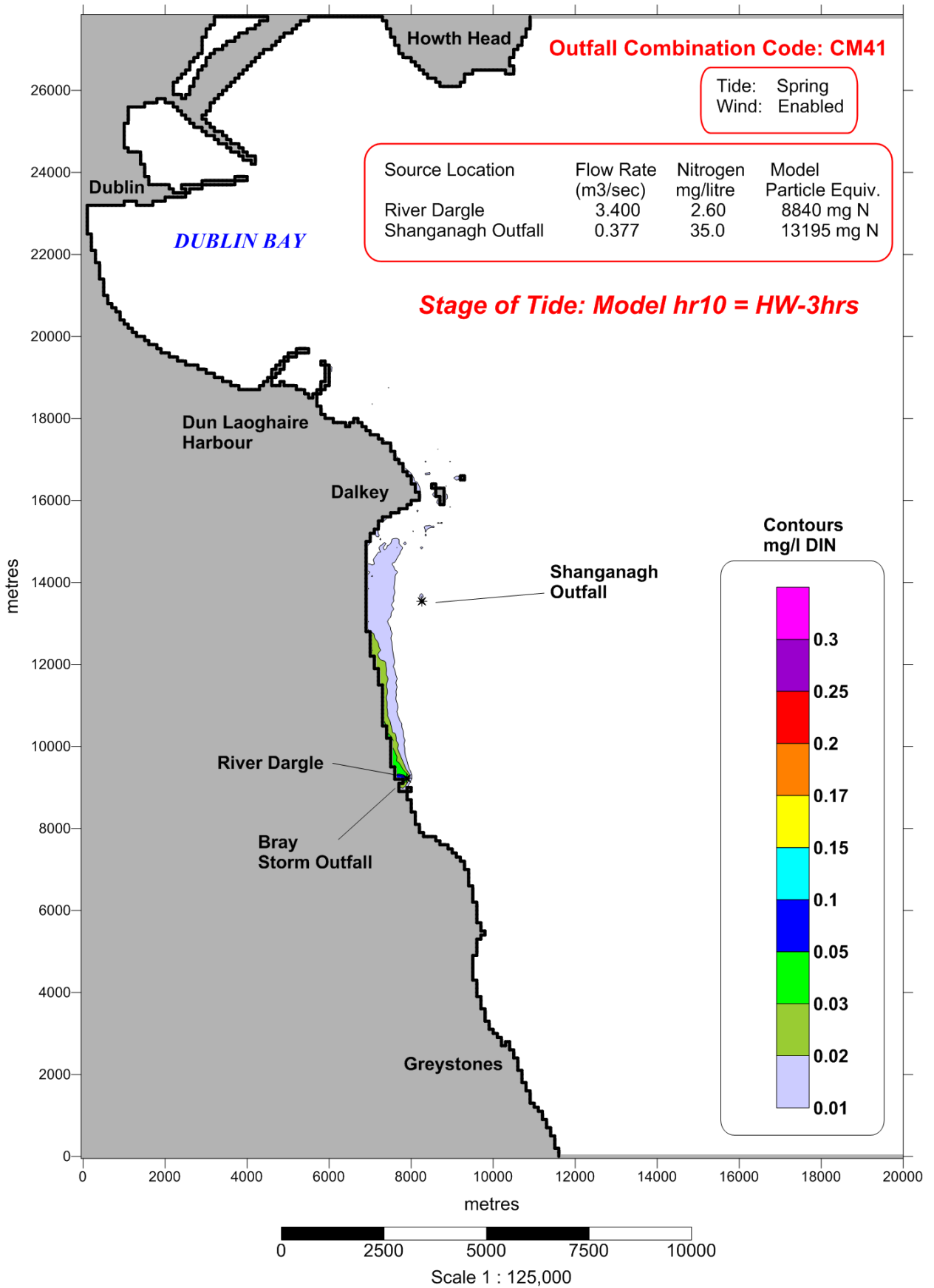


Tide: Spring
Wind: Enabled

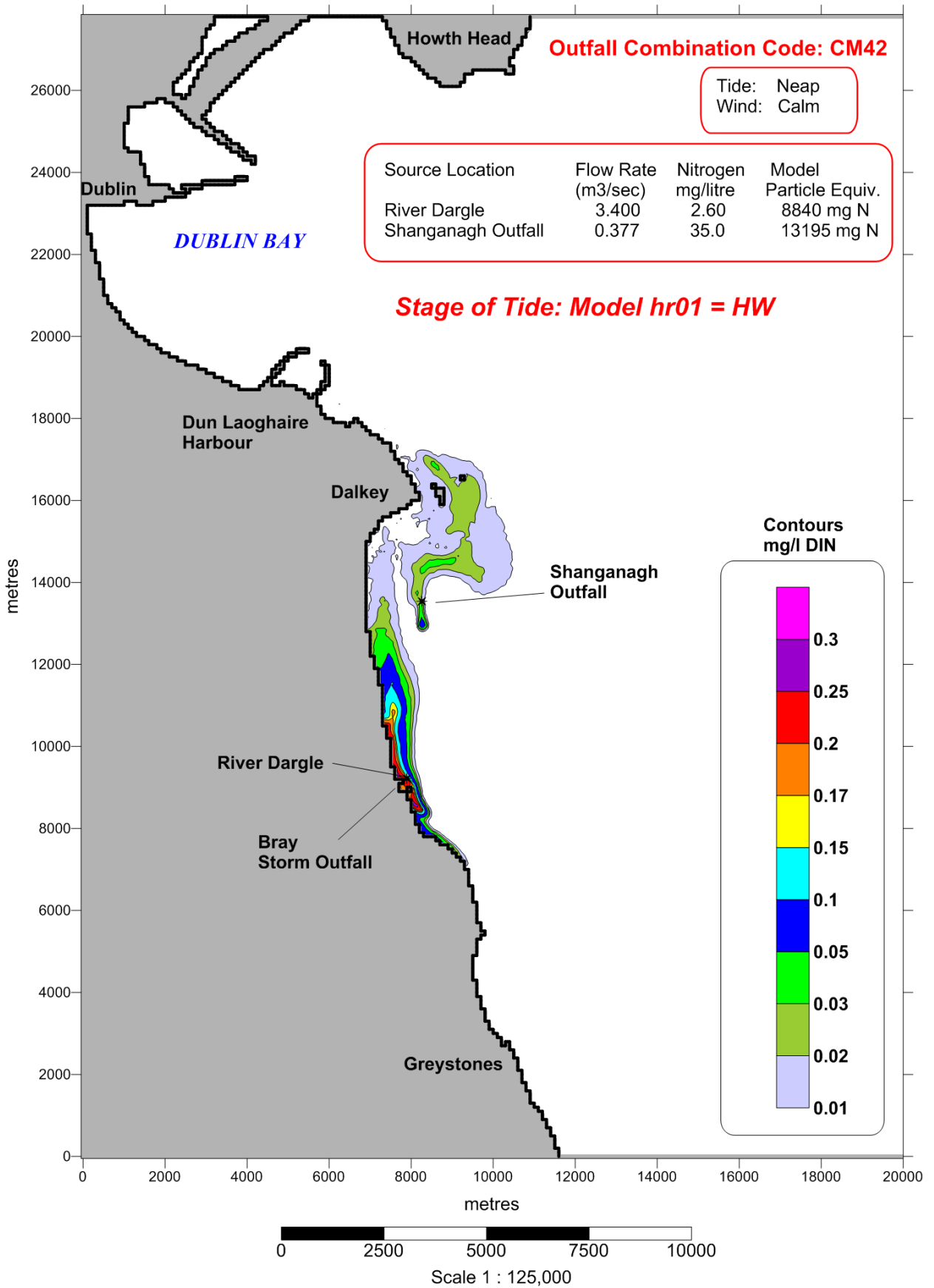


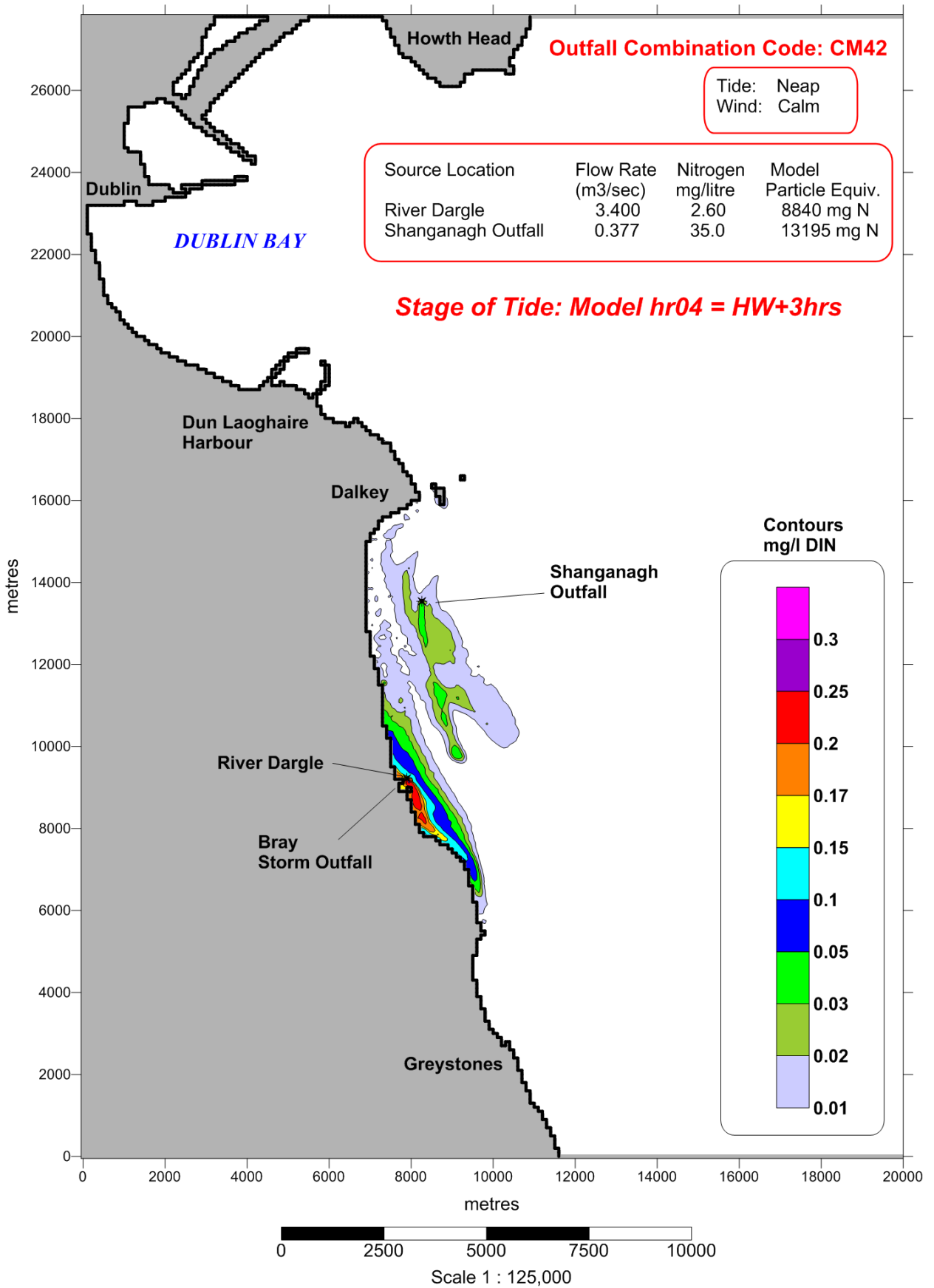


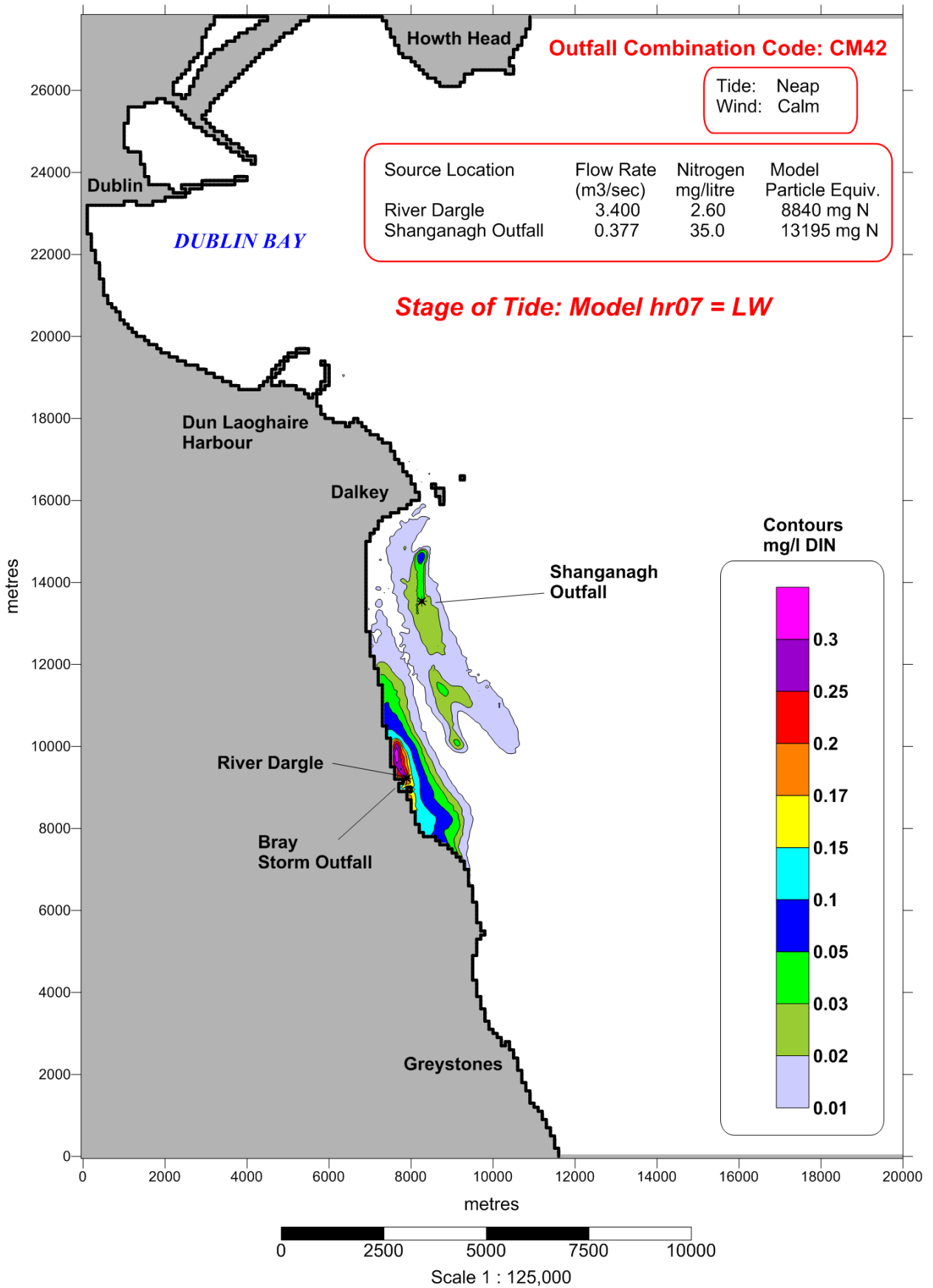


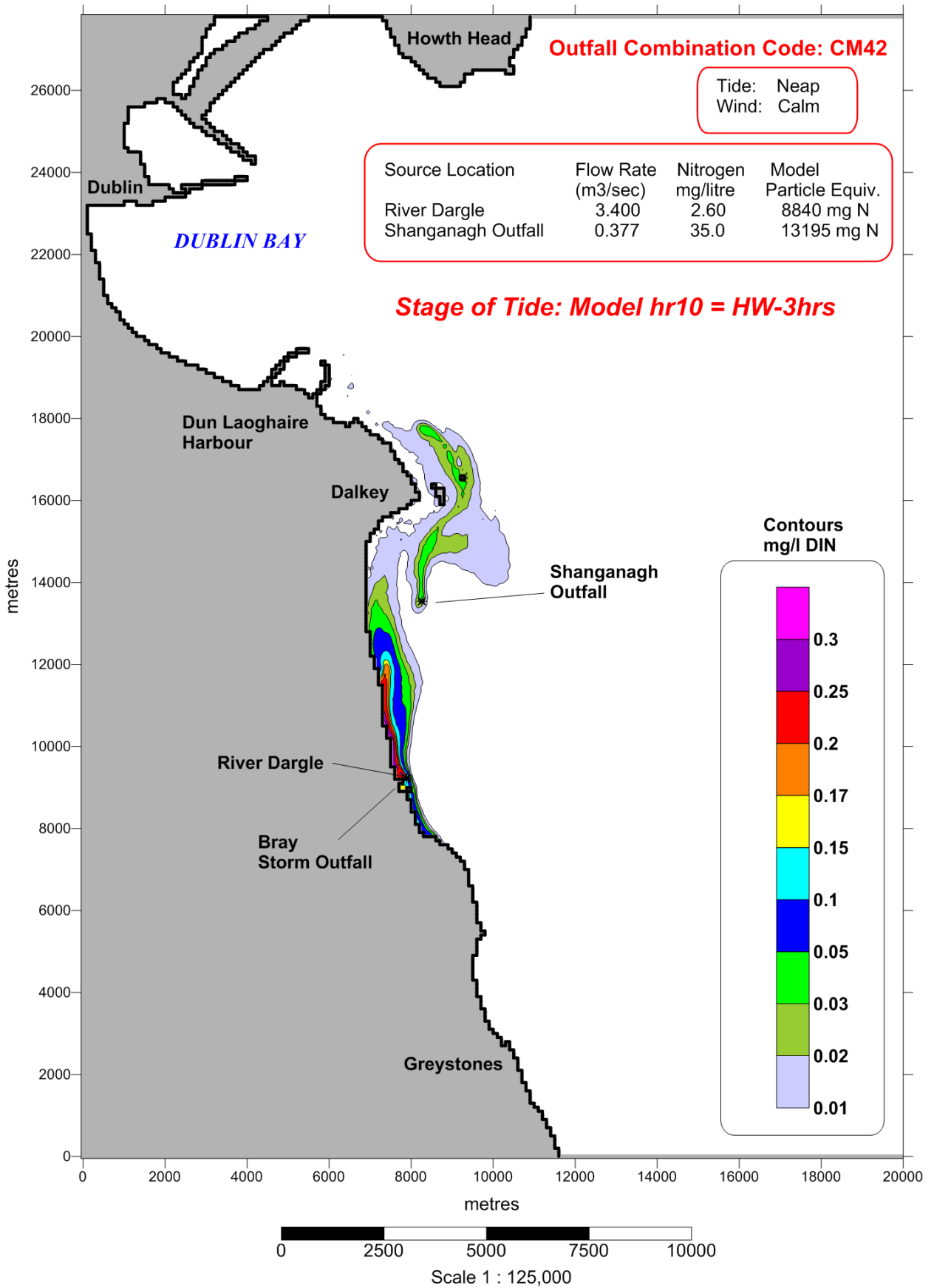


Tide: Neap
Wind: Calm

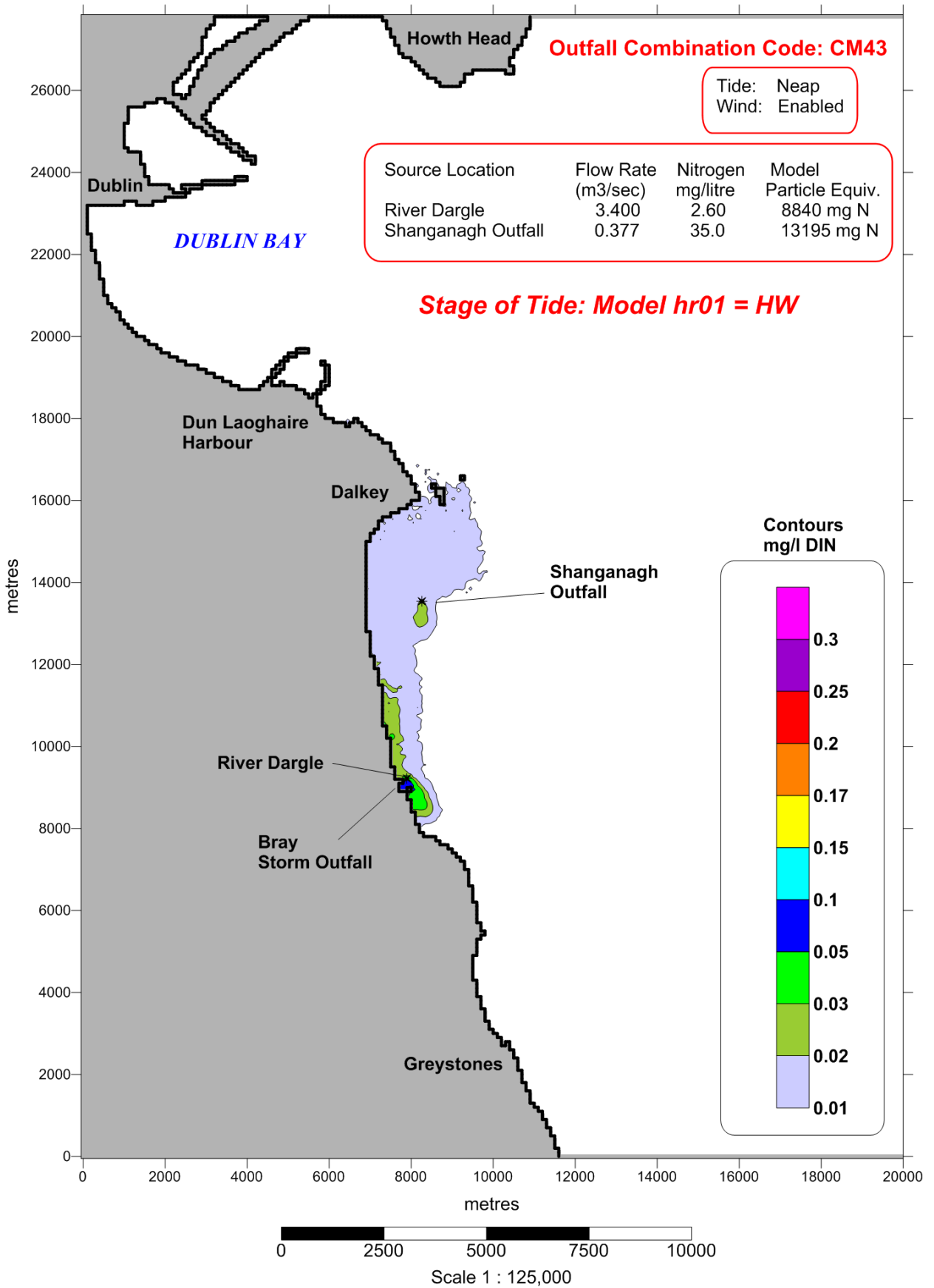


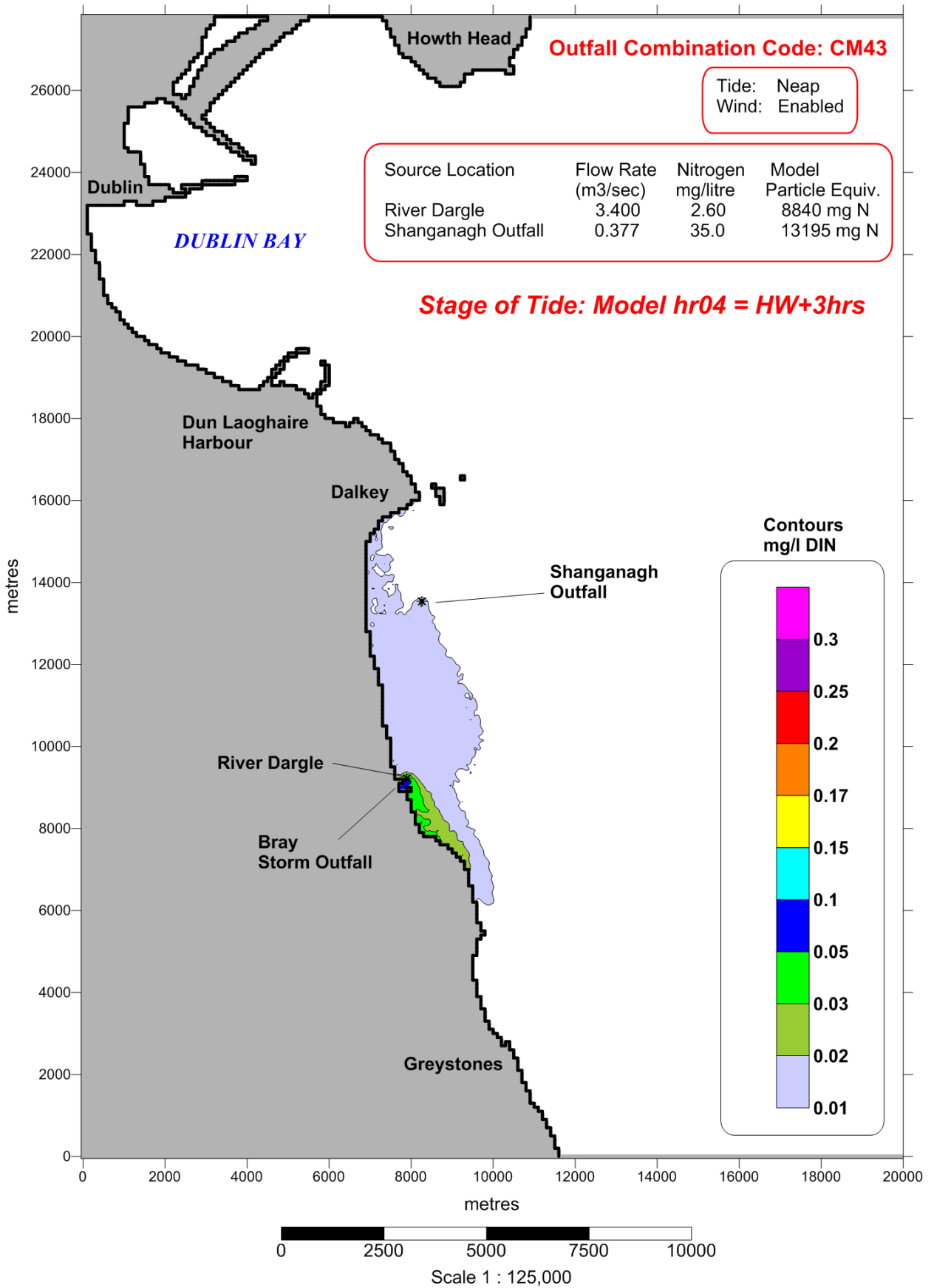


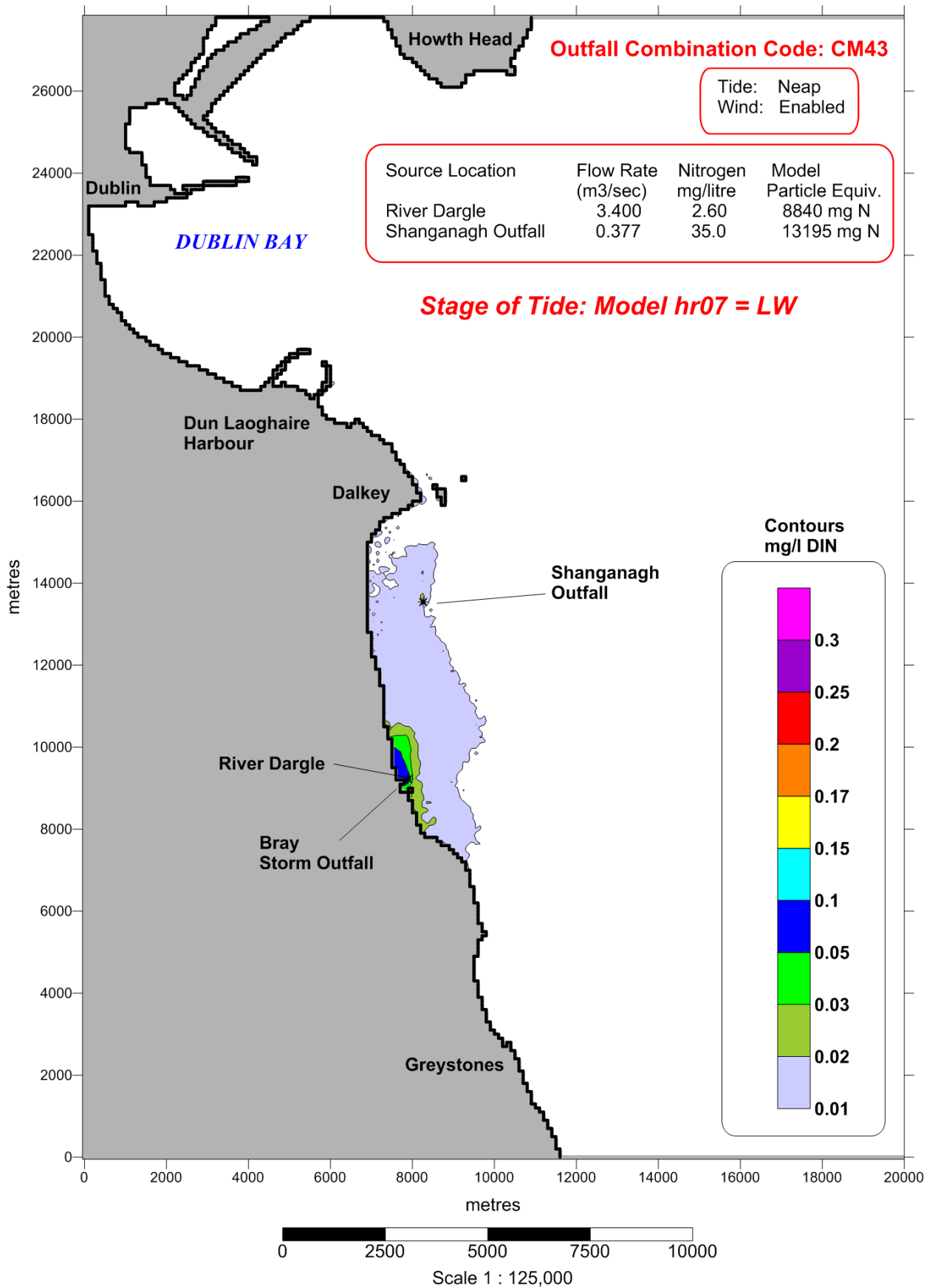


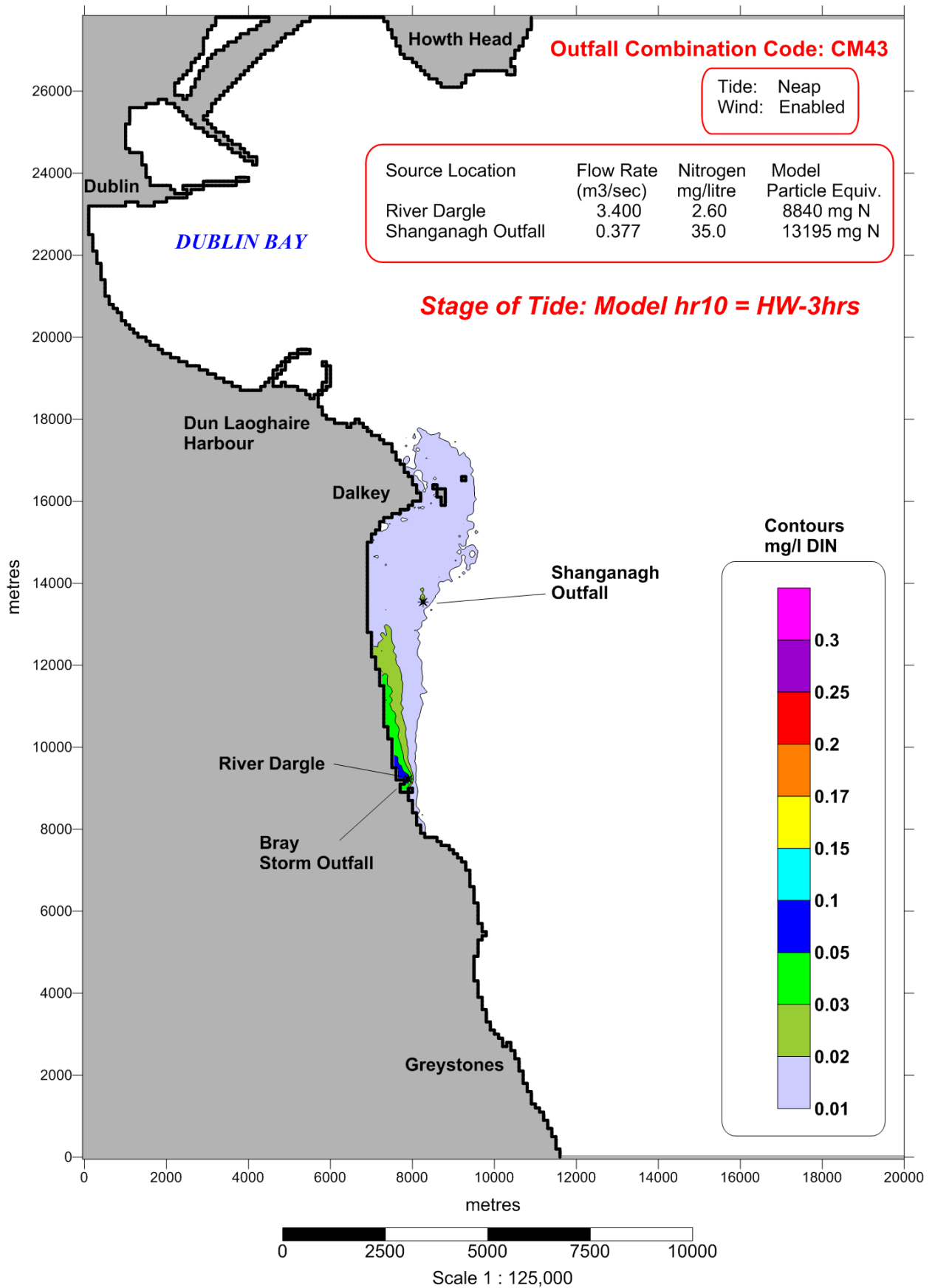


Tide: Neap
Wind: Enabled









APPENDIX 3

Model Results - Contour Plots of Concentration

Shanganagh Outfall (Design Year 2031)

Average Flow (1.25xDWF) 0.598m³/sec

Concentration: 35mg/l N

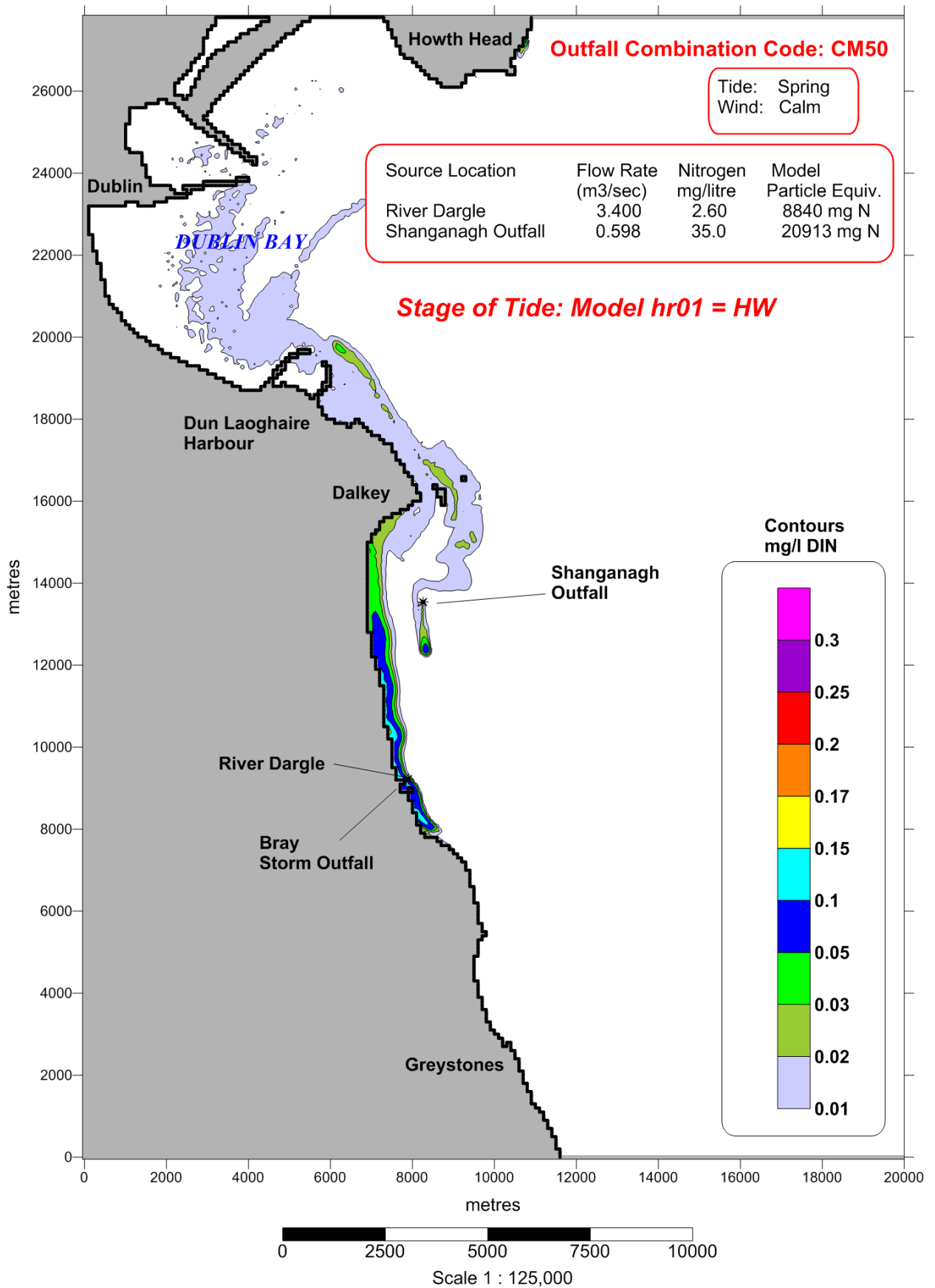
River Dargle

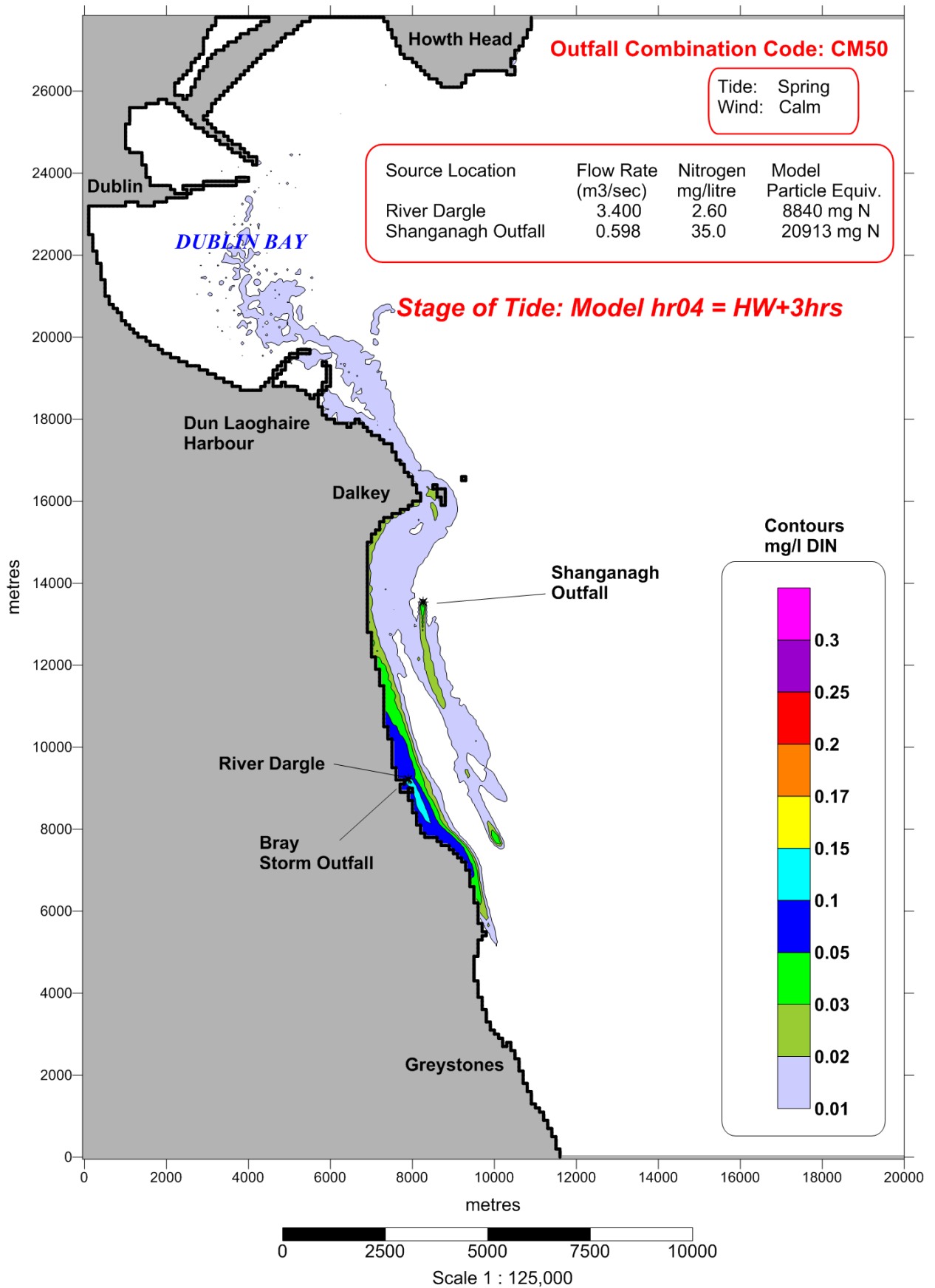
Mean Flow 3.4m³/sec

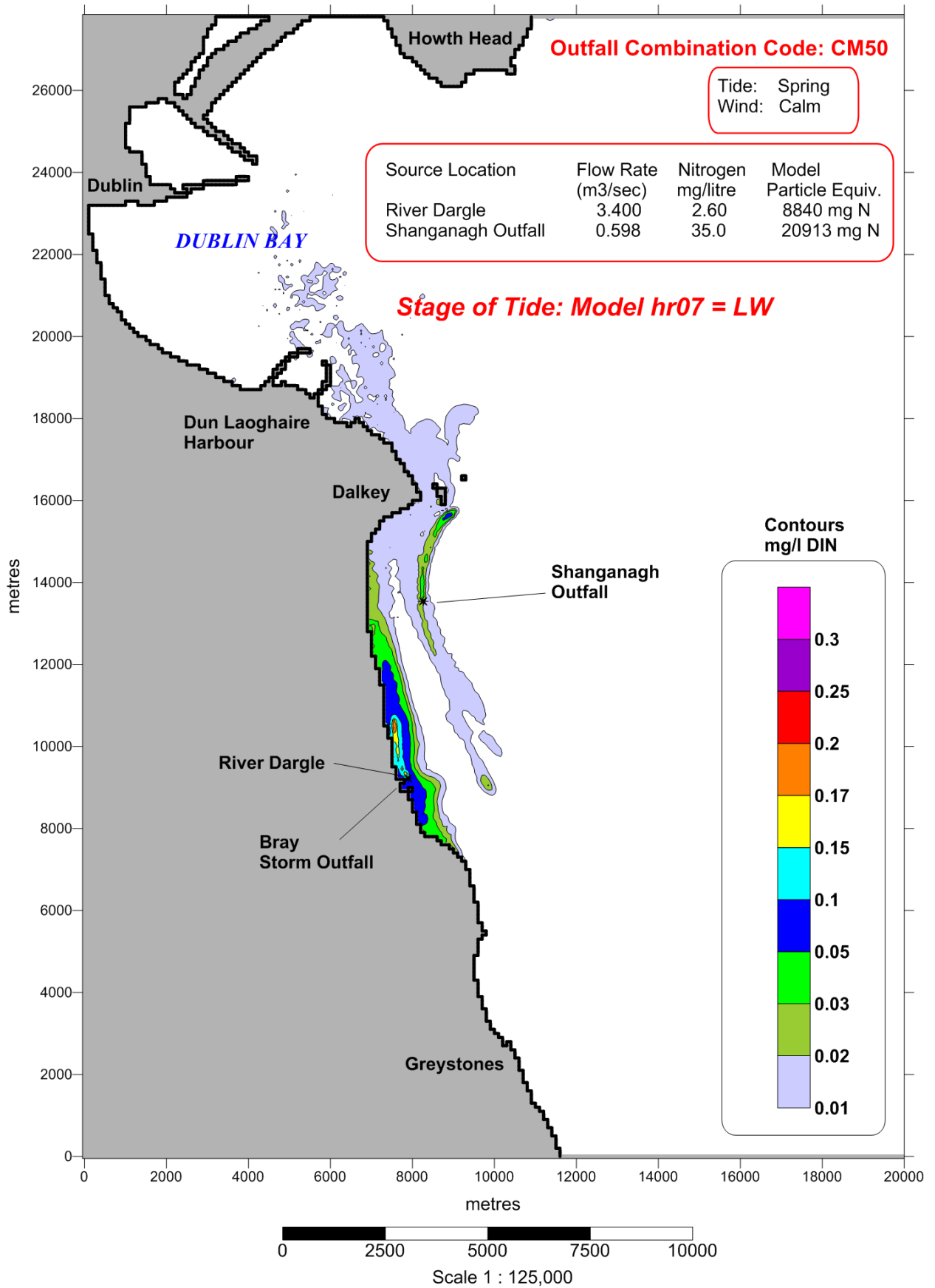
Concentration: 2.6 mg/l N

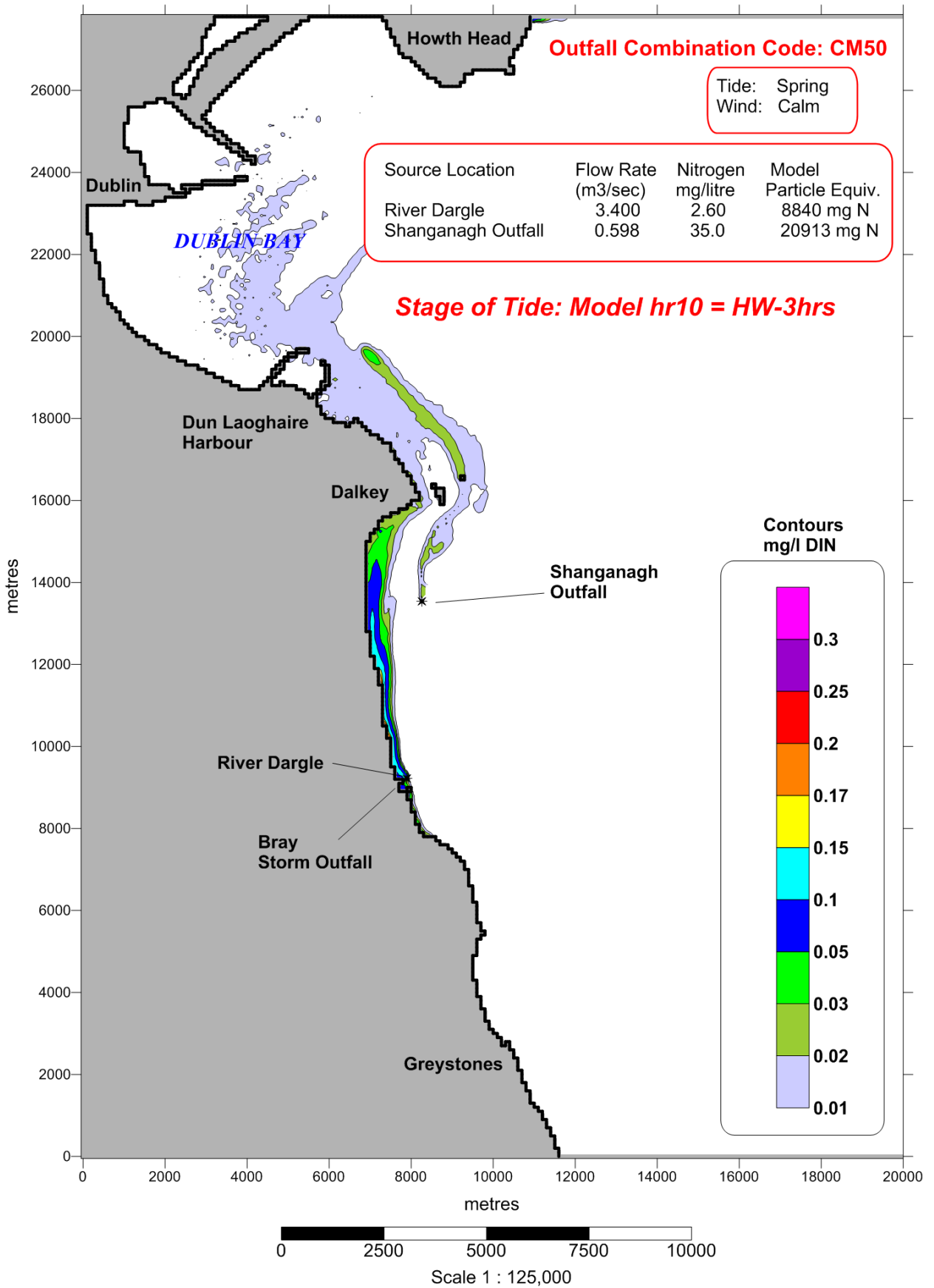
Tide: Spring

Wind: Calm

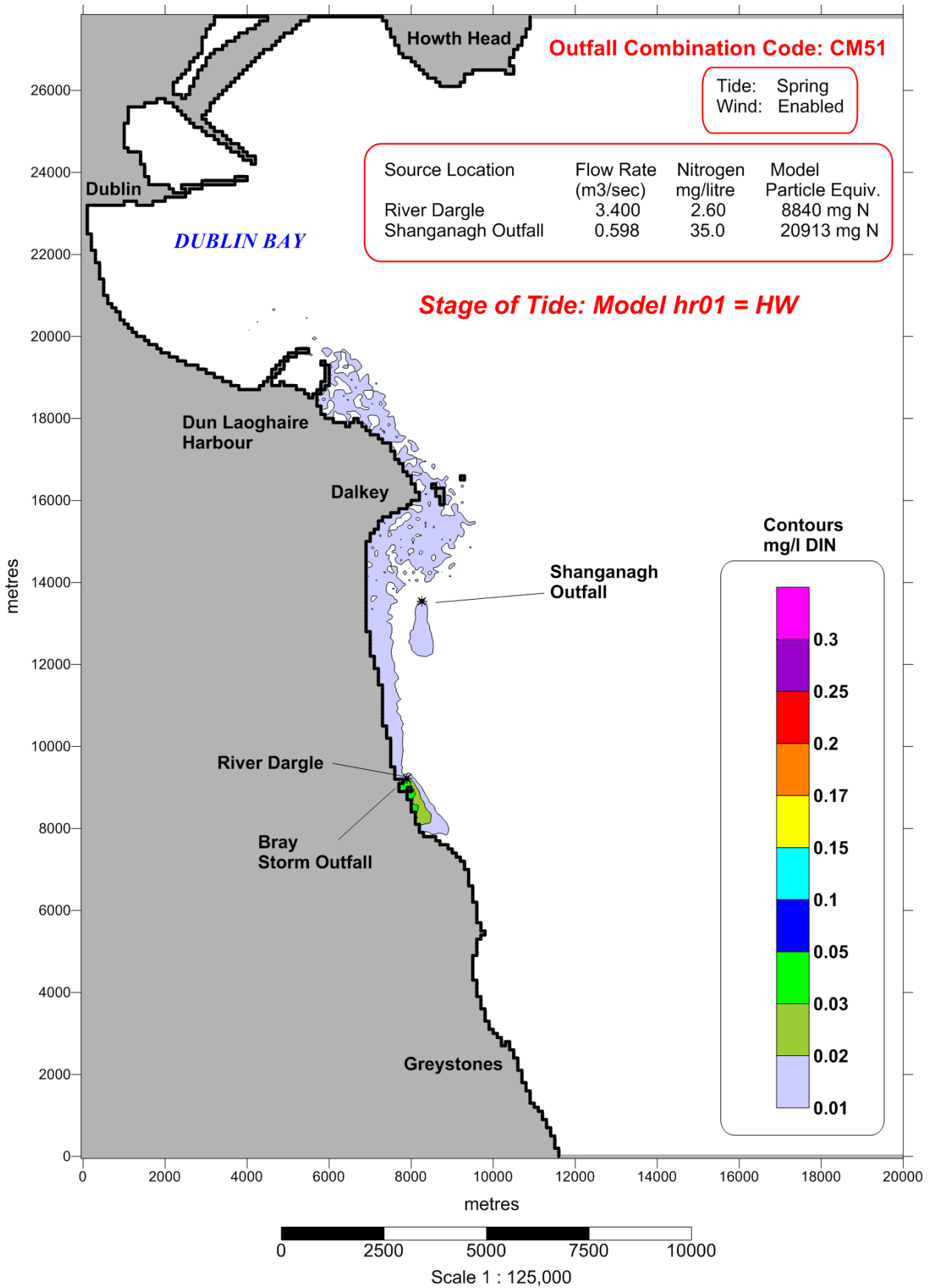


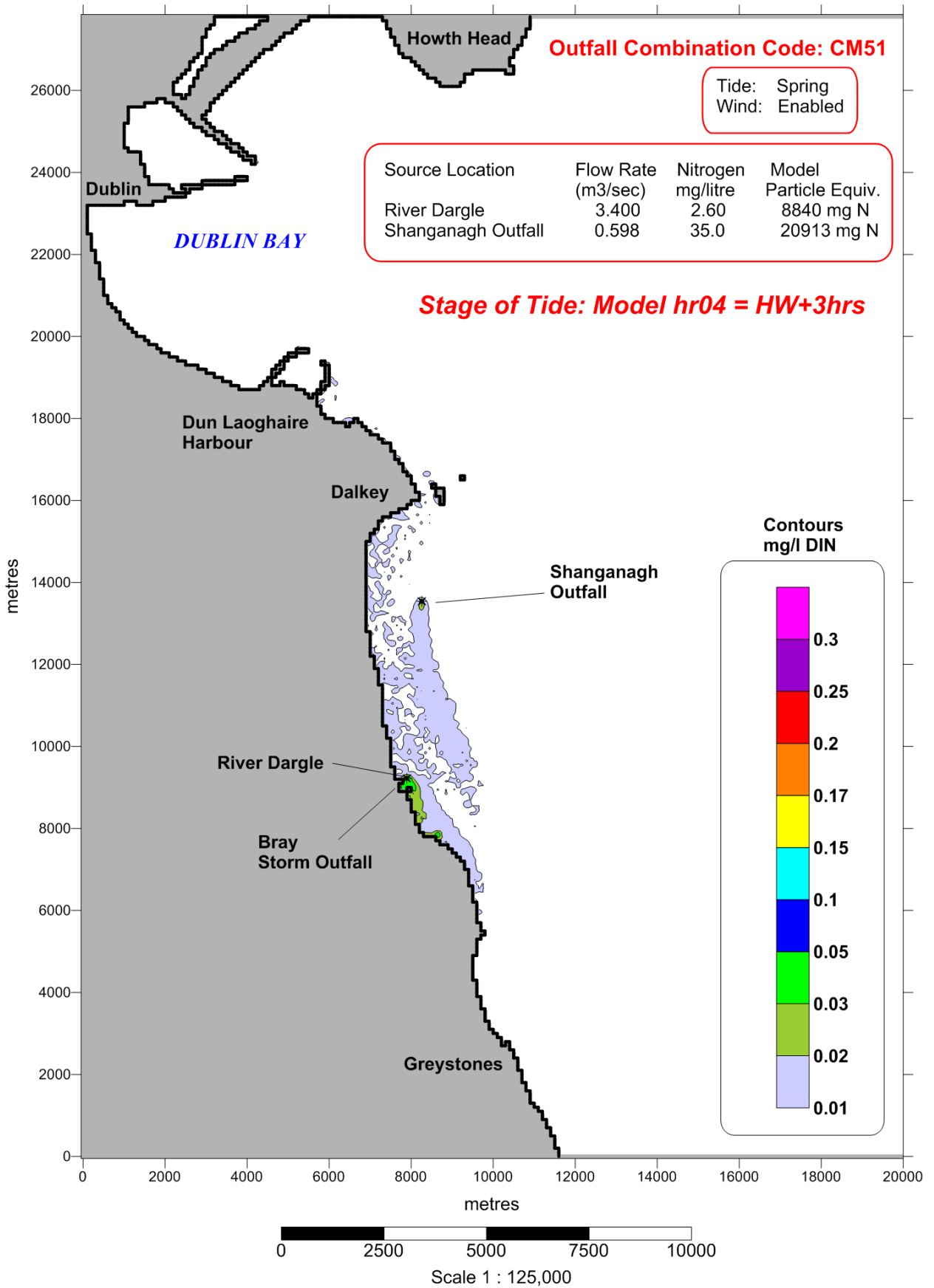


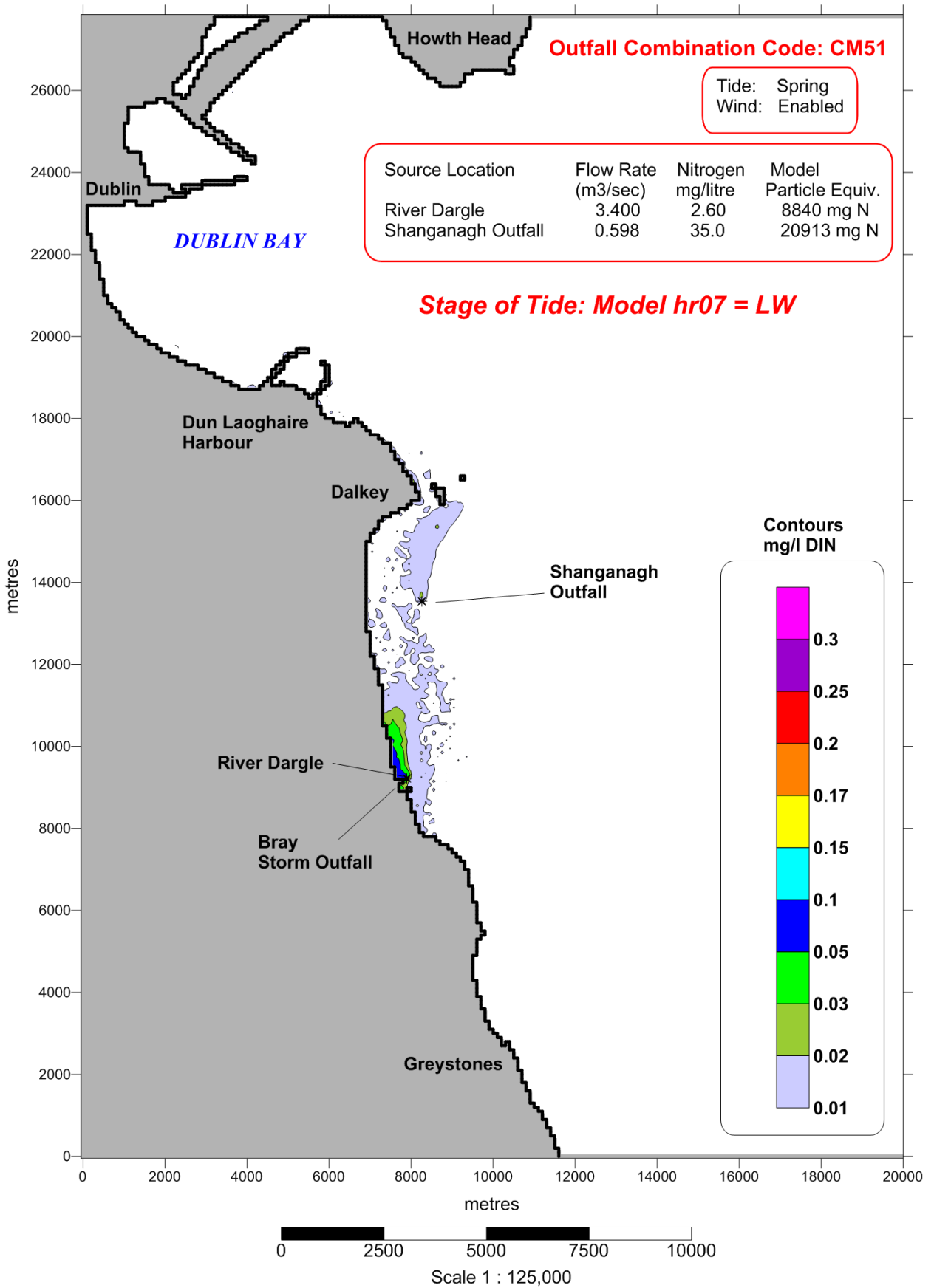


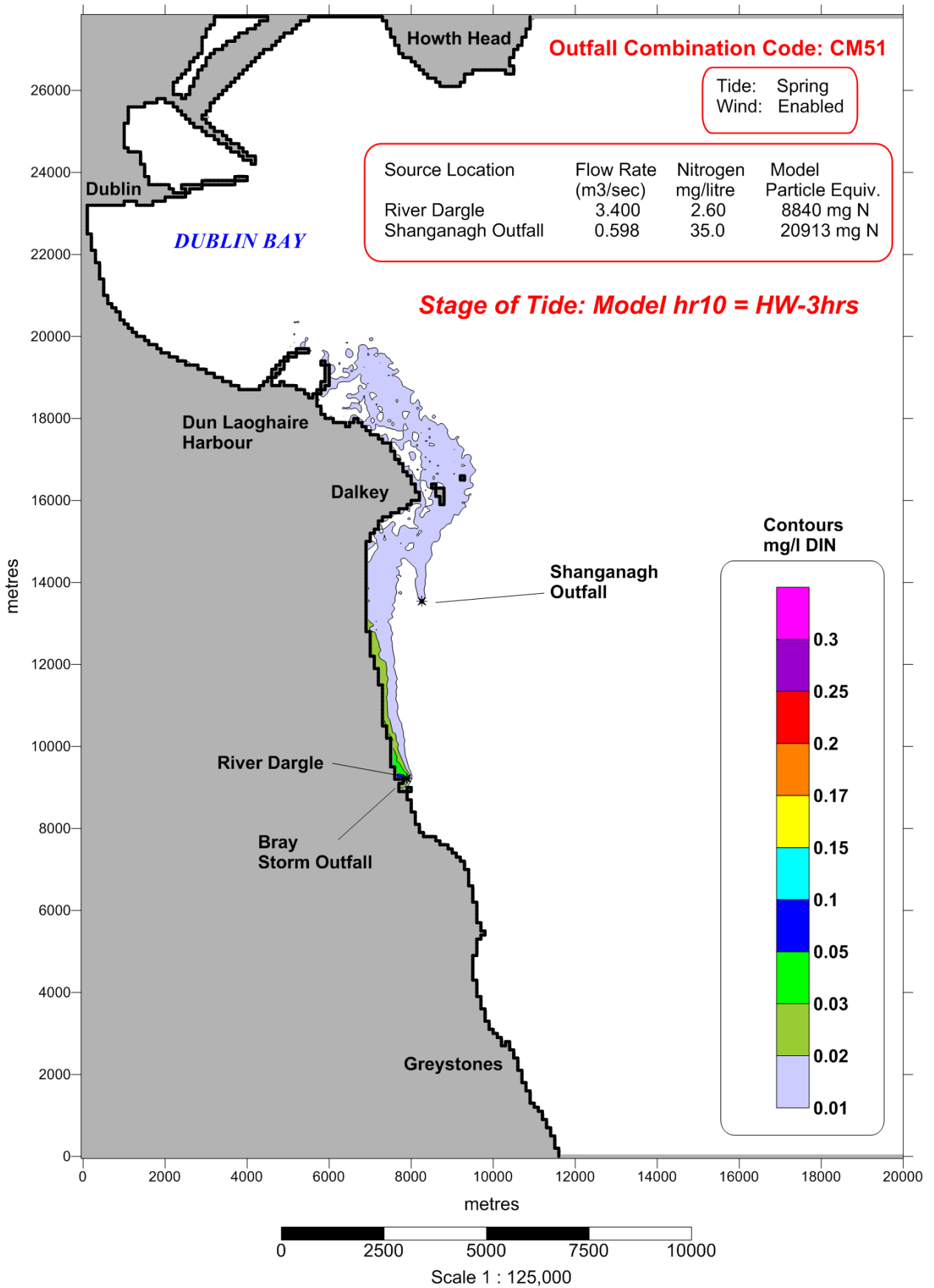


Tide: Spring
Wind: Enabled

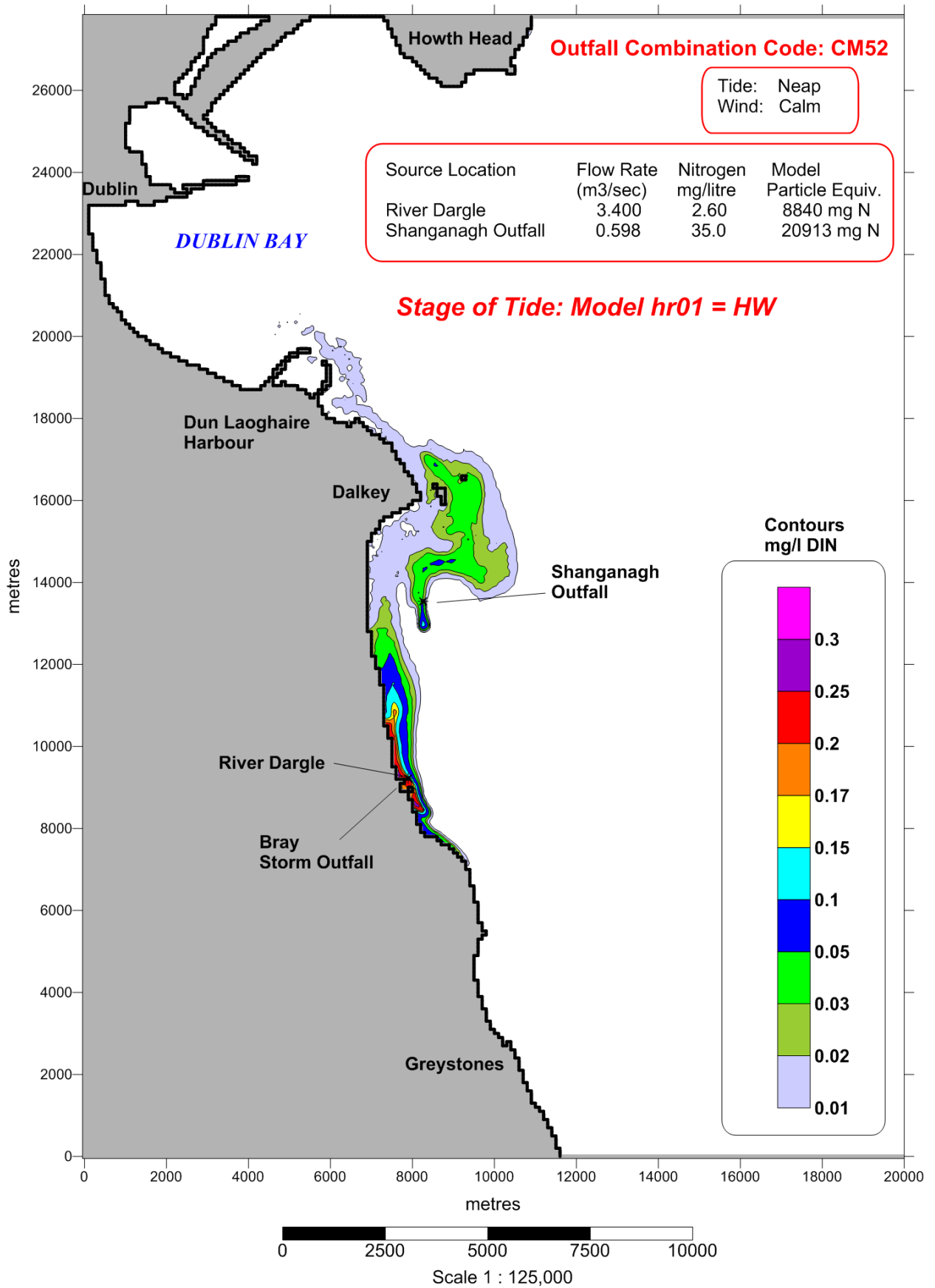


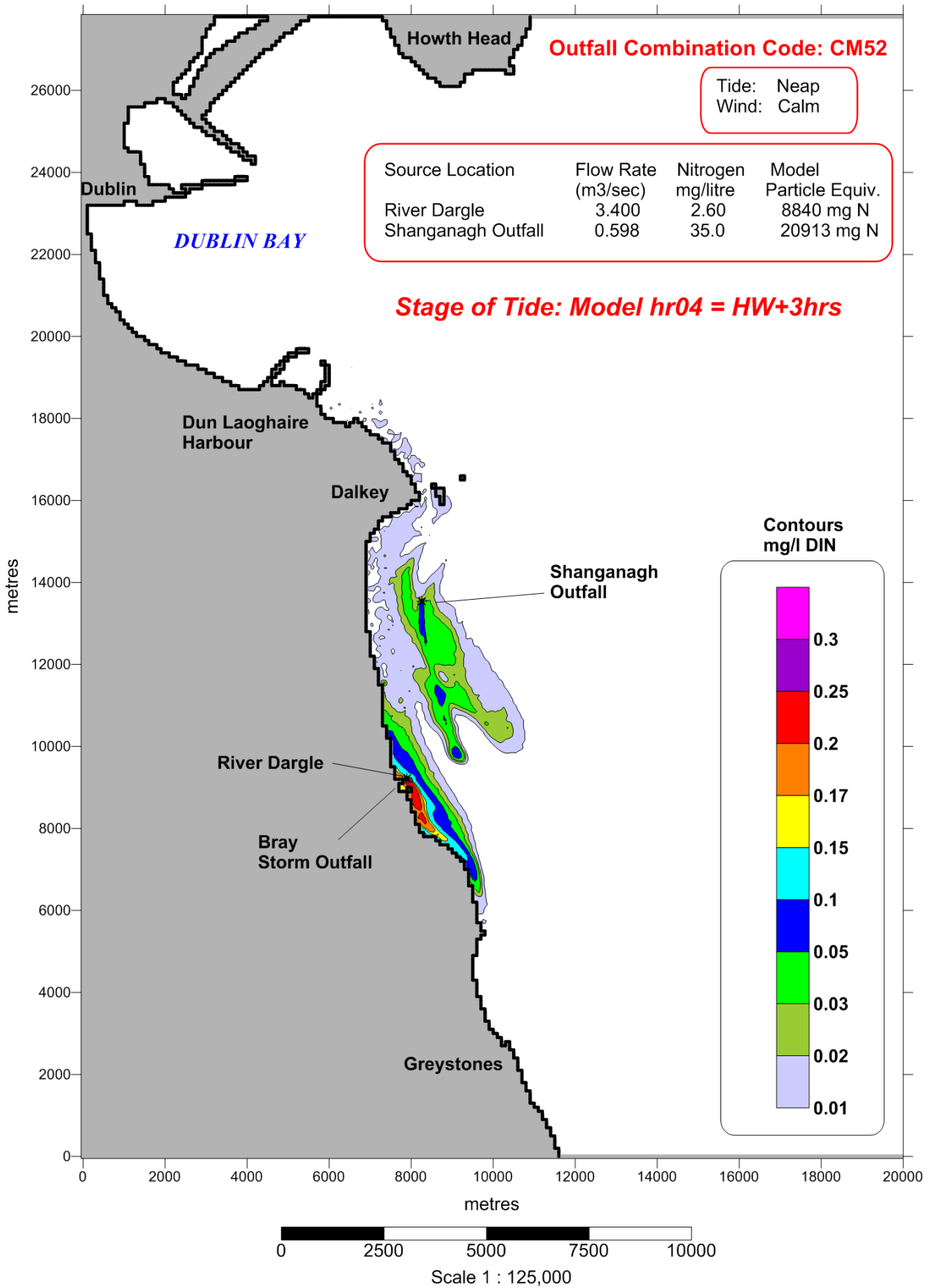


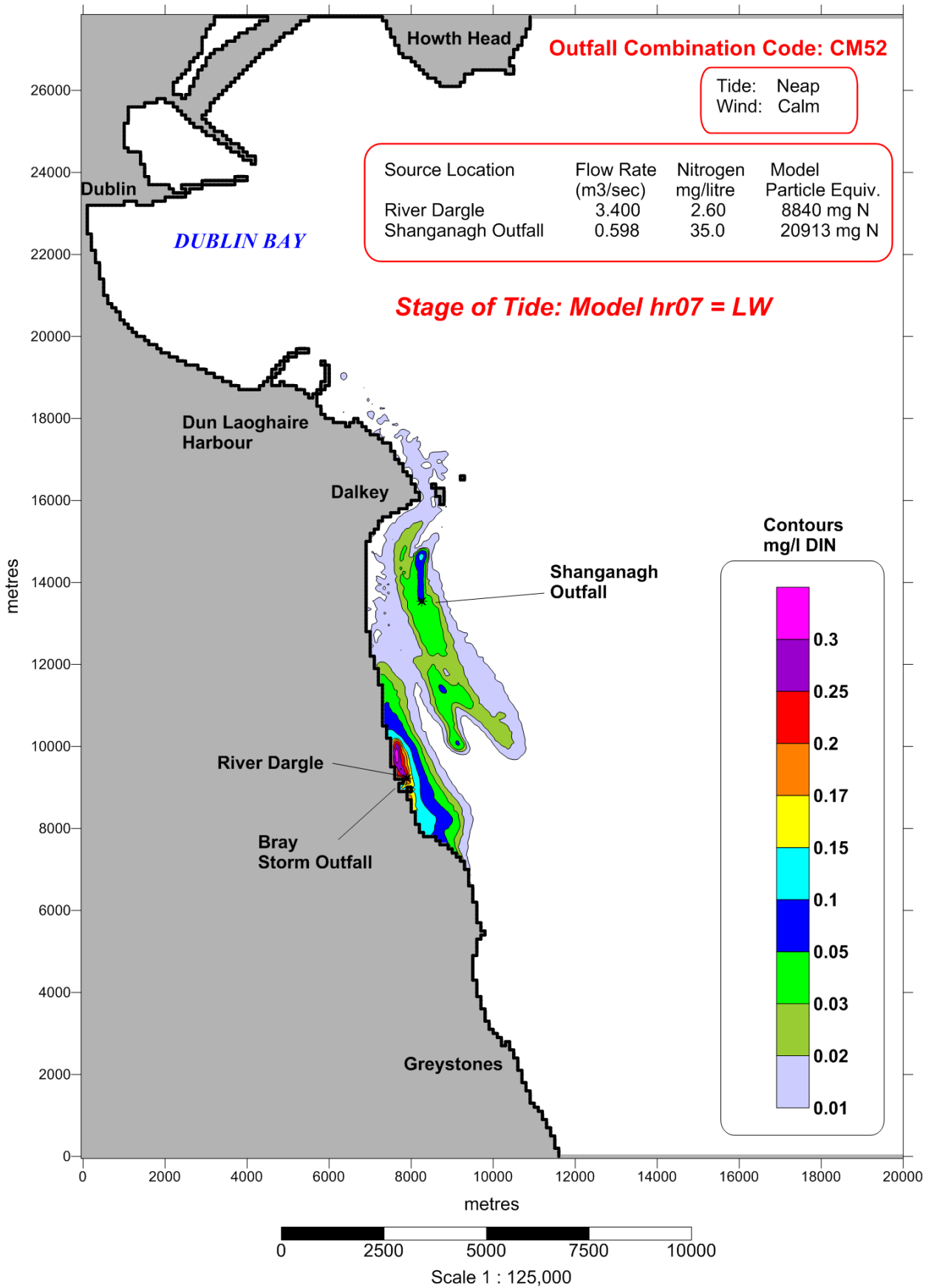


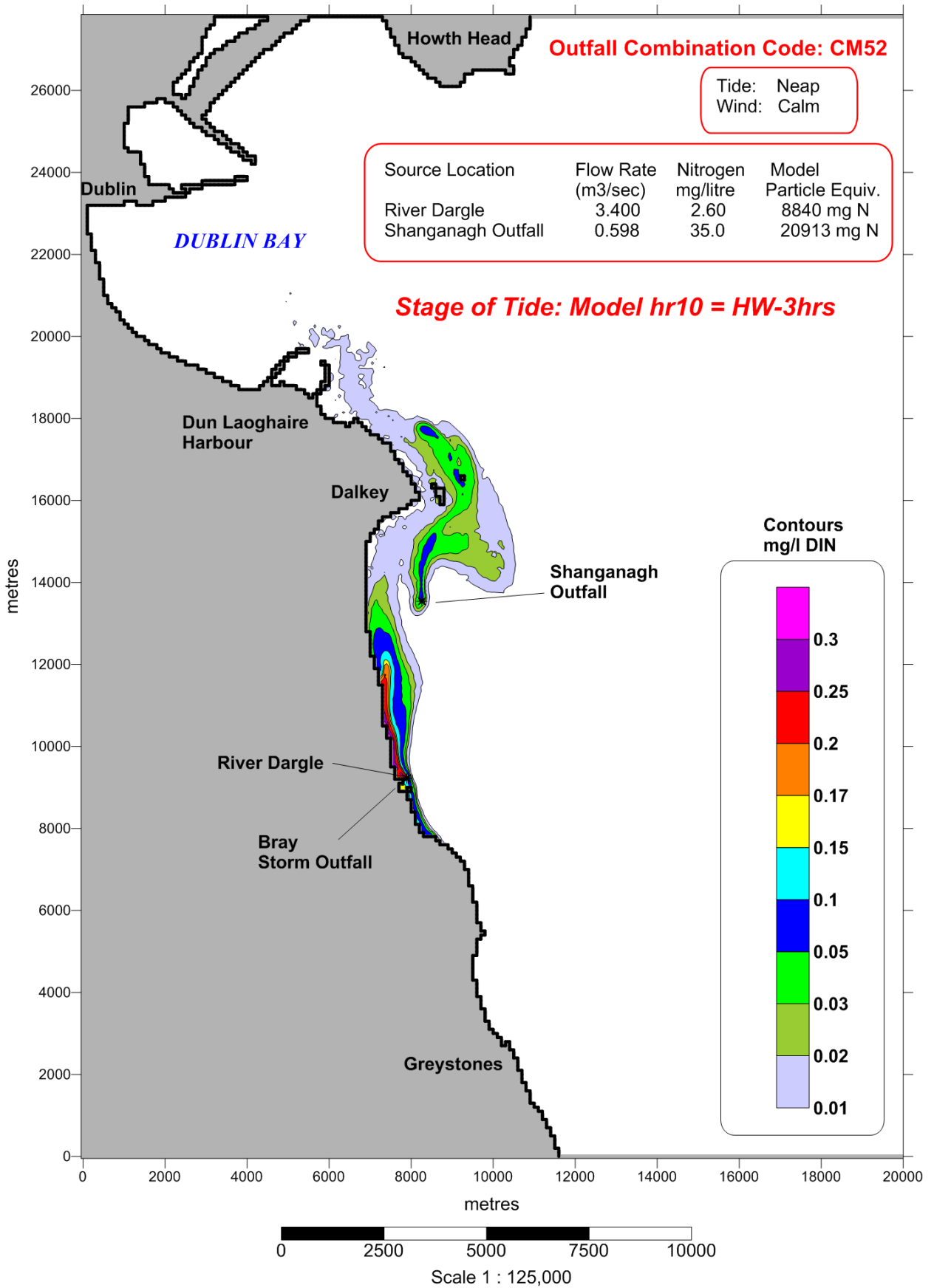


Tide: Neap
Wind: Calm

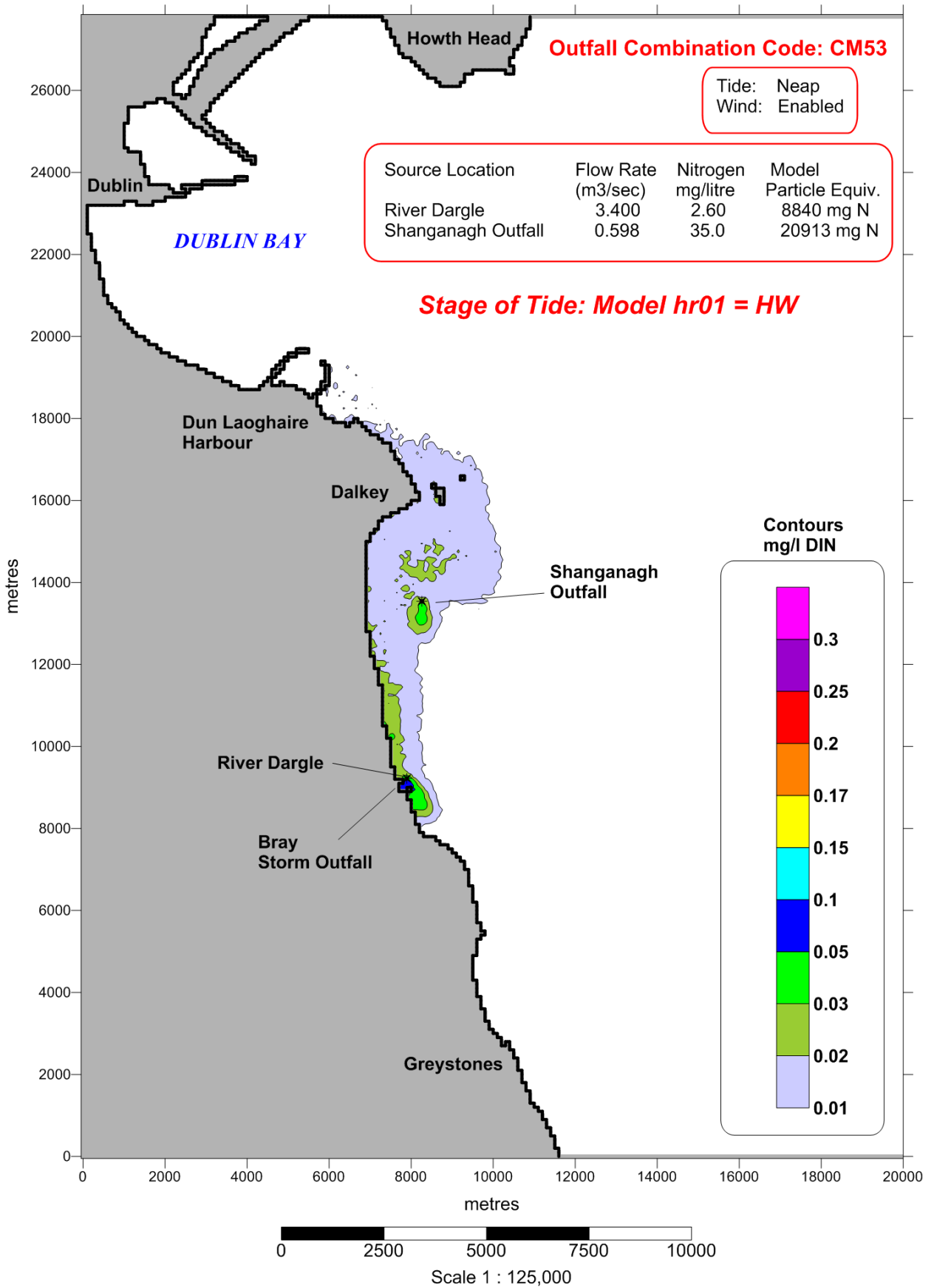


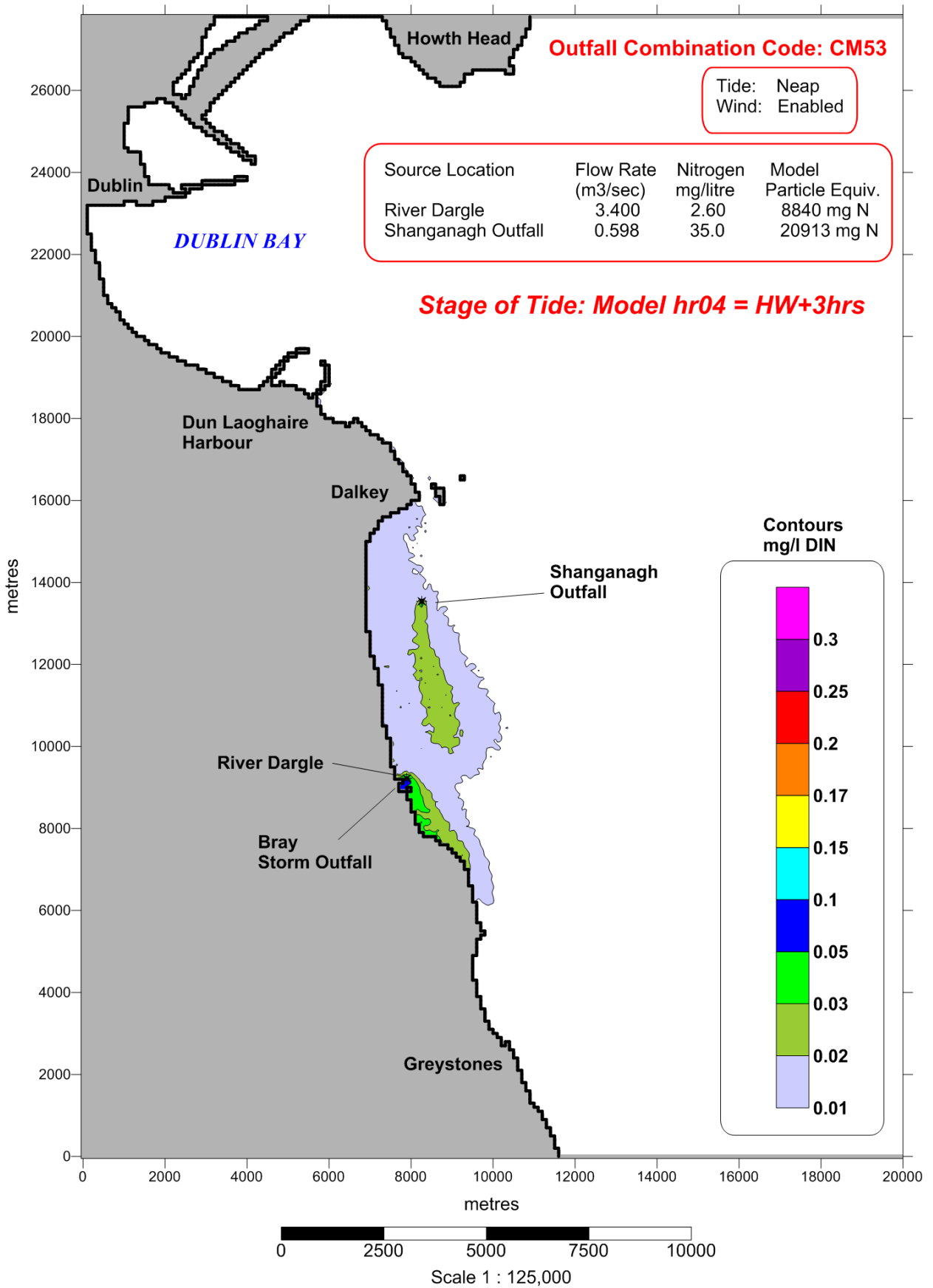


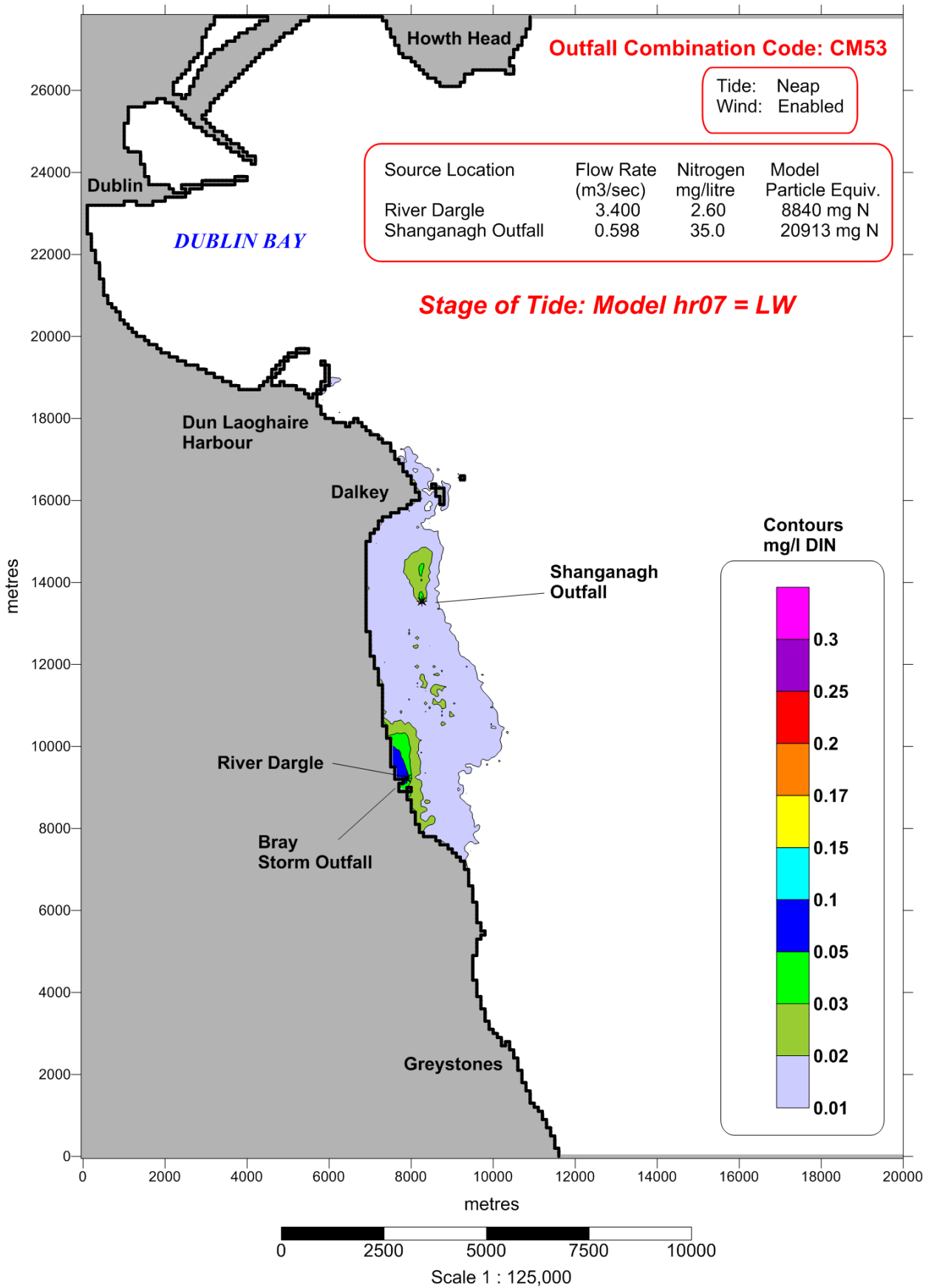


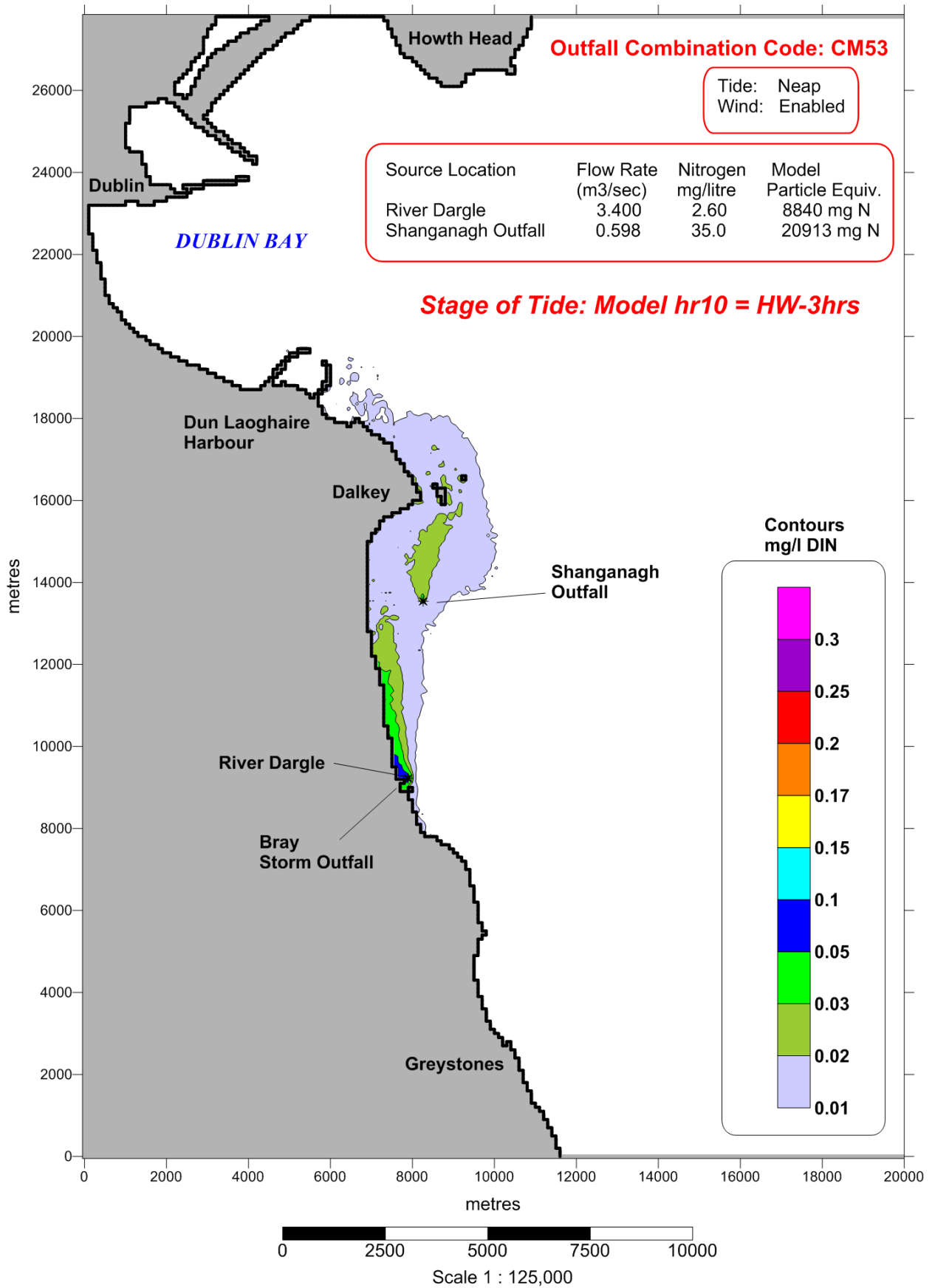


Tide: Neap
Wind: Enabled









APPENDIX 4

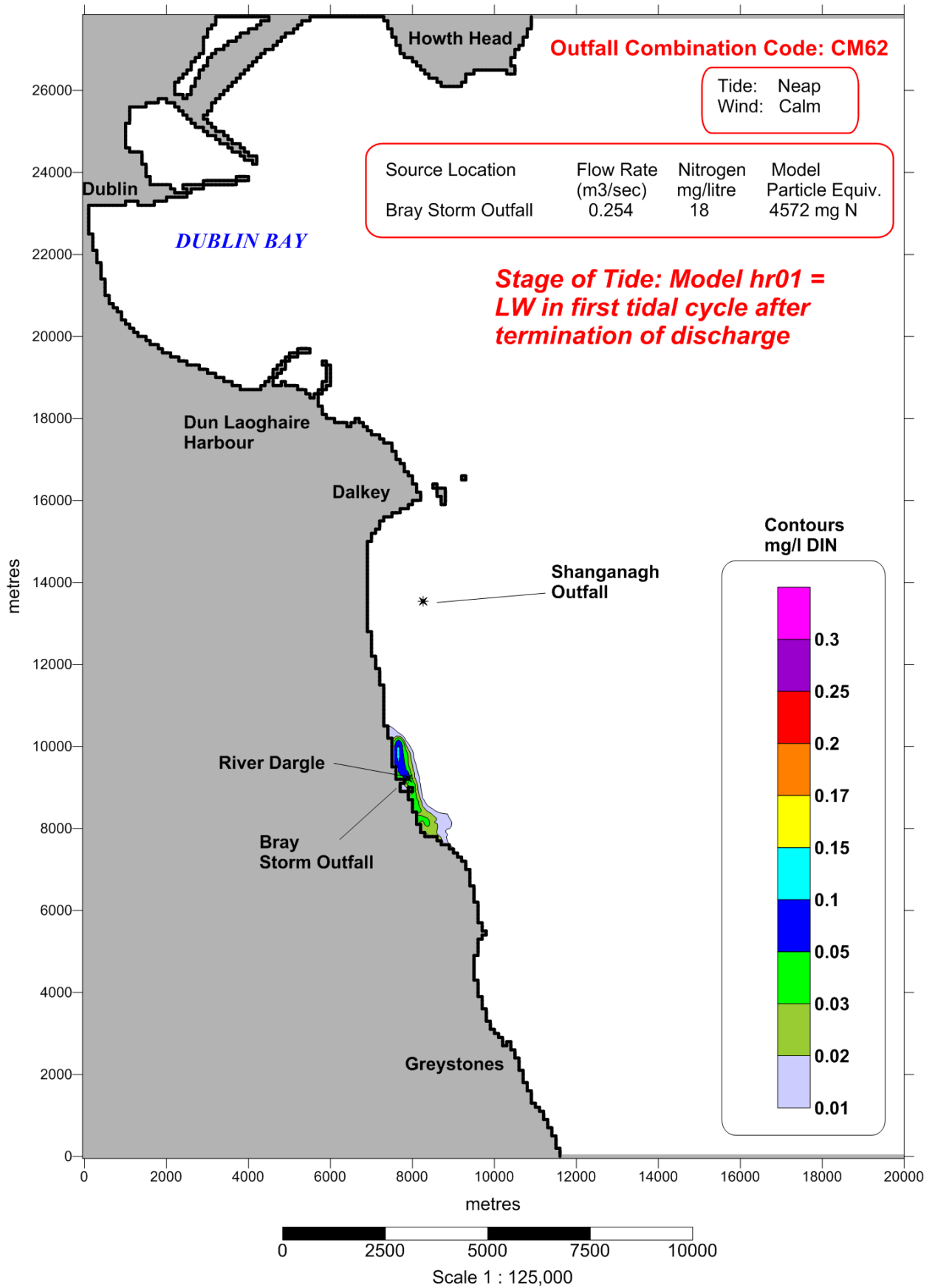
Model Results - Contour Plots of Concentration

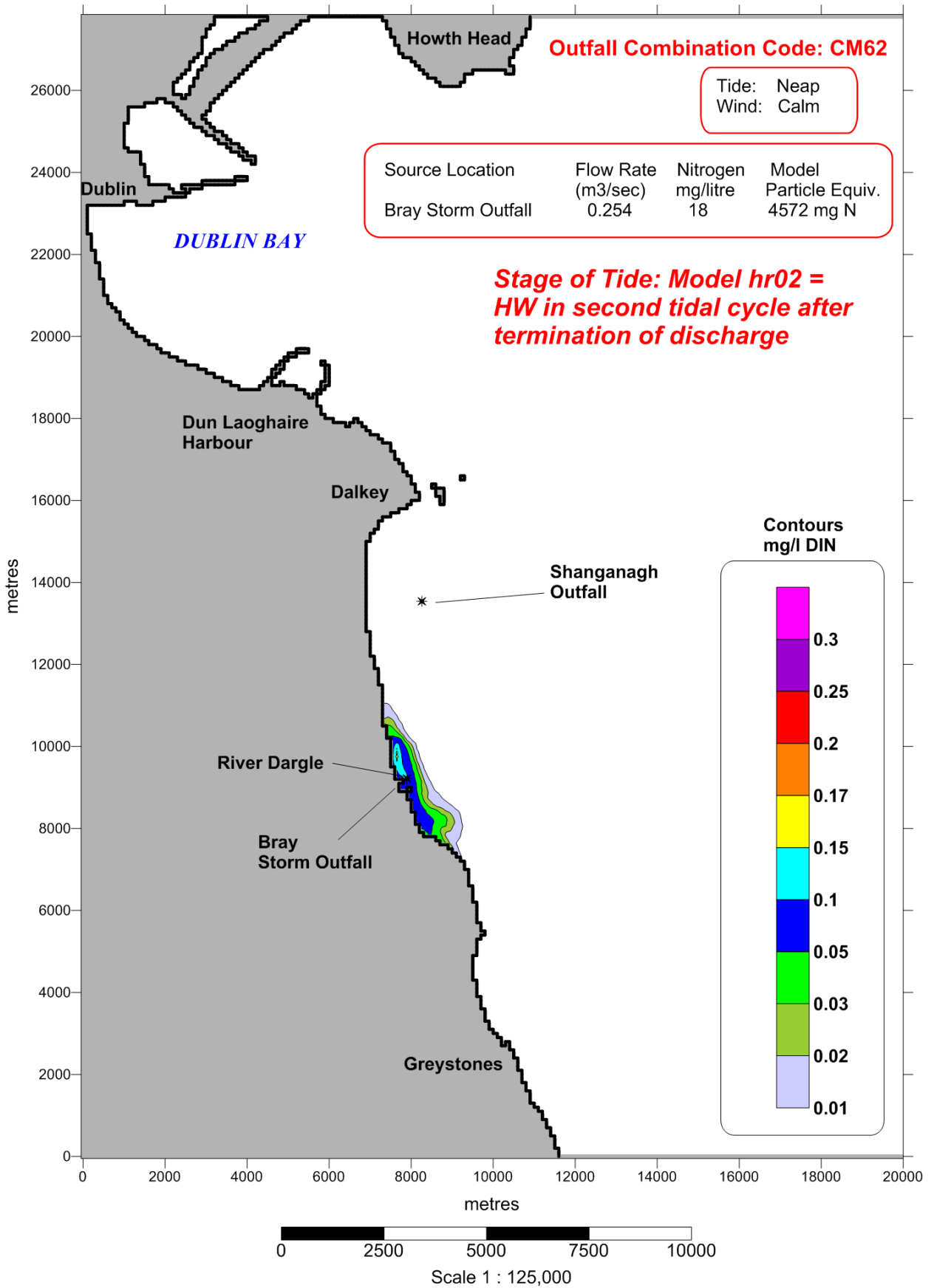
Bray Storm Overflow

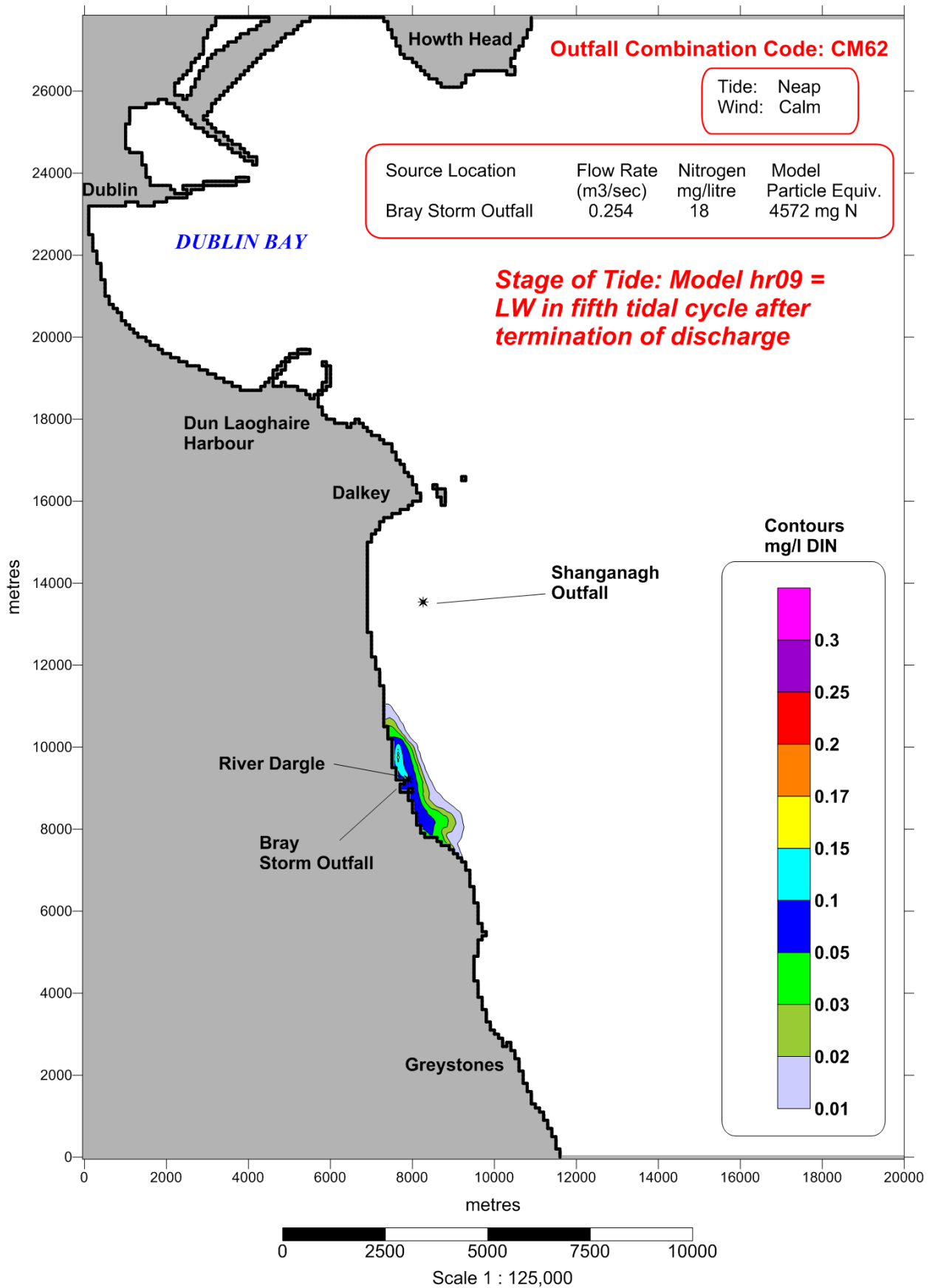
Flow 0.254m³/sec

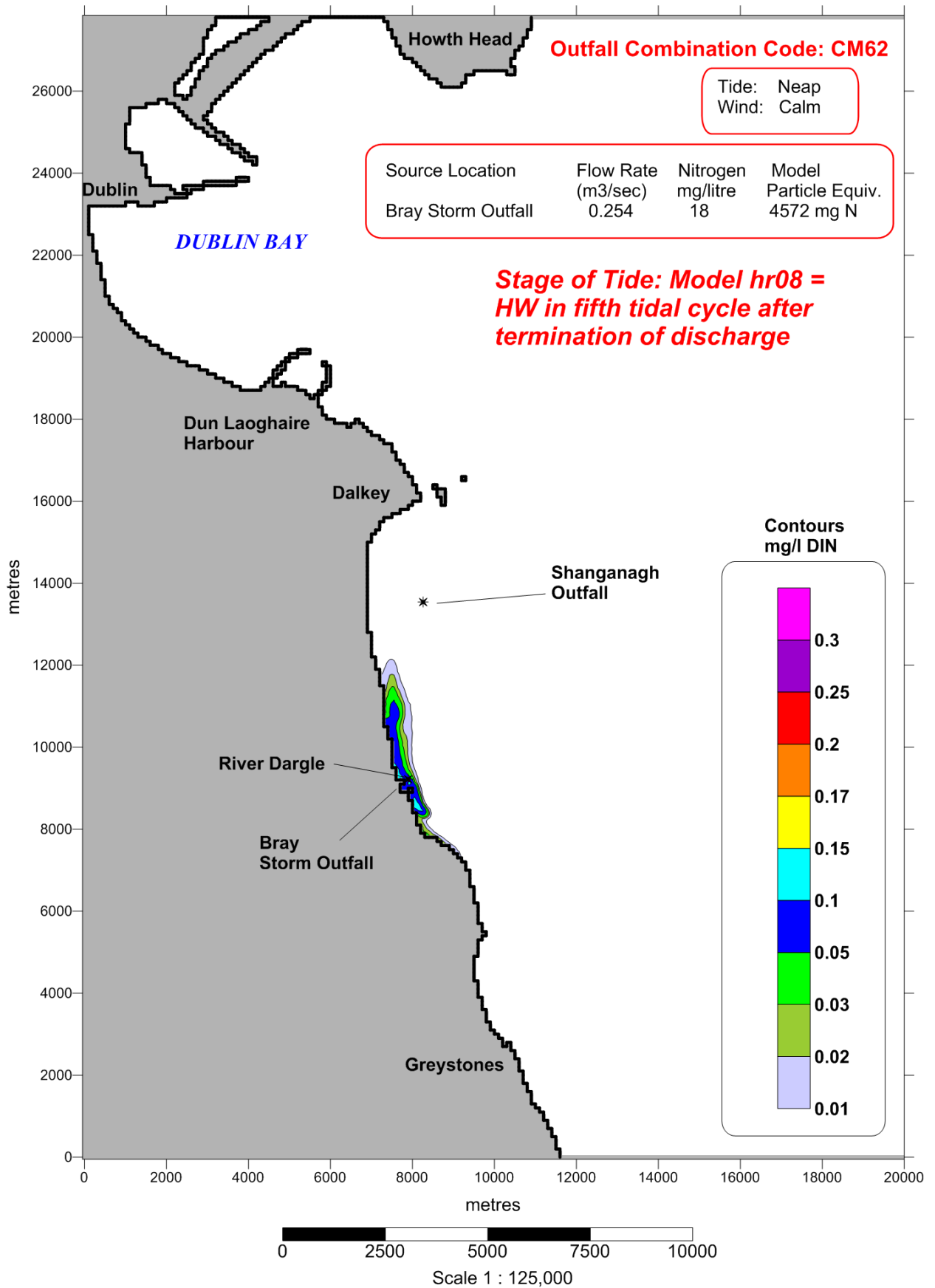
Concentration: 18 mg/l N

Tide: Neap
Wind: Calm









SECTION G – PROGRAMME OF IMPROVEMENTS

- **This section not applicable, this is a new application**