Lough Talt Regional Water Supply Scheme

Article 6(4) Compensatory Measures

Volume 3

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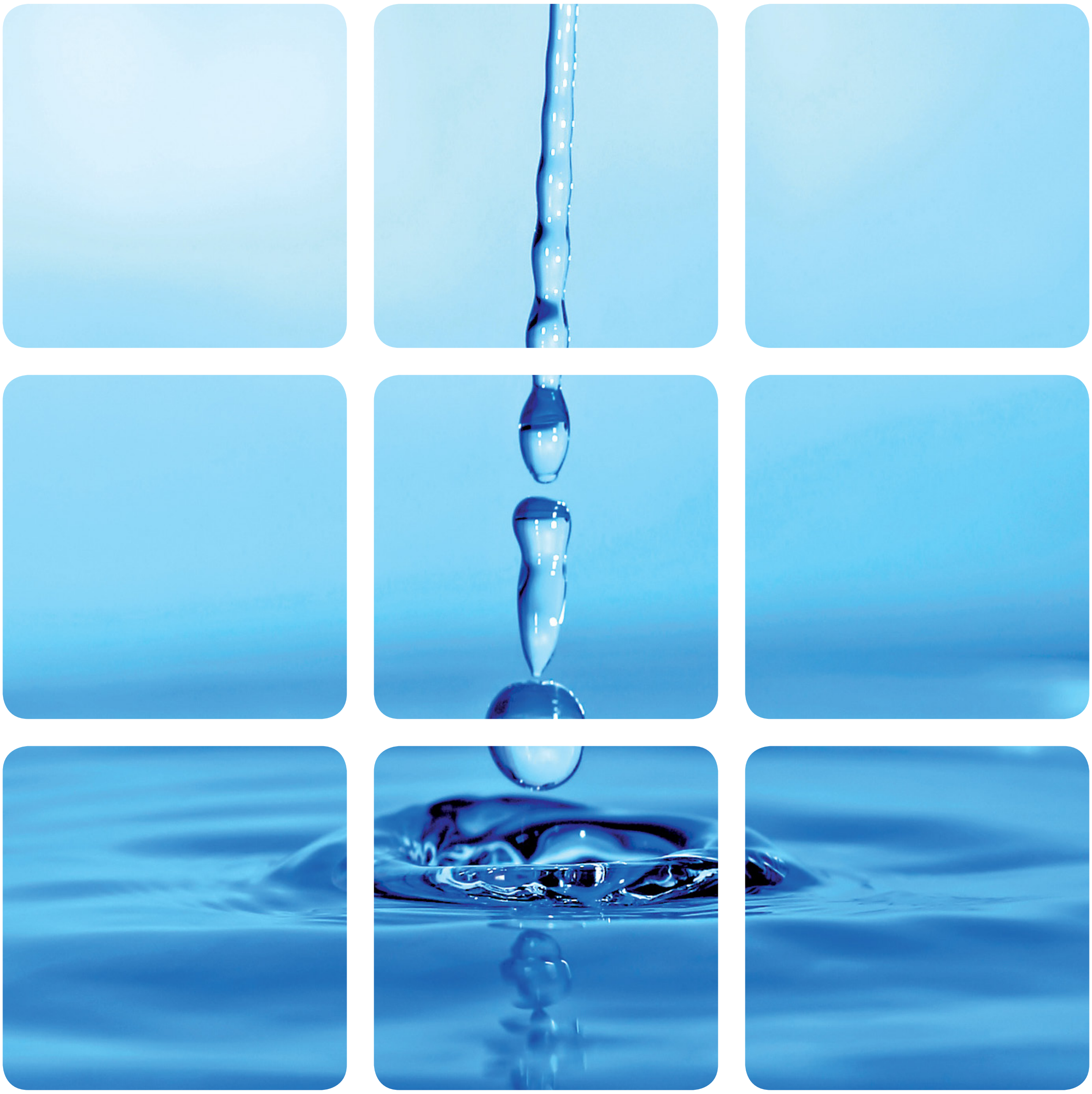

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Volume 3

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1 INTRODUCTION

This report outline the compensatory measures proposed to compensate for potential impacts to *Vertigo geyeri* populations at Lough Talt. The proposed compensatory measures are to ensure that the overall coherence of the Natura 2000 network is protected for the duration of the Imperative Reasons for Over-riding Public Interest (IROPI).

1.1 COMPENSATORY MEASURES

The following measures are proposed to compensate for potential delays in restoring favourable conservation status for the *Vertigo geyeri* population at Lough Hoe Bog SAC due to continued lake abstraction.

Compensatory measures must be practical, implementable, likely to succeed, proportionate and enforceable, and they must be approved by the Minister of Housing, Planning and Local Government and the Commission must be informed of the compensatory measures.

The compensation measures proposed incorporate key learnings from the Pollardstown Fen studies similarly focused on *V. geyeri* and other associated mollusc, extensive work completed by Evelyn Moorkens on molluscs in Ireland and internationally and a great depth of hydrogeological expertise and surface water/ groundwater interaction experience. A surface irrigation system was previously adopted for a number of years at the Pollardstown Fen *Vertigo geyeri* habitat in Co. Kildare. A review of irrigation measures used at Pollardstown Fen and their scientific and transferability value was prepared by Dr. Evelyn Moorkens in 2018. The report is provided in full in **Appendix B**.

The EU Guidance document on Article 6(4) of the Habitats Directive 92/43/EEC (2007/2012) notes *"that, as a general principle, a site should not be irreversibly affected by a project before compensation is indeed in place. However, there may be situations where it will not be possible to fill this condition."* As the abstraction at Lough Talt has been ongoing since the 1950s, this is a case where it is not possible to ensure compensatory measures are in place before the site is at risk of being affected. However, the proposed use of measures as trialled at Pollardstown Fen (as reviewed by Evelyn Moorkens) provides evidence of the efficacy of the measures proposed, and therefore positive measures for the habitat can be in place in a very short time. The use of known measures, undertaken quickly, provides the fastest approach possible for the recovery of the site.

1.1.1 Compensation Objectives

The objectives of the proposed compensation plan are as follows:

1. To reintroduce *V. geyeri* in order to compensate for historical loss due to abstraction pressures.

2. To monitor *V. geyeri* and the associated mollusc community within the fen during the period of continued lake abstraction (7 - 10 years).

Section 1.1.2 presents the proposed measures to address compensation objectives Nos. 1 and 2 above which relate to the reintroduction of *V. geyeri* and the monitoring of *V. geyeri* and the associated mollusc community during the period of continued lake abstraction.

1.1.2 Ecological Restoration Measures

It is proposed to reintroduce *V. geyeri* in order to compensate for historical loss due to abstraction pressures and to monitor *V. geyeri* and the associated mollusc community within the fen during the period of continued lake abstraction.

The restoration of a sustainable population of Geyer's whorl snail (*Vertigo geyeri*) to Lough Hoe Bog SAC is proposed through a programme of temporary irrigation of the key calcareous fen habitat on the north-eastern shore of Lough Talt until the abstraction pressure is removed from the site. In conjunction with the irrigation management, ongoing monitoring of the irrigation system function and staged translocations of snails to the fen habitat are proposed over a four year process, starting with less sensitive species and culminating in the translocation of *Vertigo geyeri* from a site where it enjoys favourable conservation condition.

These tasks are proposed over a four year process which is presented below. These measures are defined in greater detail in **Appendix A**.

The following tasks are proposed for each of the four year process:

Year 1

1) Test of water drip irrigation system
2) Set triggers for operation of irrigation system
3) Roll out of drip irrigation system
4) Monitoring of irrigation system function
5) Investigations into micro-habitat conditions
6) Monitoring of water levels

1) Test of water drip irrigation system

   This is a physical test to ensure that equipment is functional and can deliver the required gross amount of water in quantities that are appropriate at the habitat without failure through clogging or bursting of the delivery hose. This test will be undertaken on dry ground away from the habitat and is designed to troubleshoot and measure water volumes in advance of a drought. A protocol for the management of equipment outside of irrigation times and the pathway that they will be taken during equipment deployment and the exact area of deployment will be written.

2) Set triggers for operation of irrigation system

   Trigger levels will be based on the best fit of habitat (from the micro-topography study of 2016) with the water levels that coincide with loss of artesian conditions from optimal habitat (based on the multidisciplinary approach of the 2016 ecological and hydrogeological interpretive reports) and will include rainfall and temperature levels and forecasts. The trigger level will be conservative enough to include sufficient time to set up the system before negative effects are likely at the habitat level. Trigger levels will include a stand down trigger for the cessation of irrigation. The trigger levels will be reviewed as updated water level data becomes available.

3) Roll out of drip irrigation system

   The drip irrigation system will be engaged within the areas of PZ2-PZ5 when the trigger is met for the first time, and maintained until the cassation trigger is met.

4) Monitoring of irrigation system function

   During the deployment of the irrigation equipment, the locations and quantity of delivery will be monitored. Volumes delivered at different distances along the hose system will be checked. Water quality will be measures from samples taken within the phreatic tubes.

5) Investigations into micro-habitat conditions

   During the irrigation the wetness levels of the monitoring quadrats will be recorded. Use of expanded clay pellets at different times of year, including during irrigation, will monitor wetness level at points of ecological relevance to the snail community.

6) Monitoring of water levels

   The current borehole and phreatic dipwell system will continue and be used to update the water level regime information. Differences between the water level profile before and after the irrigation programme will be compared.

Year 2

1) Translocation 1 - Less sensitive mollusc species
2) Monitoring of molluscs species
3) Monitoring of micro-habitat conditions
4) Monitoring of irrigation system function
5) Monitoring of water levels
6) Workshop review and consultation with NPWS on licensing and timing of *V. geyeri* translocation

1) Translocation 1 - Less sensitive mollusc species

   In PZ2, PZ3 and PZ4, a survey using hand searching will be necessary to get an up to date list of all molluscan species present within the three 1m^2 study quadrats. Translocation of the following indicator species in order of sensitivity to wetness is then proposed: *Cochlicopa lubrica, Carychium minimum, Euconulus cf.alderi*. All have been recorded at the Ox Mountains Bogs SAC site (Site Code 002006), from where the *V. geyeri* could also eventually be donated. This is the nearest site for the species, and thus should be the closest genetic population to the lost Lough Talt population, and both sites should be relatively well matched for weather and other environmental parameters for the purposes of comparative monitoring. Any or all of these species should be collected by hand, with no fewer than 20 individuals of each species being placed in each study quadrat. Depending on the numbers of individuals found in the donor site, different species could be used in different quadrats. No more than half the number of individuals found in any 1m^2 quadrat at the donor site should be taken for translocation.

2) Monitoring of molluscs species

Monthly searches at each of the three 1m^2 translocation quadrats will be needed to assess the survival of translocated molluscs.

3) Monitoring of micro-habitat conditions

   As per year 1.

4) Monitoring of irrigation system function

   As per year 1

5) Monitoring of water levels

   As per year 1

6) Workshop review and consultation with NPWS on licensing and timing of *V. geyeri* translocation

The findings of the translocation programme of indicator species will be reviewed and presented to the client and NPWS, and (if appropriate) a derogation licence to translocate *V. geyeri* will be applied for through the Wildlife Licencing Unit of the NPWS and the translocation protocol will be agreed.

Year 3

1) Translocation 2 – *Vertigo geyeri* (if appropriate, see **Figure 1.1**)
2) Monitoring of molluscs species
3) Monitoring of micro-habitat conditions
4) Monitoring of irrigation system function
5) Monitoring of water levels
6) Workshop - Review of programme for Year 4.

1) Translocation 2 – *Vertigo geyeri* (if appropriate, see **Figure 1.1**)

   If the results from year 1 and 2 are positive and a licence is granted, the translocation of *V. geyeri* should be undertaken following the agreed protocol. Numbers of individuals are likely to depend on the numbers found in the donor site. No more than half the number of individuals found in any 1m^2 quadrat at the donor site should be taken for translocation. The likely receptor sites will be PZ2, PZ3 and PZ4, unless contra-indicated by the indicator species survey. The receptor sites will already be surveyed using hand searching for the indicator species and thus up to date information on all molluscan species present within the three 1m^2 study quadrats will be available.

2) Monitoring of molluscs species

   Monthly searches at each of the three 1m^2 translocation quadrats will be needed to assess the survival of the translocated molluscs, the recent *V. geyeri* translocations and the ongoing presence of indicator species.

3) Monitoring of micro-habitat conditions
   As per year 1.

4) Monitoring of irrigation system function

   As per year 1.

5) Monitoring of water levels

   As per year 1.

6) Workshop - Review of programme – plans for Year 4

The findings of the translocation programme of *V. geyeri* and indicator species will be reviewed and presented to the client and NPWS, and ongoing monitoring levels agreed.

Year 4 onwards

From Year 4 it is expected that a reduced monitoring regime may suffice. However, it must be sufficient to ensure the safe management of the irrigation programme, and to determine the level of establishment of the translocated snail communities. This would include hand searching in the monitoring quadrats and in appropriate micro-habitat nearby to see if the translocated snails have reproduced and/or spread. **Table 1.1** shows some important life history traits of *V. geyeri* and the indicator species. The lifespan of all the species is approximately 18 months, and all only survive days in dry conditions. All are hermaphrodite and *C. minimum* is the only species that doesn't self-fertilise well. If adult snails are translocated (i.e. snails with a developed lip), then any juvenile snails found must be the result of successful reproduction, and any adults more than 18 months post translocation are likely to belong to the next generation of the translocated population.

Table 1.1: Life history traits of species in the study. From Falkner et al., 2001 and Cameron et al., 2003).

Species	*Vertigo geyeri*	*Cochlicopa lubrica,*	*Carychium minimum*	*Euconulus cf.alderi*
Reproduction	Hermaphrodite	Hermaphrodite	Hermaphrodite	Hermaphrodite
Self-fertilise	Yes	Yes	No	Yes
Main Reproductive period	March to October	May to October	May to October	May/June and Sept/Oct
Lifespan	18 months	18 months	18 months	18 months
Survival in drought (Days/ weeks / months)	Days	Days	Days	Days

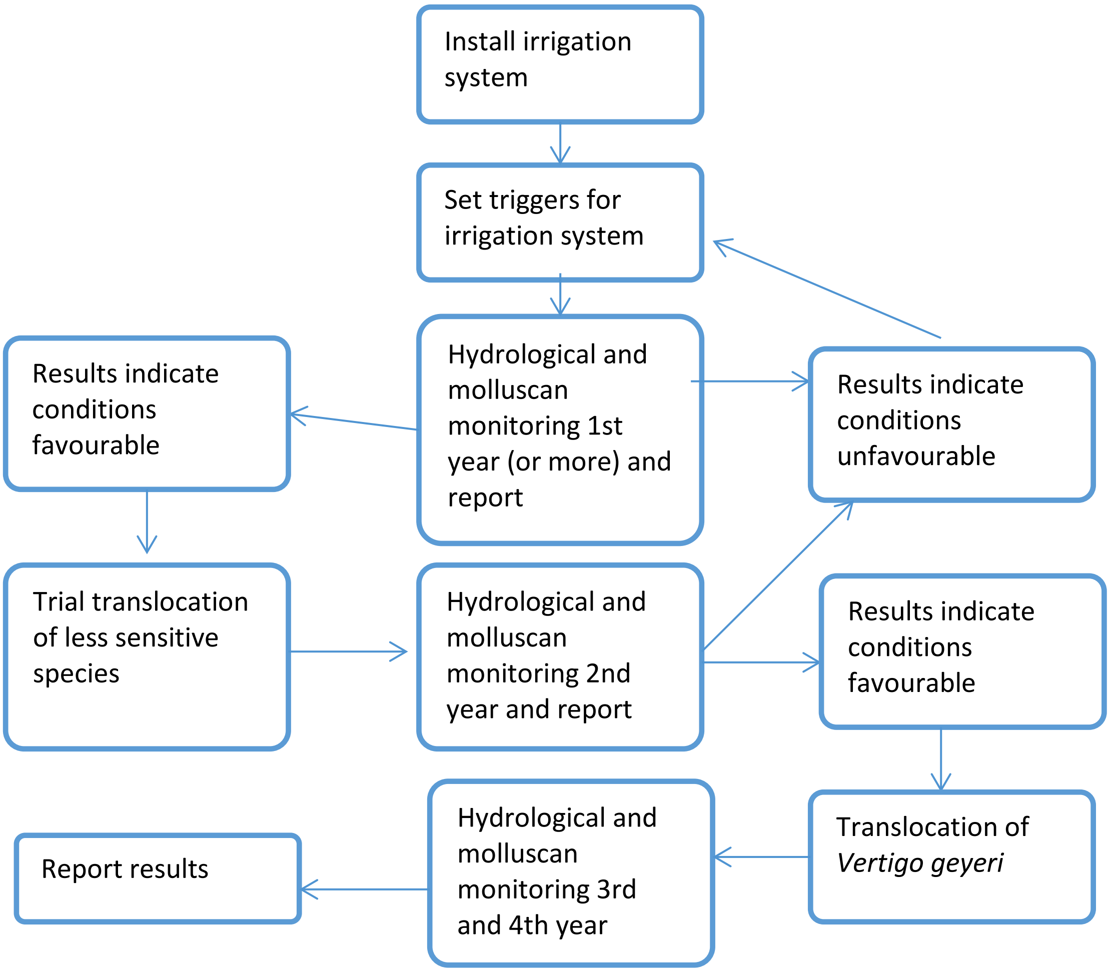

Figure 1-1: Flow diagram of *V. geyeri* compensation programme

1.2 COMPENSATORY MEASURES ASSESSMENT MATRIX

In accordance with the assessment criteria outlined in the European Commission (EC) Guidance document '*Assessment of Plans and Projects Significantly Affecting Natura 2000 Sites: Methodological guidance on the provisions of Article 6(3) and (4) of the Habitats Directive 92/43/EEC, Office for Official Publications of the European Communities, Luxembourg. European Commission*', the proposed compensatory measures for the proposed Lough Talt WTP are assessed in **Table 1.2** below.

Table 1.2: Compensatory Measures matrix for Lough Talt RWSS WTP

Assessment Criteria	Response
How were compensatory measures identified?	Compensatory measures were identified through the Appropriate Assessment process, in particular the findings of the Natura Impact Statement (Stage 2). The findings of the NIS considered that the abstraction associated with the proposed Lough Talt WTP upgrade will cause delays in progress towards achieving the Conservation Objective for *V. geyeri* for Lough Hoe Bog SAC; i.e. restore the favourable conservation condition. In order to not prevent the Conservation Objective for *V. geyeri* to

Assessment Criteria	Response
	restore the favourable conservation condition being achieved, compensatory proposals are outlined in greater detail in **Section 1.1** and in **Appendix A**
What alternative measures were identified?	Alternative measures are presented in Volume 2of this assessment. This presents a review of other water supply options for the Lough Talt RWSS and include the following: ▪ **Option A:** Do Nothing – Zero Option; ▪ **Option B:** Do nothing until and develop replacement source in place; ▪ **Option C:** Cease abstraction until and develop replacement source in place; ▪ **Option D:** Upgrade WTP and use temporarily until replacement source in place; ▪ **Option E:** Upgrade WTP and supplement Lough Talt supply with bulk import to WTP via tankering until replacement source in place; ▪ **Option F:** Upgrade WTP and progressively reduce Lough Talt supply as replacement sources became available; and ▪ **Option G:** Upgrade WTP and supplement Lough Talt supply with groundwater source during drought periods. Each of these options are considered in greater detail in **Volume 2**.
How do these measures relate to the conservation objectives of the site?	The compensatory measures relate to *V. geyeri*, a species of Qualifying Interest for Lough Hoe Bog SAC. The overarching conservation objective of this site is to maintain or restore favourable conservation condition for those habitats and species for which Lough Hoe Bog is designated. The specific Conservation Objective for *V. geyeri* is to restore favourable conservation condition. The proposed compensatory measures aim to counteract significant impacts associated with water abstraction from Lough Talt that may influence potential groundwater drawdown within the calcareous (rich) fen habitat fringing Lough Talt. It is proposed to reintroduce *V. geyeri* in order to compensate for historical loss due to abstraction pressures and to monitor *V. geyeri* and the associated mollusc community within the fen during the period of continued lake abstraction.
Do these measures address, in comparable proportions, the habitats and species negatively affected?	The proposed compensatory measures seek to reintroduce through translocation V. *geyeri* populations to suitable habitat within Lough Hoe Bog SAC. The compensatory measures will be located at the original site which supported the *Vertigo geyeri* population associated with a rich fen habitat on the north-eastern shores of Lough Talt. The area of the optimal habitat is approximately 4,000m^2; however, only a portion of this area will be required to be irrigated, approximately 1600m^2. The translocation of indicator species from the Ox Mountains Bogs SAC site (Site Code 002006) will be conducted. If the indicator snail species have successfully established, then *Vertigo geyeri* will be translocated from the Ox Mountains SAC donor site. This is the nearest site for the species, and thus should be the closest genetic population to the lost Lough Talt population, and both sites should be relatively well matched for weather and other environmental parameters for the purposes of comparative monitoring. The species will be collected by hand, with no fewer than 20 individuals of each species being placed in each study quadrat. Depending on the numbers of individuals found in the donor site, different species could be used in different quadrats. No more than half the number of individuals found in any 1m^2 quadrat at the donor site will be taken for translocation.
How would the compensatory	The proposed compensatory measures will restore the favourable

Assessment Criteria	Response
measures maintain or enhance the overall coherence of Natura 2000?	conservation condition of *V. geyeri* populations Lough Talt, through the compensatory measures (monitoring of fen and translocation of *V. geyeri* populations) outlined in **Section 1.1** of this report. These measures have been designed to achieve the attributes and targets for this species of Qualifying Interest at the Lough Talt section of Lough Hoe Bog SAC.
Do these measures relate to the same biogeographical region in the same Member State?	Yes, the proposed measures will be located within the footprint of the European site impacted by the proposed development; i.e. Lough Talt, which is designated as part of Lough Hoe Bog SAC.
If the compensation measures require the use of land outside the affected Natura 2000 site, is that land under a legal agreement between the relevant parties. The long-term ownership and control of the project or plan proponent or relevant national or local authority?	Translocation of *V. geyeri* will require sourcing of donor populations from outside of the bounds of Lough Hoe Bog SAC, such as the Ox Mountains Bogs SAC. Translocation efforts will seek to source the nearest and most suitable site of *V. geyeri*. Site access agreements will be agreed between Irish Water and the landowner to utilise and extract groundwater from this location where required.
Do the same geological, hydrogeological, soil, climate and other local conditions exist on the compensation site on the Natura 2000 site adversely affected by the project or plan?	The area / habitat supporting the proposed compensatory measures is located on the north-eastern shores of Lough Talt, within the footprint of the area of Lough Hoe Bog SAC which previously supported *V. geyeri* populations.
Do the compensatory measures provide functions comparable to those that had justified the selection criteria of the original site?	The compensatory measures will be located at the original site which supported the species of Qualifying Interest of concern; i.e. *V. geyeri* population associated with a rich fen habitat on the north-eastern shores of Lough Talt within Lough Hoe Bog SAC. The proposed compensatory measures seek to reintroduce through translocation V. *geyeri* populations to this area of Lough Hoe Bog SAC.
What evidence exists to demonstrate that this form of compensation will be successful in the long term?	The compensation measures project will incorporate key learnings from the Pollardstown Fen studies similarly focused on *V. geyeri* and other associated mollusc, extensive work completed by Evelyn Moorkens on molluscs in Ireland and internationally and a great depth of hydrogeological expertise and surface water/groundwater interaction experience. A surface irrigation system was previously adopted for a number of years at the Pollardstown Fen *Vertigo geyeri* habitat in Co. Kildare. A review of irrigation measures used at Pollardstown Fen and their scientific and transferability value was prepared by Dr. Evelyn Moorkens in 2018. The report is provided in full in **Appendix B**.

1.3 CONCLUSION

This assessment has been completed to inform Article 6(3) and Article 6(4) of the EU ‘Habitats’ Directive 92/43/EEC and provides a professional scientific examination of the project.

The conclusion of this assessment is that compensatory measures are required to compensate for potential impacts to *V. geyeri* populations at Lough Talt and to restore the favourable conservation condition for this species in the Lough Hoe Bog SAC. The compensatory measures are proposed to ensure that the overall coherence of the Natura 2000 network is protected.

APPENDIX A – PROPOSED MEASURES TO RESTORE FAVOURABLE CONDITION TO LOUGH HOE BOG SAC QUALIFYING INTEREST VERTIGO GEYERI, LOUGH TALT

COMPENSATION OBJECTIVES FOR *VERTIGO GEYERI* AT LOUGH HOE BOG

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1.0 Introduction

Lough Talt Public Water Supply serves a population of 13,663 via a single treatment plant situated 500m to the east of Lough Talt, on the R294. The supply feeds the town of Tobercurry and a large rural supply area. The catchment for the lake is steeply sloped with ground elevations ranging from 300-136m OD (malin head datum) and classified as a high risk groundwater body, due to the groundwater discharges in the vicinity of the lake, and agricultural practices.

The existing scheme has a number of deficiencies including a very high risk of Cryptosporidium in the raw water, inadequate water treatment, and an excess of Trihalomethanes. These issues need to be urgently resolved. The proposals and timelines for the development of a safe and sustainable water supply are detailed elsewhere.

The small whorl snail *Vertigo geyeri* has a population recorded in the north east fen-marsh lake shore spring-seepage slopes next to Lough Talt. The habitat areas are rich in fen sedges, within mossy seepage zones in open situations. The EU habitats present at the site are Alkaline fens: low sedge-rich communities (Annex I Habitat 7230), and rich fens of CORINE 54.2 (Romão, 1996; Devillers *et al*., 1991). This falls within the more general habitat of rich fen and flush (PF1) of Fossitt (2000), as described in Moorkens & Killeen (2011). This population is a qualifying interest for Lough Hoe Bog SAC (Site Code 000633).

The specific areas that support *V. geyeri* are within a wider mosaic of heather hummocks and denser vegetation, and are specific to emergent seepages, where they typically fit the characteristic vegetation classification within the Caricion davallianae alliance, characteristically being distinguished by *Carex viridula, Parnassia palustris, Campylium stellatum, Drepanocladus revolvens, Orchis mascula, Eleocharis quinqueflora, Pinguicula vulgaris, Carex panicea, Schoenus nigricans, Briza media, Succisa pratensis, Equisetum palustris, Mentha aquatica, Hydrocotyle vulgaris,* and *Menyanthes trifoliata* (Rodwell, 1991).

A total of 27 molluscan species have been recorded in the general area of the spring seepages, with 14 key indicator species of saturated spring seepage habitat being present in good numbers, including *Vertigo geyeri* (Cawley, 1996; Moorkens, 1997, 2006).

Monitoring of the *Vertigo* population at Lough Talt is ongoing, and surveys have been undertaken in 7 different years since 1997. In the surveys since 2007, *Vertigo geyeri* has not been found at the site. A number of ecological and hydrogeological investigations have been undertaken, and these have been summarised in Moorkens (2016) and RPS (2016).

An appropriate micro-habitat regime is a key requirement for the spring-seepage habitat to function to a level that will support *V. geyeri* and the many species that are protected under the umbrella of a habitat with this function. Hydrogeological studies to date include monitoring of the essential habitat for the snail with the wider hydrogeological profile and function. This included the installation and monitoring of three deep and shallow monitoring boreholes at the edge of the fen area, and six shallow piezometers within the *V. geyeri* habitat area. The suite of piezometers were placed to ensure they were relevant to the snail habitat, but not exactly in key habitat areas in order to avoid direct damage to the spring/seepage habitat function. Ecological monitoring to date has included surveys for snail presence by hand and through the removal and analysis of litter samples, and by measuring the micro-topography range within the habitat area to assess the function of the habitat during wet and dry phases of the annual hydrological fluctuation, and to relate these levels to the levels being measured in the phreatic tubes of the hydrogeological survey.

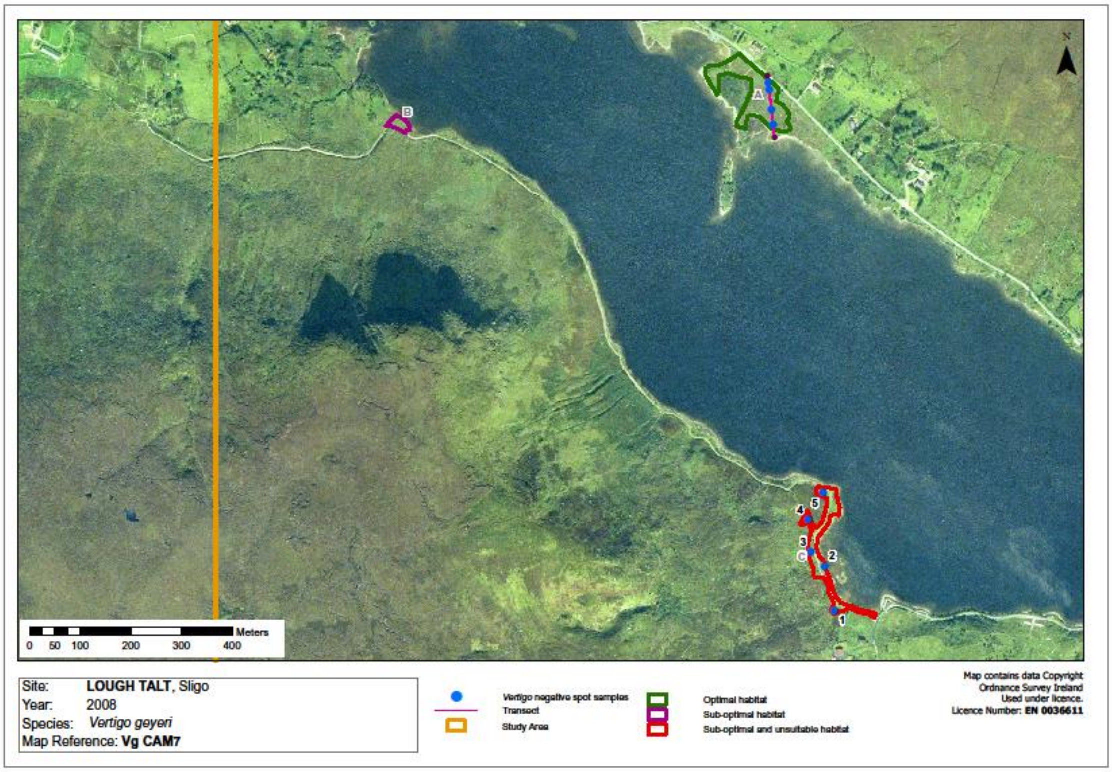
The following were the conclusions of the Moorkens (2016) study:

1) *Vertigo geyeri* is a groundwater dependent species found in fen conditions and requires active flushing groundwater at all times for survival either from direct artesian conditions, or ongoing saturation of ground for the duration of the periods where artesian conditions are slightly below the surface.
2) Abstraction from a lake where the lake levels form part of the water levels in the fen habitat is generally NOT a problem during the vast majority of time when water levels are high and excess water from the catchment is constantly moving from the lake to the river downstream.
3) Abstraction from a lake where the lake levels form part of the water levels in the fen habitat IS a problem when abstraction coincides with drought conditions to draw down the lake to levels where flushing fen conditions can no longer occur.
4) There is no abstraction rate that can be considered to be sustainable without controls that are safeguarded through automatically controlled abstraction restriction to prevent drawdown at high risk periods.
5) A strictly managed abstraction level that is designed to mechanically prevent drawdown, without relying on manual interpretation, and always maintain the fen habitat in an actively flushing state could be considered to be a safe system and compatible with the conservation objectives of the site for *Vertigo geyeri*.
6) To achieve the conservation objectives the functional habitat size at designation must be maintained at continuously favourable conditions. Ground surveys have demonstrated that previously optimal areas have reduced in quality. This could be due to changes to vegetation growth and subsequent ground-surface interface permeability during the period of loss of artesian conditions in the period from 2003 to 2007. Over time, with increased protection of artesian conditions, the area of optimal habitat may return to previous levels[Note 1.1, 1.2]. However, abstraction levels should not be set at levels that will exclude artesian conditions from currently sub-optimal habitat areas[Note 1.3].
7) The habitat to be maintained in optimal conditions is marked as A in Figure 1.1. The transect shown across area A includes PZ1, PZ3, PZ5 and PZ6. PZ2 and PZ4 are located close to this line in areas of excellent habitat. PZ1 and PZ6 are at the extreme ends of the habitat, whereas PZ2, PZ3, PZ4 and PZ5 should all have optimal conditions for the snail.
8) Criteria for design of automatic abstraction controls and triggers should be based on both water level and duration.
9) With specific regard to water level, *V. geyeri* requires two micro-habitat drivers. One is the water level driving the phreatic pressure, which keeps the moss and sedge root and plant emergent surfaces saturated at all times, and the other is a proximity to small open water pools, which keep humidity high. It was found that the snail requires a consistently damp atmosphere with relative humidity varying between 80% and 95% both summer and winter (Kuczynska & Moorkens, 2010). We can presume that the same drivers that control phreatic pressure for the flushing habitat also control the small pools, and that the water forms pools where there is lowered micro-topography and/or there is an impeded infiltration area of soil, such as a clay lens. The combinations of these requirements mean that snails are highly restricted in their individual habitat ranges, and do not generally travel more than 5cm in their lifetimes (Kuczynska & Moorkens, 2010). Each metre square may have a number of micro-populations within the overall site population that rarely interact with each other.
10) With regard to duration, loss of the snail occurs within days where open water is still present but phreatic conditions are lost (Falkner et al., 2001), or within hours if open water pools

have dried and humidity drops below 80% (Kuczynska & Moorkens, 2010). Therefore, controls on abstraction management need to have sufficient early warning to ensure that there is not a time lag during which time evapo-transpiration can extirpate these open water pools (that may only be as small as 10cm x 10cm), and that phreatic conditions are not lost between the trigger, the action and the response in the habitat. This means that controls on abstraction should be designed to ensure a low duration of conditions where they are at the edge of sustainability.

11) Control of artesian conditions could be made using a “hands off” level, controlled by the level of the abstraction outlet pipe.
12) Alternatively, the weir level could be adjusted to provide management of high water levels (to ensure no flooding) and low water levels water is held back and drawdown at the habitat level is prevented. This would require further assessment and possibly planning permission.
13) In either case, an accurate water level that ensures sufficient artesian conditions – and thus active seepages – at all times needs to be found. The fast lethal response (hours to 1-2 days depending on the continued presence of pooled water) of the snail means that the water level must be chosen with a high degree of certainty. This can only be done by relating the microtopography in each 5cm area of optimal habitat with the lake level (the work undertaken in 2016) and setting a trigger that is not so conservative that it makes the abstraction unnecessarily difficult. Neither should it be at a limit that would cause enough uncertainty or risk that would make the success of the compensatory measures unlikely. The background investigations for this were undertaken in the 2016 micro-topography and hydrogeology studies.
14) Saturated ground dries faster in hot temperatures, therefore a temperature trigger may be needed as well as a water level trigger in managing artesian conditions.

Figure 1.1 location of V. geyeri habitat



The European site conservation objectives for Lough Hoe Bog SAC (see Section 2) include targets for the presence of *Vertigo geyeri,* and for its habitat quality, including wetness. The conclusion of no adverse effect on site integrity cannot be reached for the current abstraction regime, but there is by necessity a time delay in order to set an alternative water supply in place. Thus a temporary situation arises (up to 10 years) where the negative impacts from the abstraction need to be managed by mitigation (habitat and wetness quality), along with compensatory measures to assist with the target of occupation of the eastern habitat by a living population of *V. geyeri*.

*Note 1.1 Optimal habitat definition (From Moorkens & Killeen (2011) - **Optimal** habitat is where *V. geyeri* could survive in a large area (at least 50%) of the habitat. This allows for areas that have, for example, *Schoenus nigricans* tussocks. The snail will not normally be is not found high in a tussock, but the structure of the tussock provides the variation that sustains the snail within the first 5 to 6 centimetres of its base, depending on the hydrological conditions on the day. Thus to provide this amplitude of habitat variation to cover annual variation, the growth of unsuitable microhabitat is necessary. Another example of optimal habitat is calcareous cropped open sedge swards and moss carpets within undulating terrain. The topographical changes provide the niches for wet and dry extremes; therefore by their provision for these extremes, there will always be some habitat within them that is at least temporarily unsuitable. These habitats should not be changed to “improve” them, e.g. to make them wetter for more of the time, as the range of microtopography is important.

*Note 1.2 The uncertainty regarding the restoration of optimum habitat through rewetting of a habitat that has had a temporary drying is due to the potential for phreatic preferential pathways to become blocked during excessively dry periods and for different pathways to emerge following rewetting. Where new pathways emerge in areas that cannot support *V. geyeri* habitat, some micro sites may be lost. Other pathways may change to become more suitable than before. The results of work to date have demonstrated that periods involving an absence of artesian conditions have been short at the Lough Hoe Bog site and thus it is considered that it is unlikely that there has been major damage to the phreatic pathways and that restoration of optimal habitat function can be achieved through mitigation of the effects of drought conditions when they arise. In the 2016 study, optimal habitat was found to be present in 16% of the monitoring study areas were in optimum habitat condition in March, with 26% in optimal habitat condition in September. The results were higher in the best habitat areas (known as monitoring areas PZ2 and PZ4).

* Note 1.3 Sub-optimal habitat definition (From Moorkens & Killeen (2011) - **Sub-optimal** habitat is where there are patches of vegetation and conditions that support *V. geyeri* but the majority of the habitat cannot. This can be due to terrain being generally too high, but with small suitably wet runnel flushes occurring within, or where habitat is on the margin of base tolerance for the species, where acid influence promotes mainly calcifuge species, but where occasional groundwater seepage influence provides a suitable patch that the snail can occupy. Alternatively the snail may be restricted by succession due to lack of grazing, where the snail is shaded out of most of the area, except for patches prevented from growth by being wetter than their surroundings.

2.0 Conservation objectives for *Vertigo geyeri* at Lough Hoe Bog SAC

The conservation objectives for Lough Hoe Bog were published in August 2017 (NPWS, 2017). The objective for the qualifying interest *Vertigo geyeri* is to **restore** the favourable conservation condition of Geyer's Whorl Snail in Lough Hoe Bog SAC, which is defined in the conservation objectives by the following list of attributes and targets:

Attribute	**Measure**	**Target**	**Notes**
Distribution: occupied sites	Number of occupied 1km grid squares	Restore at least one subpopulation	Geyer's whorl snail (Vertigo geyeri) has been recorded in two separate areas on the shore of Lough Talt in Lough Hoe Bog SAC within a single 1km square, G3915 (Cawley, 2006; site code VgCAM7 in Moorkens and Killeen, 2011). See map 4. The last record from the eastern side was in 2005. The current status of the population on the western shore is uncertain. The habitats occupied by Geyer's whorl snail (V. geyeri) in the SAC are areas of fen and flush close to the shore of Lough Talt.
Occurrence in suitable habitat	Number of positive records in a representative number of samples	No decline, subject to natural processes	Positive samples mean the confirmed presence of snails (living or recently dead adults and/or juveniles). See Moorkens and Killeen (2011).
Habitat area	Hectares	Area of suitable habitat stable or increasing, subject to natural processes; at least 1ha of suitable habitat in at least sub-optimal condition	Apparently suitable conditions for the species are present at several places, with the largest area on the east shore of Lough Talt. Two less extensive areas are found on the west shore. Optimal habitat in the SAC is defined (by Moorkens and Killeen, 2011) as flushed fen grassland with sedge/moss lawns 5-15cm tall, containing species such as *Carex lepidocarpa, Pinguicula vulgaris, Briza media, Equisetum palustre, Juncus articulatus* and the mosses *Drepanocladus revolvens* and *Campylium stellatum*, with scattered tussocks of *Schoenus nigricans* no more than 80cm tall. During sampling, the water table should be between 0-5cm of the soil surface, but not above ground level. Sub-optimal habitat is defined as above, but vegetation height is less than 5 or more than 15cm tall, or the water table is below 5cm, or ground is flooded at time of sampling.
Habitat quality: Soil wetness	Percentage of a representative number of sampling stops	At least 67% of a representative number of sampling stops in areas of optimal habitat should be classified as optimal wetness as defined by Moorkens and Killeen (2011); at least 25% should be optimal wetness	The soil wetness should be assessed using the criteria described in Moorkens and Killeen (2011).

		in areas of sub-optimal habitat.	

The conservation objectives above have been used to define the objectives of the programme, and the attributes that need to be measured during the monitoring programme.

3.0Mitigation and Compensation Objectives and Targets

The mitigation and compensation objectives and targets are listed in Table 3.1 below.

Aim of mitigation measures
The mitigation measures proposed are designed to prevent any negative effects on the fen habitat which supports the qualifying interest *Vertigo geyeri* during the temporary continuation of abstraction of drinking water from Lough Talt.

The mitigation measures centre around measures to ensure that the wetness levels in the *Vertigo geyeri* habitats are maintained through irrigation during periods of low phreatic pressure. The maintenance of an appropriate wetness level will have a positive impact on habitat area and quality.

Aim of compensatory measures
The compensatory measures are designed to provide additional benefits to assist with the conservation objective of occupancy of habitat by the protected species *Vertigo geyeri*. Compensation measures should be delivered in proportion with the impact of continued abstraction. The uncertainty associated with the scale of potential impacts means that the compensation measures put forward must be flexible and kept under review. A package of physical ecological measures, supported by research measures, is therefore proposed. The aims of the compensation package are:

To assess the function of the mitigated habitats through the introduction of snail species that were present in the past but are currently not present, these species should not include *V. geyeri*.

To undertake research and monitoring to inform the continued review of the snail habitat function and the reintroduction scheme, in order to provide confidence that conditions are appropriate for the reintroduction of *V. geyeri*.

The compensatory measures aim to be secured within the Lough Hoe Bog SAC rather than in an external site as the site is considered to be of high importance and the return of the snail to the site is considered to be feasible.

Table 3.1 Mitigation and compensation objectives and targets and their relation to the Conservation Objectives of the site

Attribute	Measure	Target	Mitigation	Compensation
Distribution: occupied sites	Number of occupied 1km grid squares	Restore at least one subpopulation	Monitoring of habitat beyond standard methods with interpretation of irrigation mitigation.	Introduction and monitoring of indicator mollusc species Introduction and monitoring of *V. geyeri*
Occurrence in suitable habitat	Number of positive records in a representative number of samples	No decline, subject to natural processes	No mitigation	Monitoring of introduced species beyond standard methods to include monitoring of reproductive events and snail numbers with interpretation of effects of natural processes(most notably rainfall)
Habitat area	Hectares	Area of suitable habitat stable or increasing, subject to natural processes; at least 1ha of suitable habitat in at least sub-optimal condition	No direct mitigation but Target expected to be achieved through wetness mitigation measures	Monitoring of suitable habitat area beyond standard methods and with reference to conservation objective target. The monitoring would include a tiered level of monitoring from broad level (GPS delineation of wider habitat areas) to micro-habitat level (changes to habitat mapping within 1m^2 study areas (PZ1 – PZ6). Interpretation to include hydrological and hydrogeological levels. To include monitoring of reproductive events and snail numbers with interpretation of effects of natural processes (most notably rainfall and temperature).
Habitat quality: Soil wetness	Percentage of a representative number of sampling stops	At least 67% of a representative number of sampling stops in areas of optimal habitat should be classified as optimal wetness as defined by Moorkens and Killeen (2011); at least 25% should be optimal wetness in areas of sub-optimal habitat.	Mitigation through irrigation aimed at maintaining artesian conditions across a defined target area. Monitoring of suitability of wetness conditions beyond standard methods.	Use of expanded clay pellets to monitor moisture levels at the level of the snail microhabitat to assess suitability for translocation.

4.0 Proposed programme to Compensate Project Effects on *Vertigo geyeri* at Lough Hoe Bog SAC

The combination of mitigation and compensation measures are proposed to counteract any adverse affects on the qualifying interest of *Vertigo geyeri* in Lough Hoe Bog SAC caused by the temporary continuation of abstraction at Lough Talt. The programme consists of a proposed programme of temporary irrigation of the key habitat areas until the abstraction pressure is removed from the site. In conjunction with the irrigation management, staged translocations of snails to the habitat are proposed, starting with less sensitive species and culminating in the translocation of *Vertigo geyeri* from a site where it enjoys favourable condition.

A flow chart for the process is presented in Figure 4.1.

The following tasks are proposed for each year:

Year 1

1) Test of water drip irrigation system
2) Set triggers for operation of irrigation system
3) Roll out of drip irrigation system
4) Monitoring of irrigation system function
5) Investigations into micro-habitat conditions
6) Monitoring of water levels

1) Test of water drip irrigation system

   This is a physical test to ensure that equipment is functional and can deliver the required gross amount of water in quantities that are appropriate at the habitat without failure through clogging or bursting of the delivery hose. This test will be undertaken on dry ground away from the habitat and is designed to troubleshoot and measure water volumes in advance of a drought. A protocol for the management of equipment outside of irrigation times and the pathway that they will be taken during equipment deployment and the exact area of deployment will be written.

2) Set triggers for operation of irrigation system

   Trigger levels will be based on the best fit of habitat (from the micro-topography study of 2016) with the water levels that coincide with loss of artesian conditions from optimal habitat (based on the multidisciplinary approach of the 2016 ecological and hydrogeological interpretive reports) and will include rainfall and temperature levels and forecasts. The trigger level will be conservative enough to include sufficient time to set up the system before negative effects are likely at the habitat level. Trigger levels will include a stand down trigger for the cessation of irrigation. The trigger levels will be reviewed as updated water level data becomes available.

3) Roll out of drip irrigation system

The drip irrigation system will be engaged within the areas of PZ2-PZ5 when the trigger is met for the first time, and maintained until the cassation trigger is met.

4) Monitoring of irrigation system function

During the deployment of the irrigation equipment, the locations and quantity of delivery will be monitored. Volumes delivered at different distances along the hose system will be checked. Water quality will be measures from samples taken within the phreatic tubes.

5) Investigations into micro-habitat conditions
During the irrigation the wetness levels of the monitoring quadrats will be recorded. Use of expanded clay pellets at different times of year, including during irrigation, will monitor wetness level at points of ecological relevance to the snail community.

6) Monitoring of water levels

The current borehole and phreatic dipwell system will continue and be used to update the water level regime information. Differences between the water level profile before and after the irrigation programme will be compared.

Year 2

1) Translocation 1 - Less sensitive mollusc species
2) Monitoring of molluscs species
3) Monitoring of micro-habitat conditions
4) Monitoring of irrigation system function
5) Monitoring of water levels
6) Workshop review and consultation with NPWS on licensing and timing of *V. geyeri* translocation

(Based on results of monitoring, number of irrigation events needed, outcome of habitat response – see flow diagram)

1) Translocation 1 - Less sensitive mollusc species

In PZ2, PZ3 and PZ4, a survey using hand searching will be necessary to get an up to date list of all molluscan species present within the three 1m^2 study quadrats. Translocation of the following indicator species in order of sensitivity to wetness is then proposed: *Cochlicopa lubrica, Carychium minimum, Euconulus cf.alderi*. All have been recorded at the Ox Mountains Bogs SAC site (Site Code 002006), from where the *V. geyeri* could also eventually be donated. This is the nearest site for the species, and thus should be the closest genetic population to the lost Lough Talt population, and both sites should be relatively well matched for weather and other environmental parameters for the purposes of comparative monitoring. Any or all of these species should be collected by hand, with no fewer than 20 individuals of each species being placed in each study quadrat. Depending on the numbers of individuals found in the donor site, different species could be used in different quadrats. No more than half the number of individuals found in any 1m^2 quadrat at the donor site should be taken for translocation.

2) Monitoring of molluscs species

   Monthly searches at each of the three $1m^2$ translocation quadrats will be needed to assess the survival of translocated molluscs.

3) Monitoring of micro-habitat conditions

   As per year 1.

4) Monitoring of irrigation system function

   As per year 1

5) Monitoring of water levels

   As per year 1

6) Workshop review and consultation with NPWS on licensing and timing of *V. geyeri* translocation

   The findings of the translocation programme of indicator species will be reviewed and presented to the client and NPWS, and (if appropriate) a licence for the translocation of *V. geyeri* applied for and a translocation protocol agreed.

Year 3

1) Translocation 2 – *Vertigo geyeri* (if appropriate, see flowchart)
2) Monitoring of molluscs species
3) Monitoring of micro-habitat conditions
4) Monitoring of irrigation system function
5) Monitoring of water levels
6) Workshop - Review of programme for Year 4.

1) Translocation 2 – *Vertigo geyeri* (if appropriate, see flowchart)

   If the results from year 1 and 2 are positive and a licence is supplied, the translocation of *V. geyeri* should be undertaken following the agreed protocol. Numbers of individuals are likely to depend on the numbers found in the donor site. No more than half the number of individuals found in any $1m^2$ quadrat at the donor site should be taken for translocation. The likely receptor sites will be PZ2, PZ3 and PZ4, unless contra-indicated by the indicator species survey. The receptor sites will already be surveyed using hand searching for the indicator species and thus up to date information on all molluscan species present within the three $1m^2$ study quadrats will be available.

2) Monitoring of molluscs species

   Monthly searches at each of the three $1m^2$ translocation quadrats will be needed to assess the survival of the translocated molluscs, the recent *V. geyeri* translocations and the ongoing presence of indicator species.

3) Monitoring of micro-habitat conditions

   As per year 1.

4) Monitoring of irrigation system function

   As per year 1.

5) Monitoring of water levels

   As per year 1.

6) Workshop - Review of programme – plans for Year 4.

   The findings of the translocation programme of *V. geyeri* and indicator species will be reviewed and presented to the client and NPWS, and ongoing monitoring levels agreed.

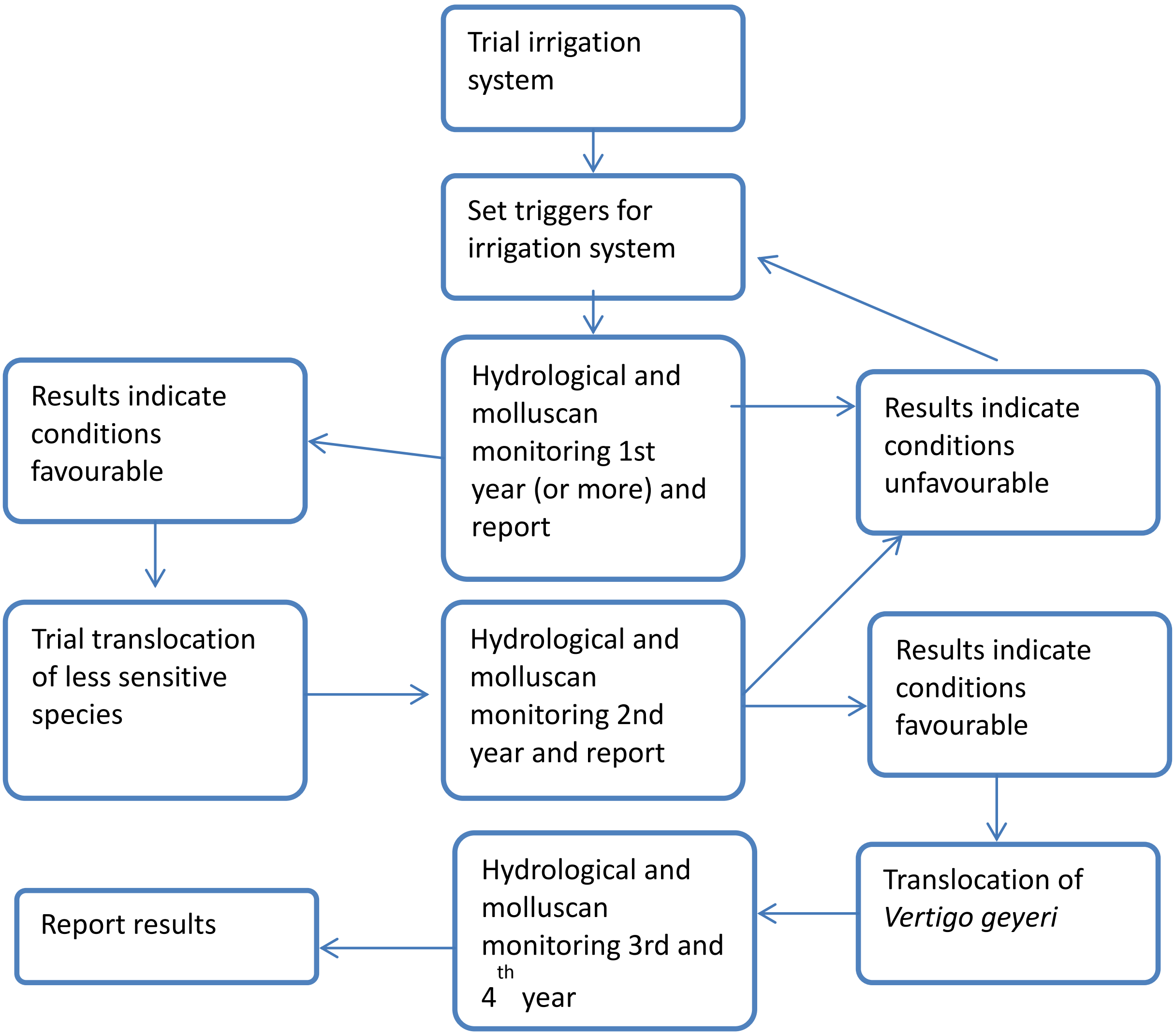
Year 4 onwards

From Year 4 it is expected that a reduced monitoring regime may suffice. However, it must be sufficient to ensure the safe management of the irrigation programme, and to determine the level of establishment of the translocated snail communities. This would include hand searching in the monitoring quadrats and in appropriate micro-habitat nearby to see if the translocated snails have reproduced and/or spread. Table 4.1 shows some important life history traits of *V. geyeri* and the indicator species. The lifespan of all the species is approximately 18 months, and all only survive days in dry conditions. All are hermaphrodite and *C. minimum* is the only species that doesn't self fertilize well. If adult snails are translocated (i,e, snails with a developed lip), then any juvenile snails found must be the result of successful reproduction, and any adults more than 18 months post translocation are likely to belong to the next generation of the translocated population.

Table 4.1 Life history traits of species in the study. From Falkner et al., 2001 and Cameron et al., 2003).

Species	***Vertigo geyeri***	***Cochlicopa lubrica,***	***Carychium minimum***	***Euconulus cf.alderi***
Reproduction	Hermaphrodite	Hermaphrodite	Hermaphrodite	Hermaphrodite
Self fertilize	Yes	Yes	No	Yes
Main Reproductive period	March to October	May to October	May to October	May/June and Sept/Oct
Lifespan	18 months	18 months	18 months	18 months
Survival in drought (Days/ weeks / months)	Days	Days	Days	Days

Figure 4.1 Flow diagram of *V. geyeri* compensation programme



The details of any compensation and reintroduction programme must be considered very carefully to ensure that the methodology is designed to result in the positive measure required in a manner that there will be no damage due to either the disturbance caused by the measure, or no confounding effects that could be caused by the changes brought about by any measure. Monitoring must also be carefully considered to ensure that the frequency, parameters, equipment and methods are appropriate and necessary and will not be damaging themselves. They should fulfil the requirements of SMART:

S – scientific, tested, evidence-based

M – measurable, quantified performance

A – Achievable, deliverable on site

R – repeatable, strength-test / power analysis for monitoring

T – timely, meets required schedule.

The trial irrigation system, its equipment and operation are outlined in a separate report (RPS, 2018). Table 4.2 is a preliminary account of the likely risks of the proposed programme, and how damage would be avoided. This will need to be reviewed on an ongoing basis as the programme is developed and results are interpreted.

Table 4.2 Measures, risks and mitigation of risks in proposed programme

Item	**Relevance to Conservation Objective**	**Potential Risk**	**Mitigation of risk** To be reviewed as the programme is developed in greater detail
Habitat irrigation	Habitat wetness	Habitat disturbance - during irrigation system installation	Minimise the number of people entering the habitat area. Minimise the number of trips into the habitat area. Access the habitat area from high ground, stay on dry ground or high ground (rocks, heather, hummocks, etc.) wherever possible. Use light weight equipment wherever possible. Only carry minimal required equipment to assemble the irrigation system to minimise loading on the habitat during access. Install the irrigation system on dry and high ground wherever possible in order to keep equipment out of the most sensitive habitat area, and also when the system needs to be manipulated access to more sensitive habitat is not required. Monitor: disturbance to the site
Habitat irrigation	Habitat wetness	Habitat disturbance - during irrigation system operation	Minimise the number of people entering the habitat area. Minimise the number of trips into the habitat area. Access the habitat area from high ground, stay on dry ground or high ground (rocks, heather, hummocks, etc.) wherever possible. Use light weight equipment wherever possible. Only carry minimal required equipment to minimise loading on the habitat during access. Use automated equipment (e.g. data loggers)

			wherever possible in order to minimise the number of trips into the habitat area. Monitor: disturbance to the site
Habitat irrigation	Habitat wetness	Habitat contamination - during irrigation system installation, operation and monitoring	Ensure that all equipment brought into the habitat is clean and does not introduce contaminants (e.g. oil, grease or other hydrocarbons) into the fen area. Personnel entering the habitat should not have applied any sun screen or insect repellents. Monitor: groundwater water quality
Habitat irrigation	Habitat wetness	Flooding/inundation of habitat – due to excess flow discharge from surface irrigation system	Start with only small discharges to the fen habitat and increase slowly as required. Constant visual inspection at the start of irrigation to ensure water levels not rising significantly in habitat area. Regular monitoring of weather forecast with regards to predicted rainfall and temperature. Monitor: habitat wetness, groundwater levels
Habitat irrigation	Habitat wetness	Drying out of habitat – due to insufficient discharge from the surface irrigation system	Constant visual inspection at the start of irrigation to ensure moisture being maintained or increased appropriately. Regular monitoring of weather forecast with regards to predicted rainfall (or lack thereof). Use of pellets to measure moisture content and ensure that moisture targets are being achieved*[see Note 4.1]. Monitor: habitat wetness, groundwater levels
Habitat irrigation	Habitat wetness	Drying out of habitat – due to cessation of pumping due to theft of equipment	Secure equipment with lockable devices where possible (including locked borehole covers with slots for pipework). Prevent un-approved vehicular access (if possible). Discrete positioning of equipment. Monitor: habitat wetness, groundwater levels
Habitat irrigation	Habitat wetness	Irregular or uneven irrigation	Measure output based on trialled flow output, evenness and monitor tendency to clog, tear or otherwise fail. Hose materials and frequency of irrigation holes and/or number of "leaky joint" locations will be carefully chosen and monitored. Monitor: habitat wetness, groundwater levels
Habitat irrigation	Habitat wetness	Irrigation water source inappropriate	The water source should be compatible with the groundwater currently present at the habitat springs. Borehole groundwater is therefore the proposed source. Monitor: groundwater water quality

Habitat irrigation	Habitat wetness	Irrigation water source results in groundwater deficiency	The removal of groundwater should not result in any deficit in the deep groundwater levels. There is a contingency to change the borehole water such that it is sourced from a more remote borehole if necessary. Monitor: Groundwater levels
Mollusc habitat monitoring	Habitat area	Area of suitable habitat not meeting the target of at least 1ha of suitable habitat in at least sub-optimal condition	Suitable habitat has been meeting this target although the snail has not recovered. Monitor: Habitat condition and area
Mollusc monitoring, mollusc translocation	Number of occupied 1km grid squares Distribution: occupied sites Occurrence in suitable habitat	Conditions unsuitable	Translocation should be a process that begins with ensuring conditions are suitable throughout the year. Translocations should begin with less sensitive species before any translocation of *V. geyeri.* Monitor: Habitat condition, snail composition and density prior and subsequent to translocation, snail survival rates at Lough Talt habitat areas
Mollusc monitoring, mollusc translocation	Number of occupied 1km grid squares Distribution: occupied sites Occurrence in suitable habitat	Translocation unsuccessful	Interrogation of the data from the unsuccessful translocation may highlight changes needed to the protocol.
Translocation process	Number of occupied 1km grid squares Distribution: occupied sites Occurrence in suitable habitat	Damage to donor population of *V. geyeri*	Emphasis on finding snail species in the field *[see Note 4.2] Intensive Monitoring: Habitat condition, snail composition and density prior and subsequent to translocation, snail survival rates at donor site

Note [4.1] Pellets

Surface wetness levels can be measured using small (5 mm diameter) clay pellets. The expanded clay pellets are half of the weight of sand and gravel and can absorb up to 30% of their own weight in water. They mimic snails and to measure the ‘‘moisture stress” that a snail is likely to experience under dry conditions. The wetness conditions of different areas can be compared by measuring the change in weight of the pellets after exposing them to different surface wetness conditions, according to the methods of Kuczynska & Moorkens (2010).

Note [4.2] Reliance on hand searching

The number of individuals to be translocated at a time would be too small to allow for destructive sampling. Monitoring must therefore be more intensive than the standard methods of Moorkens & Killeen (2011). Mollusc monitoring should be undertaken by hand searching through timed searches. This is the least damaging method of non-destructive sampling, with semi-quantitative (accurate within errors of visibility) numbers of snails of different species being counted within 0.25x0.25m quadrats or smaller within each experimental 1m^2 quadrat. This method has been used in previous studies, such as at Pollardstown Fen (for *V. geyeri*), Doonbeg (for *V. angustior*) and the Newbury bypass, UK (for *V. moulinsiana*) (Moorkens, 2003; Moorkens & Gaynor, 2001, Killeen & Moorkens, 2003). Count sites must be accessible from higher ground in order to ensure that there will be no damage to the sensitive habitats. This would avoid the need to build counting platforms or trolleys, as was required in the Pollardstown study due to the flat terrain. Monitoring frequency is proposed to be monthly between March and October.

Reporting should be regular and integrated from the multi-disciplinary team, with the acceptance of staged reports triggering the next stage of the programme.

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APPENDIX B – COMPENSATION OBJECTIVES FOR VERTIGO GEYERI AT LOUGH HOE BOG - A REVIEW OF IRRIGATION MEASURES USED AT POLLARDSTOWN FEN AND THEIR SCIENTIFIC AND TRANSFERABILITY VALUE

COMPENSATION OBJECTIVES FOR *VERTIGO GEYERI* AT LOUGH HOE BOG

A review of irrigation measures used at Pollardstown Fen and their scientific and transferability value

April 2018

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This review is a short supplement to proposals for compensatory measures for *Vertigo geyeri* at Lough Hoe Bog SAC. It summarises the objectives for the proposed irrigation of the spring seepage habitat that formerly supported a population of the Annex II whorl snail *Vertigo geyeri*. It also provides information on a previous use of irrigation in a similar habitat at Pollardstown Fen SAC.

The information in this report is taken from some of the C. 250 unpublished reports prepared during the Pollardstown project. Acknowledgement is given to all the contributors to the Pollardstown fen studies, in particular Anna Kuczyńska, Paul Johnston, Katy Duff, Geert Van Wirdum, Jim Ryan, Teri Hayes, and White Young Green Consultants. The data and analysis presented in this report should not be republished, it remains the property of the various authors and their clients and they are presented here for context, not as an attempt to reduce the vast amount of work undertaken over ten years into a few pages. The review focuses on the relevance of scientific demonstration from the Pollardstown project in the proposals of the compensatory measure of **irrigation** in the context of Lough Talt.

Objectives of the irrigation proposal

The objectives of the proposed irrigation at Lough Hoe Bog SAC closely reflect the objectives of the irrigation at Pollardstown Fen during the period of dewatering associated with the M7 road construction project. These objectives are outlined below:

Lough Hoe Bog proposal	Pollardstown Fen project
Objective 1: To maintain artesian conditions where they currently occur	Objective 1: To maintain artesian conditions where they currently occur
Objective 2: To provide suitable habitat for *Vertigo geyeri* throughout the year and thus support the reintroduction of the snail	Objective 2: To provide suitable habitat for *Vertigo geyeri* throughout the year and thus maintain the presence of the snail

The difference between the objectives in the two projects is that *Vertigo geyeri* was present during this period at Pollardstown Fen, but requires reintroduction at Lough Hoe Bog cSAC.

Objective 1 is to ensure that sufficient water is delivered to key habitat areas to prevent the surface layer from drying out and forming a crust that is less permeable than the sub-soil. The snail microhabitat requires surface saturation, supported by preferential pathways of artesian water pressure. As water follows the path of least resistance, there is a risk that groundwater pathways will change during dry conditions. Such changes can have negative effects on the location and extent of surface seepage habitats. For example, if groundwater found a path of lower resistance through a deeper peat area, that water may no longer have the ability to reach the surface and that seepage habitat would be lost.

As there is a risk of lower than natural groundwater pressure during dry periods because of the continued abstraction from Lough Talt, the proposal is to irrigate areas that would support water emergence at the key seepage zones for the duration of the time periods where there is a risk to their wetness.

This aspect would support the conservation objective attributes of "habitat area" and "habitat quality: wetness" (NPWS, 2017).

Objective 2 of the irrigation is to ensure that the habitat conditions are suitable habitat for *Vertigo geyeri* throughout the year and thus support the reintroduction of the snail. As well as avoiding the risk of surface drying and permanent change to artesian pathways, the management of good saturation of the surface throughout the year would make it safe to attempt the translocation of indicator snails and *Vertigo geyeri* to the habitat during the period of the compensatory measures so that a population of the Annex II species is in place at the Lough Talt site before the abstraction from the lake ceases.

This aspect would support the conservation objective attributes of "distribution: occupied sites" and "occurrence in suitable habitat" (NPWS, 2017).

Example of a previous project that used irrigation: Pollardstown Fen – Kildare Bypass project

Background to the Pollardstown Fen project

Pollardstown Fen is a Natura 2000 candidate SAC and Statutory Nature Reserve situated on the northern margin of the Curragh, approximately 3km north-west of Newbridge town, Co. Kildare. It is located some 4.5 kilometres from the Kildare bypass. It is a spring-fed, post-glacial fen occupying an area of 220ha. The Fen lies in a shallow depression and is maintained by groundwater which continuously flows into it from approximately 40 springs and seepage zones. Most of the springs arise around the margins of the depression above the level of the fen and carry groundwater from the Curragh Aquifer. It is drained by the Milltown Feeder which flows into the Grand Canal.

The Kildare Town bypass had a long period of gestation from its proposal in 1982 to construction commencement in 2000 to the road opening in 2003.

The delay was caused by concern for the high risk to Pollardstown Fen from dewatering of the Curragh aquifer from the section of the road nearest to the fen, which was designed to be in cut (below the ground surface).

In order for the road to proceed, the cut length of the road scheme that would have affected the aquifer was tanked with an impermeable barrier so that acceptable groundwater levels could be maintained. This meant that groundwater levels would be largely unaffected by the road during the operational phase.

However, there was a risk of a substantial decrease in groundwater levels during the period of construction, as the aquifer had to be dewatered in order to construct the tanked section.

The presence of living *Vertigo geyeri* at tufa-producing permanent seepage sites was considered to be the threshold for integrity of the ecology at Pollardstown Fen during the road construction.

Investigations that led to the irrigation measures

Monitoring of botanical, molluscan, other invertebrate species and groundwater quantity and quality was undertaken from 1997 to 2008, encompassing the pre-construction, construction, and 5 years of post-construction monitoring.

Surveys and monitoring included:

- widespread mapping of habitats and species (baseline studies)
- repeat surveys of ten 20x20m quadrats throughout the site (Permanent Quadrat studies)
- intensive monitoring of 4 transects, at the highest slope areas at the margins of the fen (Fen Interface Study (FIS), Site Response Study (SRS), Ecological Sensitivity Study (ESS))

The hydrological component comprised the bi-weekly recording of groundwater levels in forty specially installed dipwells and piezometers in the area around and between the cutting and the fen, as well as in several domestic wells and in ten pairs of standpipes in the fen, and flow measurements in some rivers and canals. In addition, the conceptual understanding of the regional hydrogeology was numerically modelled in the Kildare Aquifer Model (KAM), which could produce “expected” flows and groundwater levels to which the observations could be compared.

The botanical baseline monitoring consisted of the recording of the botanical composition in ten “permanent quadrats” distributed throughout the fen, associated with the ten pairs of standpipes mentioned. The interpretation of the botanical results was mainly by association with Ellenberg indicator values for wetness.

The faunistic component included repeated snail inventories of the above sites, plus counts of whorl snails (*Vertigo*) in selected places, as well as a inventories of hover flies (Syrphids), moth flies (Psychodids), and certain beetles (Staphilinids) in representative habitats. With this programme of observations, the ecological effects of major drawdowns of potential groundwater levels (hydraulic heads under the fen) were assessed as likely to be damaging in the case of an untanked construction.

The tanked construction would only require a serious dewatering during construction, and it was expected that possible impacts would only be relevant to the margins of the fen, where potential groundwater levels (hydraulic heads in the aquifer) would decrease in the order of 0.04-0.07m, according to the results of a modelling study undertaken in 1999. As the margins of the fen are the most important locations of priority habitats and species, the groundwater decrease still involved risk to these habitats. This would only be acceptable if practical measures could be put in place to reduce the risk, and knowledge gaps of the effects of change were filled.

To address the issues at the fen margins, enhanced monitoring started in 2001 and was focussed on the critical habitats near the fen margins. It included elements of investigation to close gaps in understanding - to inform about process directions, states and intensities, and about the actual conservation state of the habitats. The Fen Interface Study (FIS), the Site Response Study (SRS), and the Ecological Sensitivity Study (ESS) were distinguished as the main parts. A consideration fundamental to the enhanced monitoring programme was that it was deemed essential to control and decrease remaining risks during construction and to be able, after construction, to deal with critical questions as regards the state of the habitats in the fen and possible causes of any unfavourable changes, bypass construction in particular. To the first end, a protocol was designed, by which decisions could be based on observations. A Mitigation Remedial Plan was prepared.

The Fen Interface Study informed the conceptual understanding of the hydrogeology at the fen margin and a consequent refinement of the hydrological impact levels predicted at the seepage faces and springs in the fen margin. It also produced accurate measurement of flow rates for the calibration of the Kildare Aquifer Model. Main elements of the study were the geohydrological structure of the “interface” between the aquifer and the fen margin through the coring of middle deep profiles in a grid layout at the margin study sites with 10 boreholes at each site. In most boreholes sets of piezometers and dipwells for bi-weekly monitoring were installed with their screens at different depths. High-frequent monitoring and hydrochemistry were also included, and flow measurement instruments were installed.

The Site Response Study looked at the response of ecologically relevant site factors, particularly humidity and temperature at the soil surface, relative to the variation in water levels, hydraulic potentials and flow rates in the “interface” between the fen and the aquifer. At the fen end, the study concentrated on the locations of individuals of *Vertigo geyeri* (Moorkens, 2003). A trolley system was installed to prevent trampling of the sensitive habitats. This study involved a detailed high-frequent monitoring of water levels, hydraulic head, soil and air humidity and temperature, hydrochemistry at the local level, and the installation and operation of a local weather station. In this study attempts were also made to use “snail dummies” in order to better record the variation of physical factors at the snail level. The study was supported by detailed measurements of the microrelief and vegetation structure.

The Ecological Sensitivity Study investigated which site factors were ecologically relevant to the favourable state of the conservation habitats, and which critical levels formed the envelope of that favourable state for *Vertigo* and indicator plant species.

Hence, Biological Limits of Acceptable Change (BLACs) were agreed as a provisional envelope of the favourable conservation state, using whorl snail (sub) populations as the most relevant case. In the Ecological Sensitivity Study, the BLACs were related to environmental factors, the state of which were coupled to the Kildare Aquifer Model via the Site Response Study and Fen Interface Study results. It was assumed that only very limited parts of this chain could be evaluated in full numerically, but that this could still be made useful to finally provide early triggers for the construction and remediation control protocols.

The irrigation measures at Pollardstown Fen

The triggers were ultimately used to take action to increase the wetness of the most vulnerable margin habitat area by drip irrigation. The highest spring area was on the west margin of the fen, and this area showed a drying response when road dewatering commenced. The time delay of the water response to the pumped dewatering meant that the worst of the spike of reduced water reached the fen after the road construction was completed. Thus although this was the period of post-construction monitoring, it was the period of greatest impact from the road construction.

In 2004 the water levels continued to decline at the upper south west springs, and action was taken to remediate the effect when the artesian conditions no longer reached the ground surface and the levels in the monitoring boreholes were steadily reducing.

The following irrigation system was then installed:

Two 30 m long perforated irrigation pipes were placed along the fen margin upslope of the spring habitat areas. The pump was set to operate for 10 minutes every hour.

The charging unit consisted of two car batteries connected to a wind turbine, removing water from a system of two connected duck Ponds, located to the north west of the irrigation area.

The irrigation system was installed in 2004, as in May 2004 the last positive record of *Vertigo geyeri* in the highest spring area was seen.

Monitoring of the irrigation system was undertaken by Evelyn Moorkens (*Vertigo*), Katy Duff (vegetation, bare soil and open water cover, bryophyte and litter cover), Anna Kuczyńska (hydrogeology and micro-environment) and White, Young, Green (water levels).

The irrigation was active during periods from 2004-2006 but following this the trigger levels for irrigation were not exceeded and thus active irrigation was not undertaken.

Photographs of the irrigation system are shown below.

	
Charging unit within metal bin (photo: A Kuczyńska)	Irrigation pipe in closed position (photo: A Kuczyńska)

Drips emerging from the perforated pipe (photo: E Moorkens)

Vertigo geyeri in the drip irrigation area, 2004 (photo: E Moorkens)

View of high zone 1, August 2008 showing tall black bog rush tussocks (photo: K Duff)

Irrigation Zone 2, Close look at the vegetation and standing water (photo: K Duff)

Below irrigation Zone 3, dense thatch of rushes and sedges, but also *Tomentypnum nitens* moss present beneath. (photo: K Duff)

Ditch zone 4, with *Palustriella commutata* moss, blunt flowered rush and carnation sedge (photo: K Duff)

Results of the drip irrigation molluscan monitoring

Monthly molluscan sampling rounds consisted of taking two replicate samples from each of four zones – upslope of the irrigation (high zone 1), in the vicinity of the irrigation (irrigation zone 2), downslope of the irrigation ("below irrigation" zone 3) and at the base of slope below the irrigation ("ditch at base of A" zone 4). During 2004, comparisons were made between snails counted in the field, and those found in samples, but by 2005 no *V. geyeri* could be found by eye in the field, as vegetation became drier and more built up, with less low saturated areas on which snails could be observed.

Areas for sampling were chosen in suitable habitat, or within remnants of areas that did hold suitable habitat in the past, i.e. in the vicinity of *Schoenus nigricans*, particularly areas that had *Carex viridula* and either *Campylium stellatum* or *Drepanocladus revolvens* present.

Each sample was sieved through a series of mesh sizes, and the number of *V. geyeri* counted and their whorls counted to determine their maturity. Whorl snails grow by increasing their shells by adding larger and larger whorls as their body size gets bigger. Adult *V. geyeri* have 5 whorls and a fully formed lip. All other snail species were identified and individuals counted. Snails were classed as live or dead, live snails being fresh with natural colour and visible flesh inside.

Figure 1 (From Moorkens, 2008) shows a sketch map of the area surveyed in the irrigation monitoring. Figure 2 shows the changes in all live *Vertigo geyeri* numbers in samples in the different zones over time. Figure 3 shows the numbers of juvenile *V. geyeri* found in the different zones over time, it can be seen that snails were maintained in the irrigation zone, and that successful reproduction events occurring regularly in the irrigated area.

Figure 4 shows the lack of *V. geyeri* in the high zone, the regular presence of *V. substriata*, and the continuation in 2008 of *V. pygmaea* in the high zone, having colonised this area in 2006. The numbers of two other characteristic grassland species over time, *Carychium tridentatum* and *Nesovitrea hammonis,* are shown in Figure 5. This constitutes a characteristic change in the molluscan assemblage, from alkaline fen to grassland in this zone.

The results of the counts made to date must be viewed in the knowledge that the main habitat for *V. geyeri* from 1997 to 2002 was the high zone 1 area. The depression area (i.e. the irrigated area) and the ditch area at the base of A were too wet for the snail during those years. Quantitative sampling of the irrigation measures began in June 2004, after the last live recording of *V. geyeri* in the intensive quadrat was made (May 2004). Figure 1 shows that between 2004 and 2008, the high zone has not been a viable habitat for *V. geyeri*. The decline in *V. geyeri* in the high zone also corresponds with the increased presence of *V. substriata* and *V. pygmaea*, both associated with drier habitats. Similarly, the grassland species *Carychium tridentatum* continued to increase in number in the high zone, although *Nesovitrea hammonis* numbers were lower in 2008 compared to 2007. While *Carychium tridentatum* and *Nesovitrea hammonis* are both grassland species, *Nesovitrea hammonis* is much less tolerant of shade than *C. tridentatum*, and only further survey over time would be able to show if the trend towards grassland habitat has continued or if the habitat recovered over time. This intensive monitoring survey stopped in 2008.

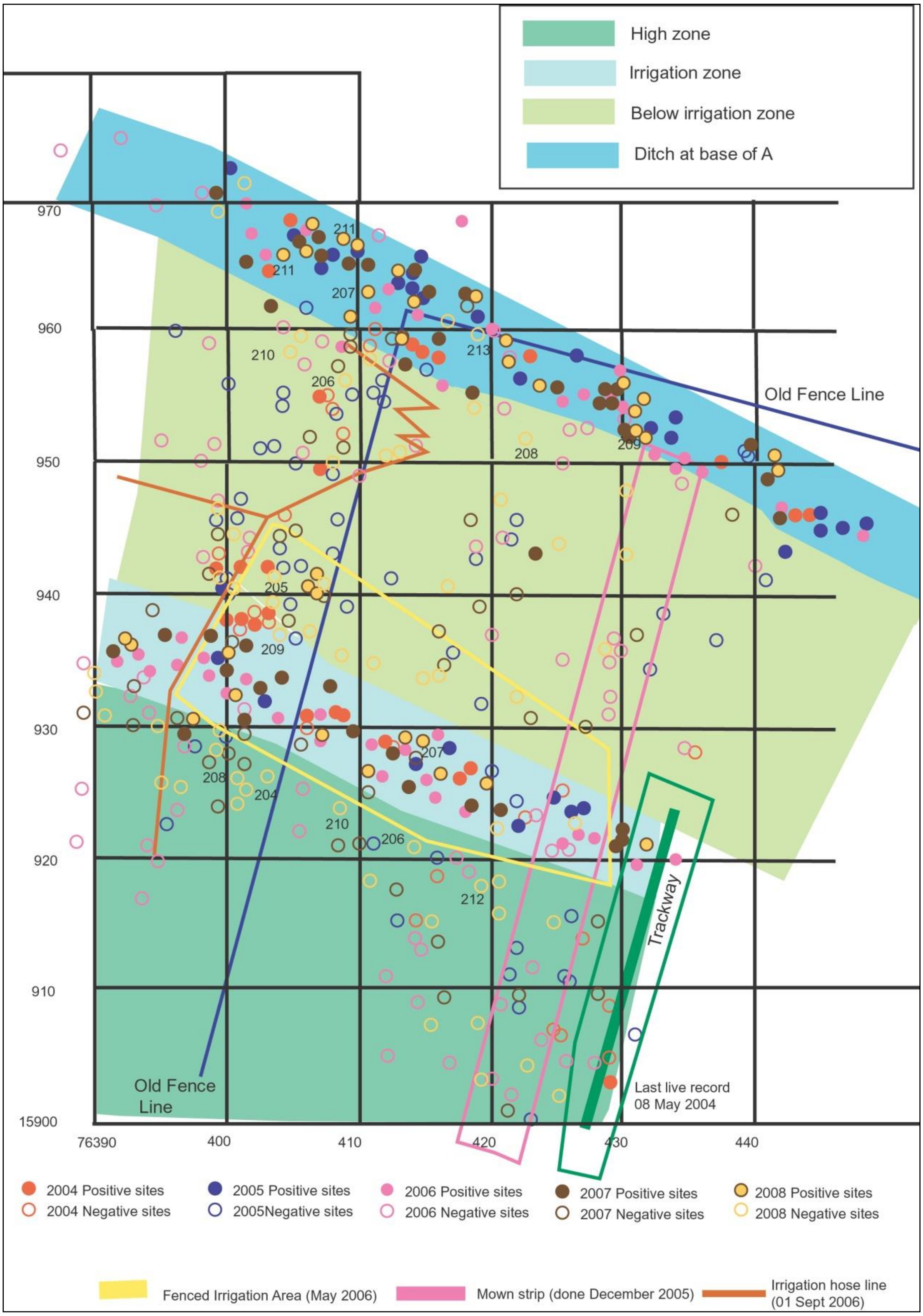


Figure 1 Summery of irrigation monitoring sample results 2004-2008

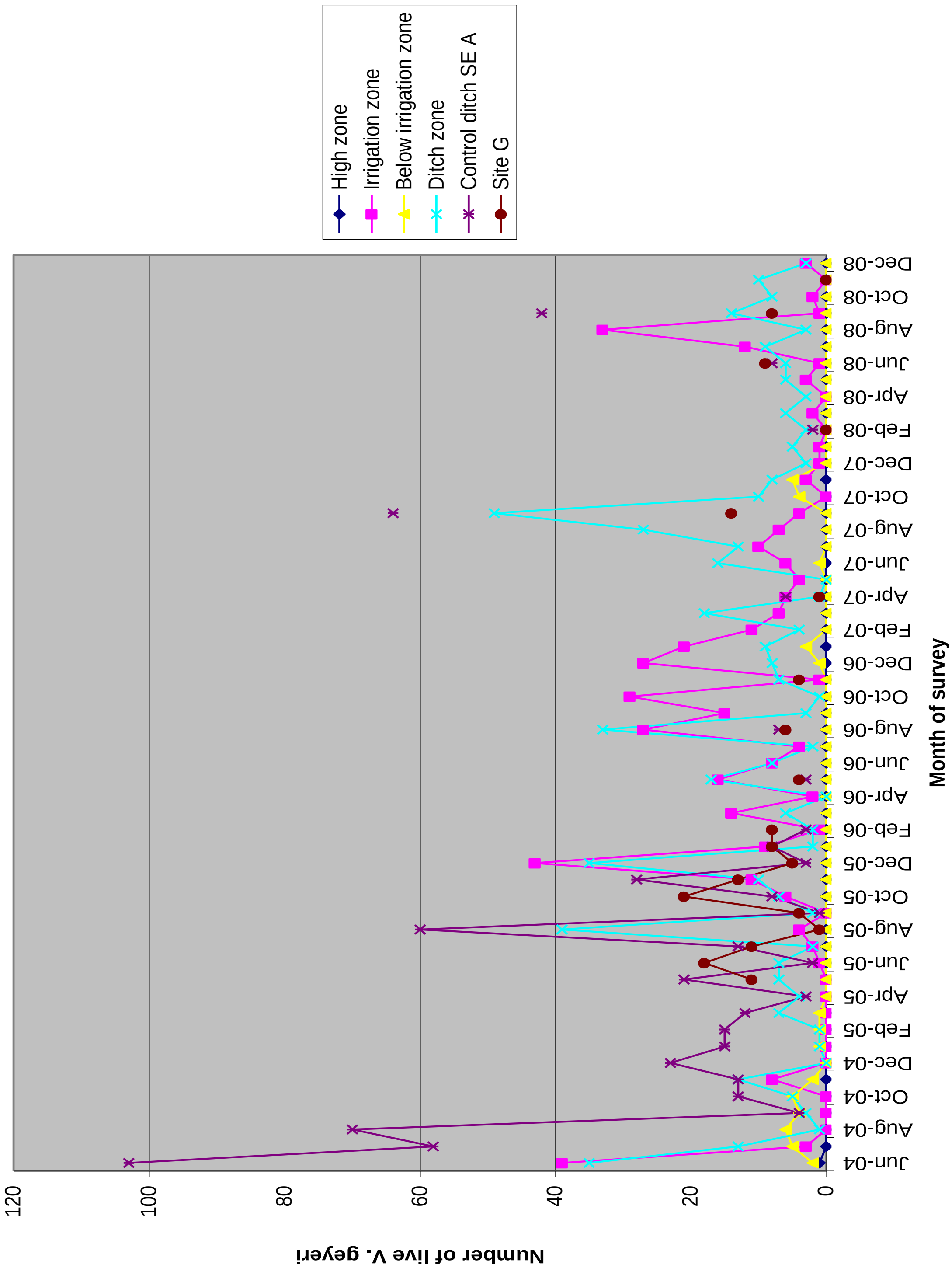


Figure 2 Numbers of living *V. geyeri* (adults and juveniles combined) found in monthly samples by zone (includes 2 further control areas).

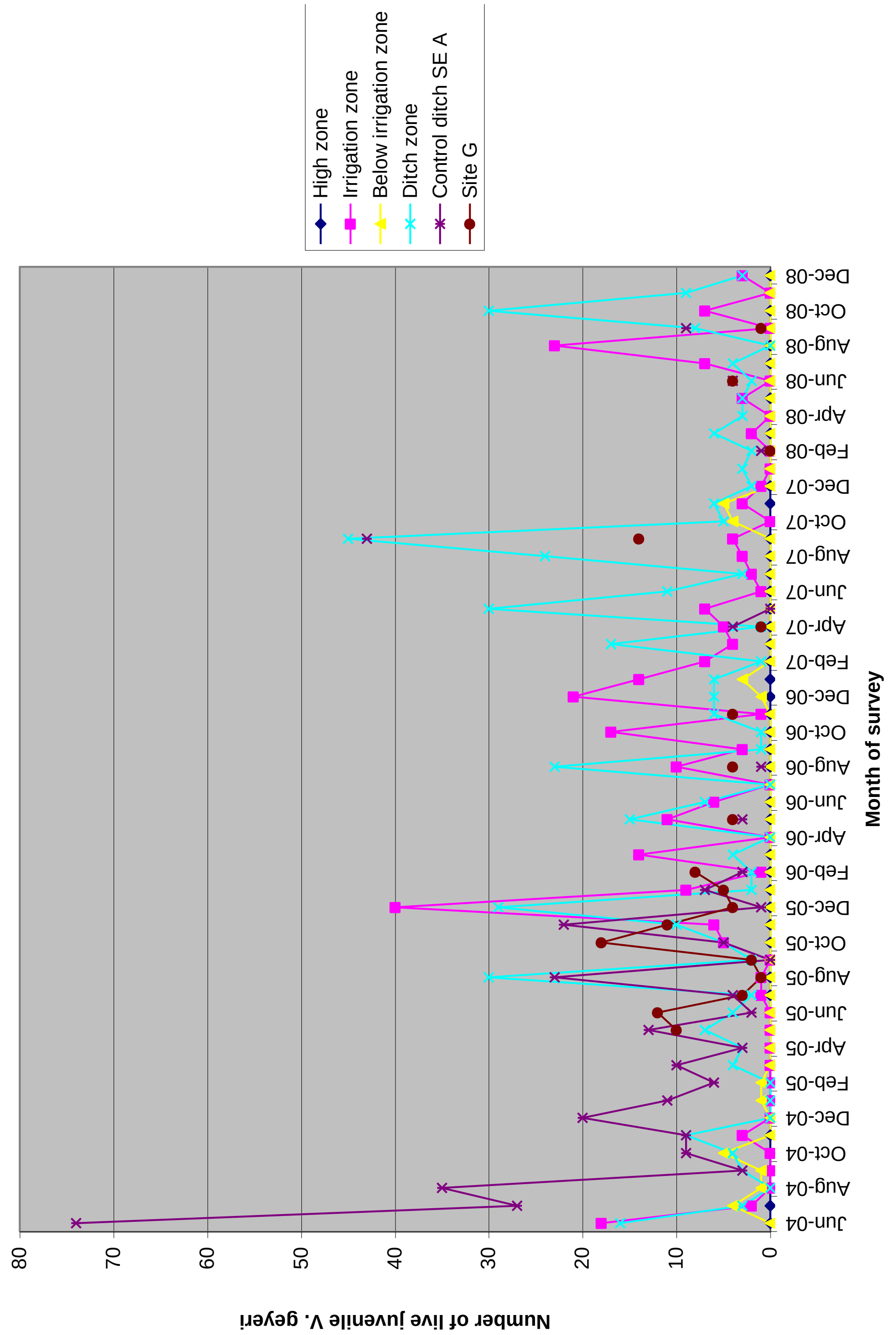


Figure 3 Numbers of living juvenile *V. geyeri* found in monthly samples by zone.

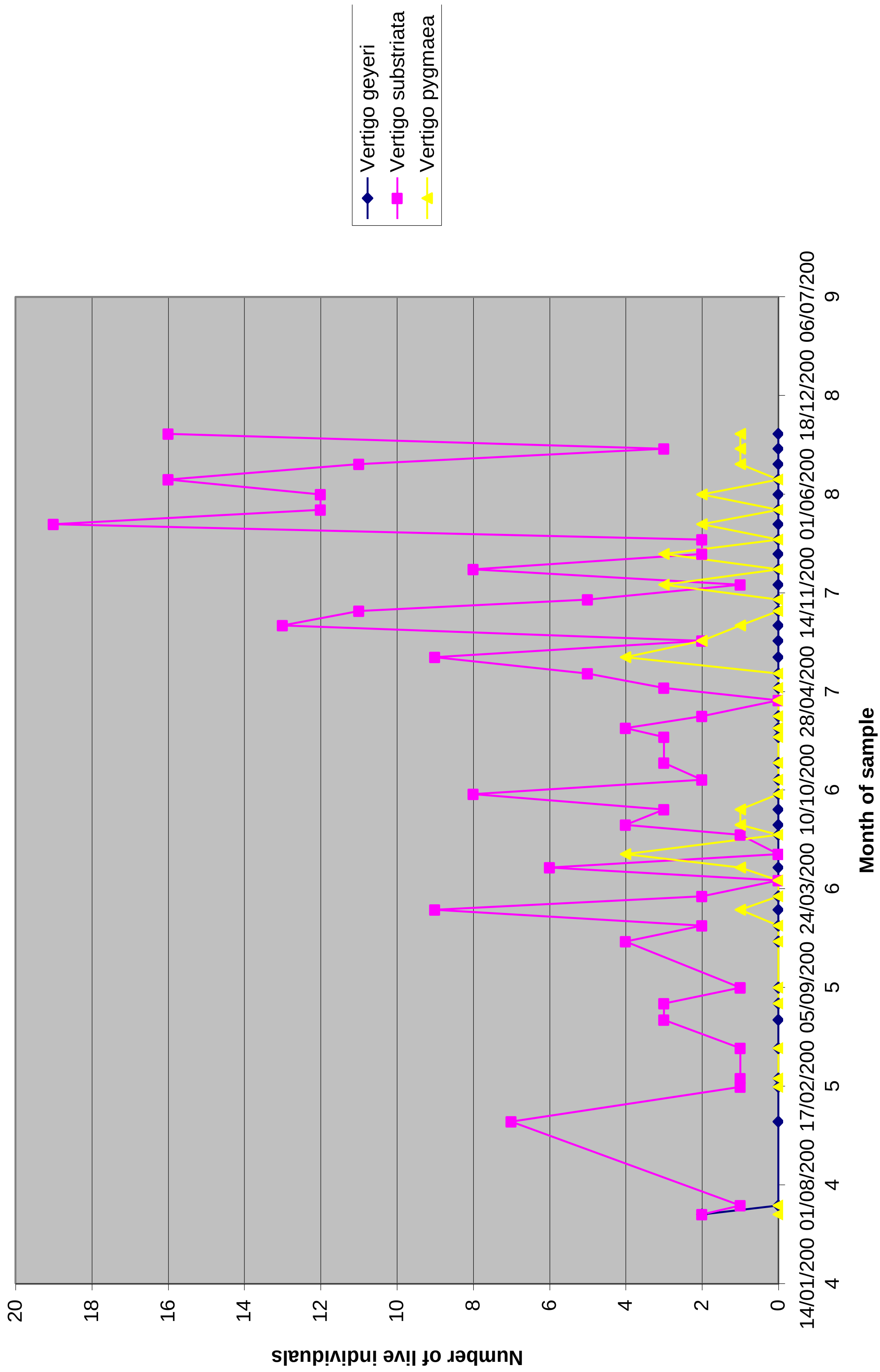


Figure 4: Changes in *Vertigo* species found in the high zone over the sampling period 2004-2008.

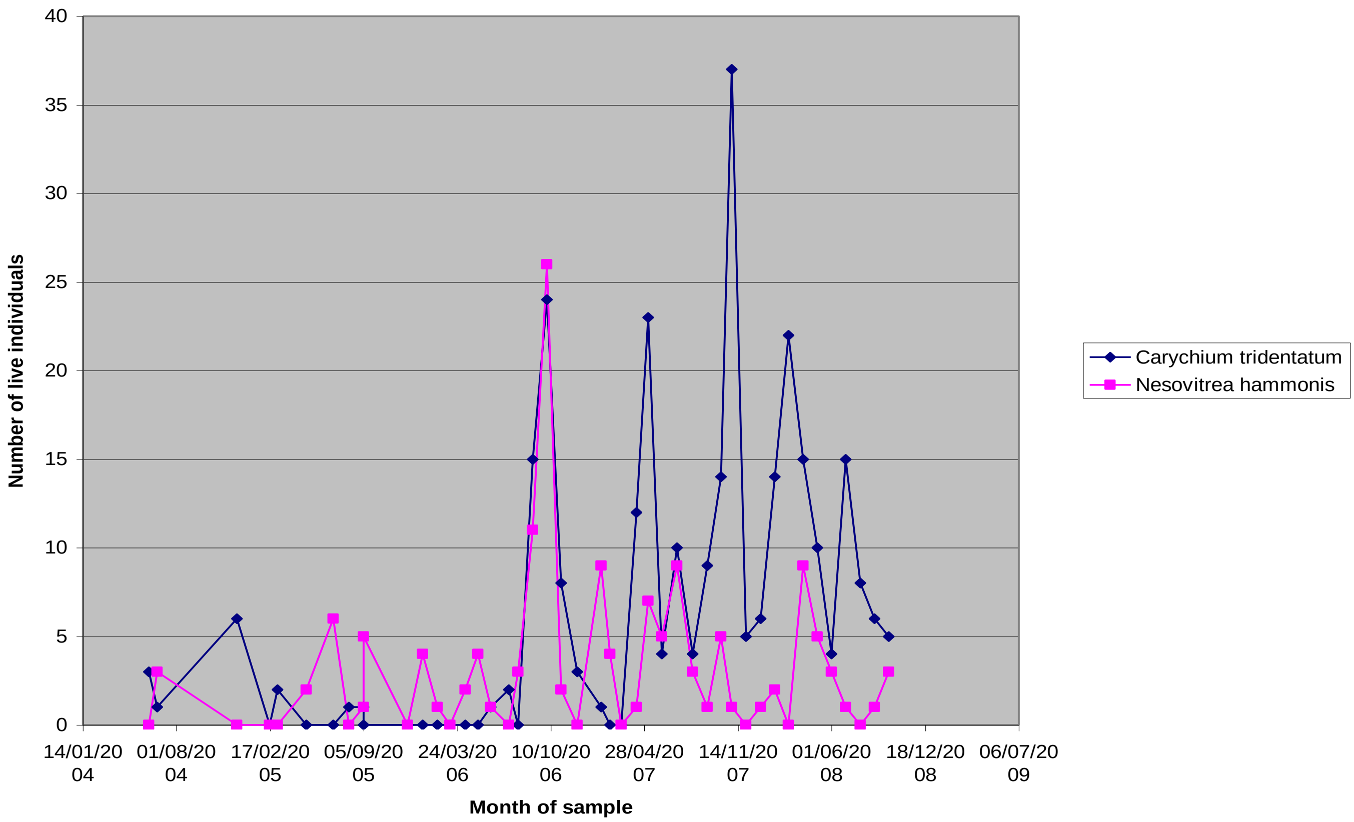


Figure 5: Changes in other grassland species found in the high zone over the sampling period 2004-2008.

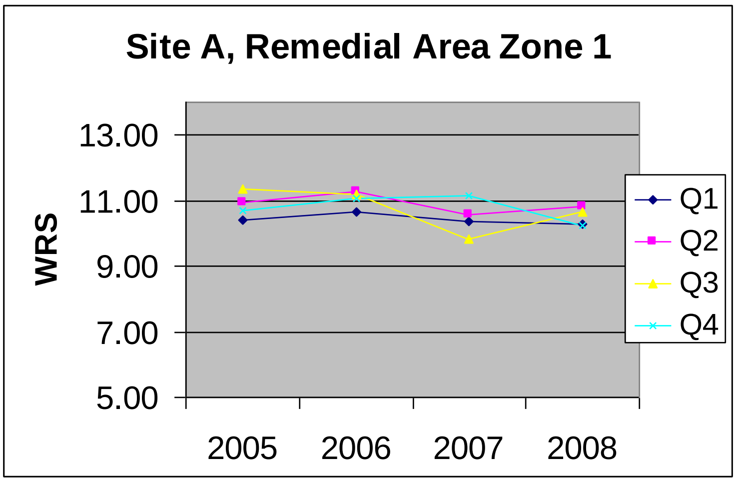
Results of the drip irrigation botanical monitoring (work of K. Duff, 2008)

Three to four relevée locations were repeated per zone annually from 2005 to 2008. Plant species cover abundance was recorded and a brief description of changes in the vegetation. Wetness index values were derived from this.

Above irrigation zone 1

There was little change in the species composition of the dominant higher plant species over time. The vegetation of the black bog rush tussocks continued to grow more rank and overshadow the smaller species in the runnels between the tussocks. The moss flora was generally poor with the indicators of calcareous seepage sparse or missing. However, by 2008 the moss *Campyllium stellatum* (which requires moist calcium rich substrates), had shown a trend of increasing in cover. The WRS (wetness index) shown in Figure 6 show values changed only slightly but overall the trend was towards getting slightly wetter.

Figure 6: Site A remedial area Zone 1 wetness index (WRS) (*Wrs wetness index value: Wet 1 → 16 Dry)*

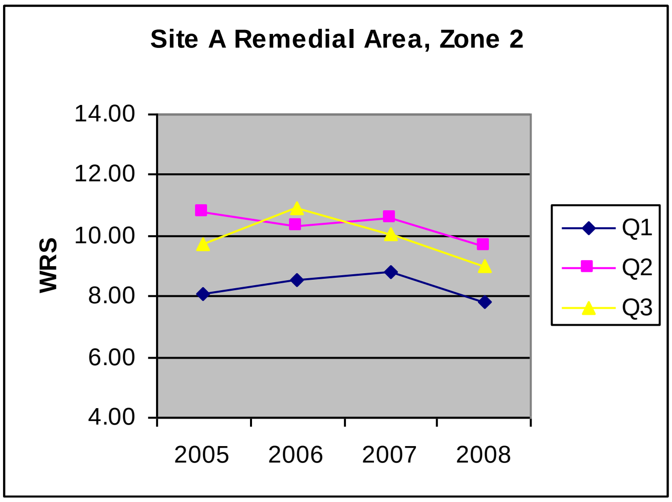


Irrigation Zone 2

This was the irrigation area with active irrigation from 2004-2006. The former ditch along the southern edge of zone 2 remained saturated, with abundant black bog rush and blunt-flowered rush.

Although the taller rushes seemed to be overshadowing the smaller species, the overall wetness index became marginally wetter Figure 7). The cover of good indicator mosses such as *Drepanocladus revolvens* and *Tomentypnum nitens* were retained throughout.

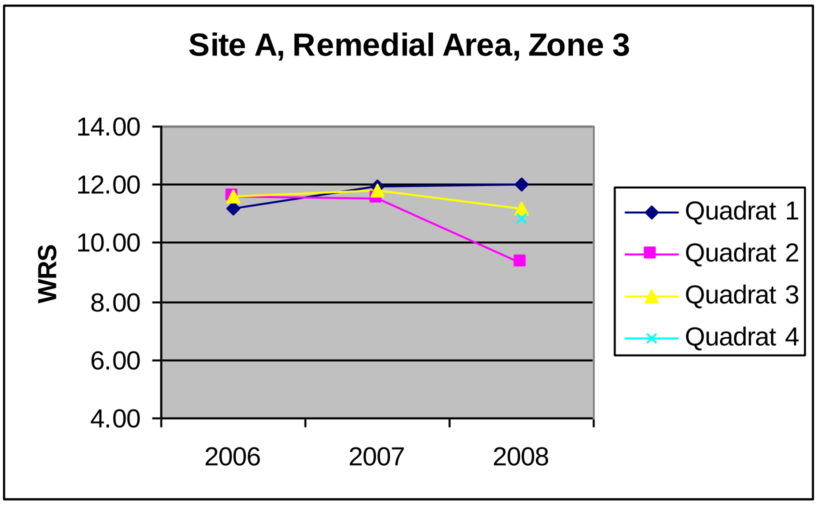
Figure 7: Site A remedial area Zone 2 wetness index (WRS)



Below irrigation Zone 3

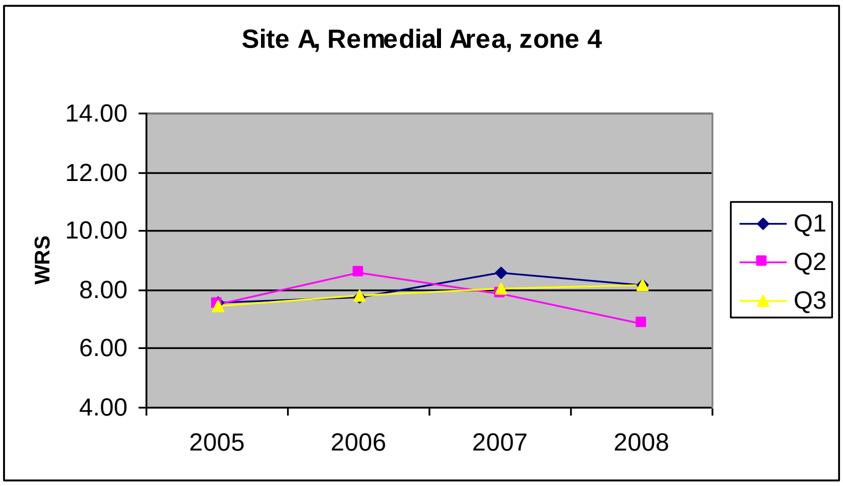
This was somewhat higher but flatter ground with a more uniform mosaic of vegetation physiognomy. Although there was an overall trend of the vegetation getting slightly wetter, there were small changes in many species with no clear trend (Figure 8).

Figure 8: Site A remedial area Zone 3 wetness index (WRS)



Zone 4 comprised a former ditch which delineates the northern part of the remedial Area. The ditch had returned to saturation by 2008 (Figure 9) and was completely clogged with vegetation comprised mostly of rushes, sedges and mosses. Healthy patches of mosses (*Cratoneuron commutata* and *Drepanocladus revolvens*), and the stonewort alga (*Chara sp.)* were noted along the ditch which was evidence of a continued supply of calcium-rich water.

Figure 9: Remedial area Zone 4 wetness index (WRS)



Results of the drip irrigation hydrogeological monitoring

Irrigation at Site A began in summer 2004 as a temporary mitigation measure to the drying out of the habitat in the area. The original irrigation system was first installed for summer 2004, it was rearranged in 2005 and 2006 to maximise the habitat areas that needed additional wetness.

The maximum winter effective rainfall (October to April) since 1968 occurred in 1979 (October 1979 to April 1980) with 466mm; the minimum was in 1975 when there was 178mm of effective rainfall. The maximum summer effective rainfall (May to September) was in 2007 with 217mm; prior to this the maximum was in 1993 with 198mm. The minimum summer effective rainfall is 0mm, occurring in 1977 and 2001. A summary of the total and the winter and summer effective rainfall can be seen in Figures 10 and 11. The high summer effective rainfall in 2007 assisted in keeping groundwater levels high and irrigation was not needed.

Figure 10: Monthly Effective Rainfall, 2005 to 2007.

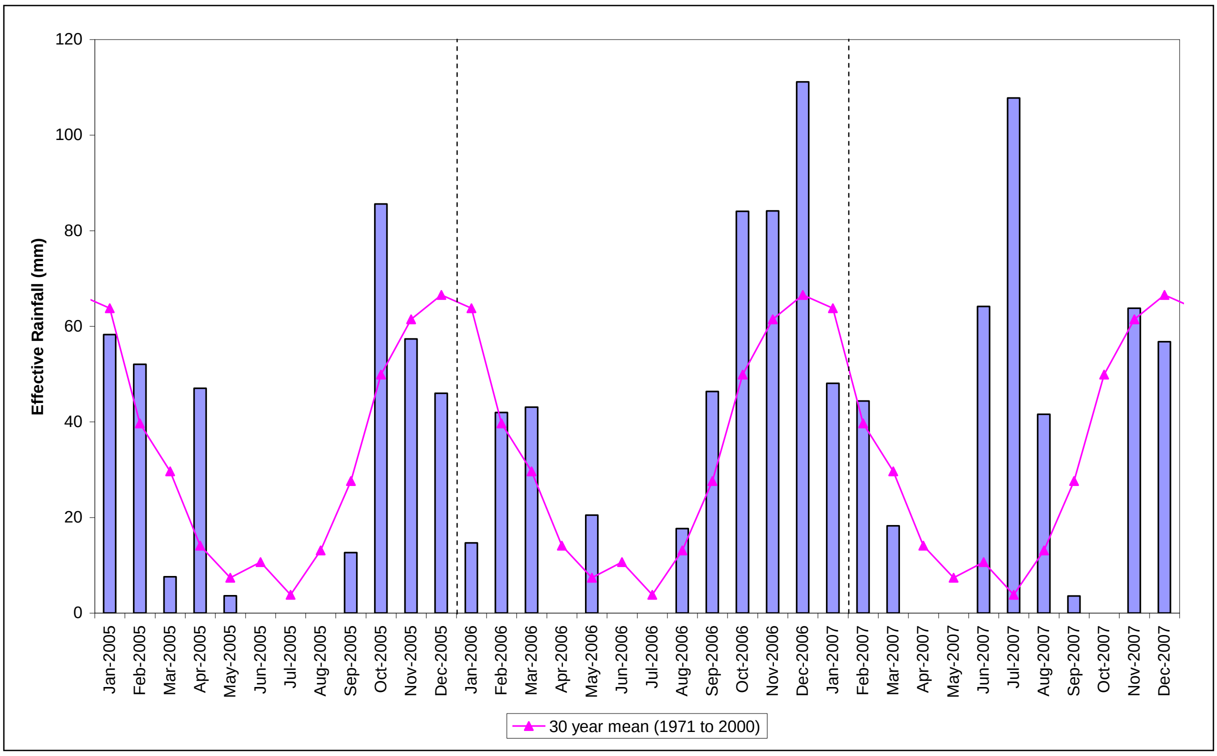


Figure 11: Summer and Winter Effective Rainfall.

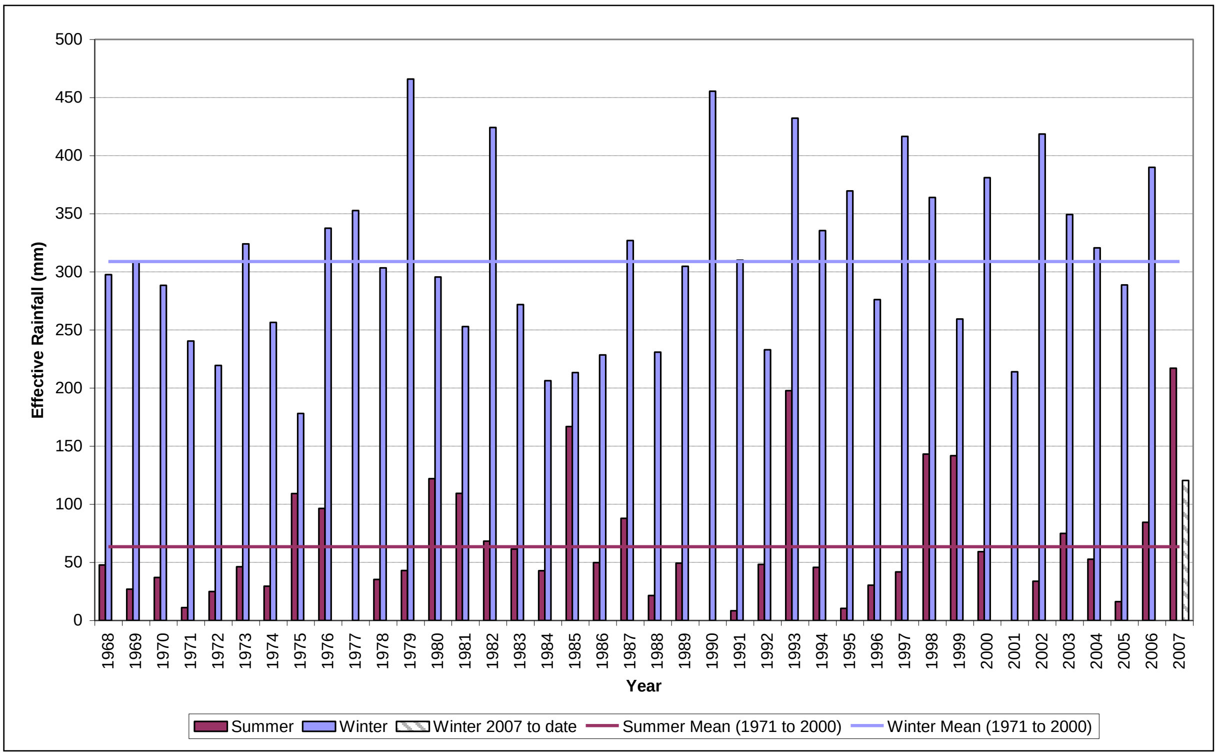
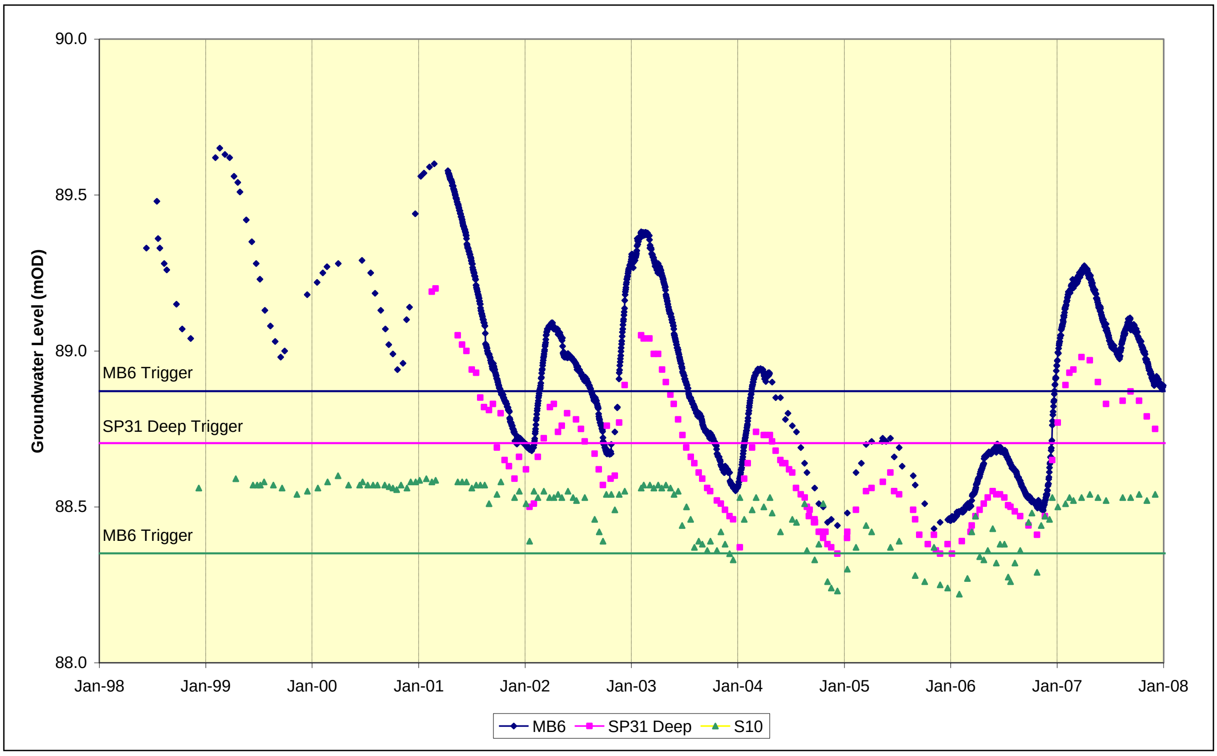


Figure 12 shows the borehole level values compared with their trigger levels used for irrigation commencement, showing that the triggers for irrigation were not met after 2006.

Figure 12: Irrigation Trigger Wells - MB6, SP31 Deep and S10.



Lessons from the drip irrigation and its monitoring at Pollardstown Fen that are of relevance to the Lough Talt proposals

The positive scientific demonstration from the work undertaken at Pollardstown Fen can be summarised as follows:

- A drip irrigation system has been effectively managed for 2 years.
- Triggers were developed and irrigation was used when these triggers were met, using borehole water level data, demonstrating that irrigation can be managed for the times it is needed.
- Molluscan, vegetation and hydrogeological monitoring have been shown to be clearly related to the water levels at the site.
- Monitoring can be clearly related to distinguishable habitat zones.
- Associated microhabitat data collected in association with the habitat and species experts during the PhD study of Anna Kuczyńska has increased the scientific knowledge of the microhabitat requirements of *V. geyeri*, as published by Kuczyńska & Moorkens (2010).
- Specific survey techniques that were first developed in the Pollardstown Fen study have already been used at Lough Talt. The microtopography study undertaken in 2016 allowed the relationship between groundwater levels and the snail habitat locations to be interpreted and thus assist the trigger level development at the Lough Talt area (Moorkens, 2016; RPS Aquaterra, 2016).
- Other study techniques that were first developed in the Pollardstown Fen study are also relevant to the Lough Talt study. In particular, the use of soil and air humidity and temperature measurements at the micro level, and the use of "snail dummies" (expanded clay pellets) in order to record the variation of physical factors at the snail level has relevance to the proposed compensatory measures. The latter have been proposed to be used in the Lough Talt measures as a first proxy for snails prior to the translocation of indicator species (Moorkens, 2018, and see also RPS, 2018).

The knowledge gaps following the work undertaken at Pollardstown Fen can be summarised as follows:

- The Pollardstown Fen irrigation area was part of a large, wet spring seepage slope with a better ability to move upslope and downslope than is likely to be possible at the Lough Talt slopes. This is due to the greater undulation of land, with high heather hummocks at the Sligo site that would not become suitable habitat for the snail even if lower on the general gradient than a seepage zone upslope. The irrigation zone was in habitat that was too wet for the snail before the dewatering took place.

- There is therefore a higher risk of loss of seepage habitat at the Sligo site, such habitats were not tested in the Pollardstown study. There is a greater importance in maintaining wetness at the limited seepage zones that were identified in the Moorkens (2016) report (see also RPS, 2016), and their equivalent habitats.
- The monitoring work at Pollardstown Fen ceased in 2008 when the vegetation was showing signs of recovery, but the snails had not yet returned to habitats in the higher slopes. Vegetation recovery is expected to precede snail recovery as the moisture increases are manifested earlier due to the uptake of water occurring at the subsurface root level. The recovery of snail habitat and the time taken for that recovery is not known.
- A return to Pollardstown Fen to survey the irrigation zone and the related zones upslope and downslope of the irrigation would be very useful as a comparison 10 years later.
- Another unknown aspect is that the in-combination effect of abstraction and drought may manifest quite differently from the in-combination effect of a dewatering spike and drought. The dewatering spike at Pollardstown Fen was severe and prolonged. It is likely that unless there is a prolonged drought, the Sligo stress events would be less severe, thus the trigger level exceedance at Lough Talt is likely to be more short lived and rare.
- The gaps in the scientific knowledge that remain from Pollardstown are due to the time lag in the dewatering spike between the road and the fen. The monitoring programme was finished before the ecological recovery could be monitored, thus scientific proof for aspects of this irrigation measure is absent. A compensation measure would be a closure of remaining gaps, and their publication for the scientific community.

The likelihood of achieving the objectives using irrigation at Lough Talt are therefore summarised as follows:

Objective 1 - to ensure that sufficient water is delivered to key habitat areas to prevent the surface layer from drying out and forming a crust that is less permeable than the sub-soil.

The likelihood of achieving this is high as the key seepage areas at Lough Talt are discrete and few, and can be focused on with the benefit of the wealth of data from the Pollardstown project. The benefit of the experience of the irrigation process, and of linking triggers to the water level data is extremely helpful in this regard.

Objective 2 - to ensure that the habitat conditions are suitable habitat for *Vertigo geyeri* throughout the year and thus support the reintroduction of the snail.

The likelihood of achieving this is high as the microhabitat conditions required for *Vertigo geyeri* has been detailed from the Pollardtown project, and particularly in the thesis of Anna Kuczyńska (2008) and the publication of Kuczyńska & Moorkens (2010).

The knowledge gained from the Pollardstown project provides a high level of confidence in the choice of translocation microhabitats.

The unknown element in the likelihood of achieving a sustainable population of *Vertigo geyeri* following translocation lies in the final structure and spread of optimal and sub-optimal habitat to allow the species to spread and to move the small distances needed as a reaction to temporary weather extremes. The unknowns include possible changes to local weather patterns since 2007, possible changes in catchment management that may have an effect at the fen, and permanent changes that may have occurred in the microhabitat affecting seepage direction and emergence that may have occurred before the potential impact from the abstraction was identified. These are all elements that are beyond the control of the proposed project and leave a residual uncertainty in the project. However, the proposed measures provide the best possible means of achieving a continuity of the function of the appropriate habitat areas and the achievement of a successful translocation of *Vertigo geyeri* and an ongoing living population at the Lough Hoe Bog cSAC.

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