# Memo

## North Star Extension: Potential impacts to groundwater recharge from changes in surface water flow

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| **OUR REF** | **NS-5700-RP-WM-0001** | **DATE** | 10-Oct-23 |
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| **FROM** | Michael Carroll | | |

This technical memorandum has been developed to assist the Environmental Approvals team respond to item 6f of the February 2023 Section 40(2)(a) notice requiring information for assessment.

*"Holistically consider the impacts to drainage lines and catchment changes to subterranean fauna and any riparian/groundwater dependant vegetation."*

The objective of the work is to provide an indication of the relative impact to groundwater recharge, and associated sensitivity of groundwater level changes, from changes to the surface water flow regime.

## CONTEXT

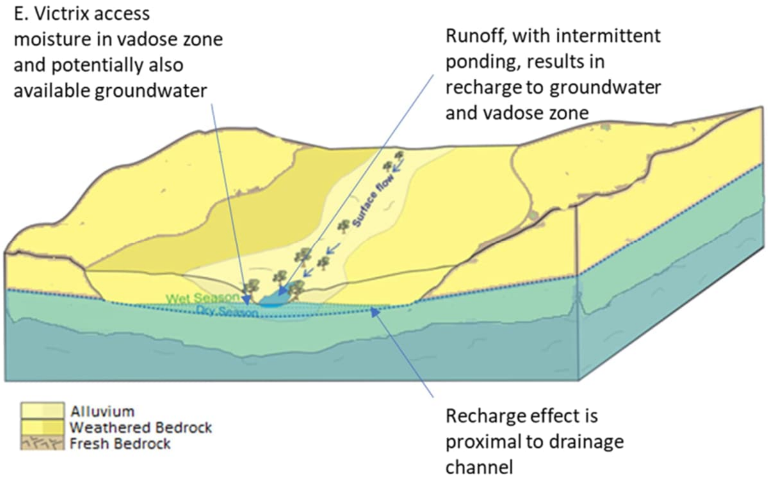
The nature recharge at Iron Bridge was discussed in the *Iron Bridge Mine Area Hydrogeological* Assessment (IB-5700-RP-WM-0002). Recharge is in response to direct rainfall infiltration and streamflow events, with key observations as follows:

- Recharge responses are more evident in areas with shallow groundwater
- Recharge responses are more evident in areas proximal to drainage lines
- The two conditions above are often coincident (i.e. groundwater levels are shallower beneath drainage lines
- Drainage lines comprise a small portion of the overall aquifer area so while recharge rates are increased beneath drainage lines, overall recharge volumes are not only dependent on surface water/groundwater interaction

The nature of surface water/groundwater interaction is illustrated in Figure 1 below; which indicates the mechanisms of recharge and associated groundwater impact in drainage channels. It stands to reason that the exact nature of this interaction would be dependent on the specific setting of each drainage channel, and its underlying hydrogeology. This may also change along each drainage channel, with the following influencing factors:

- Catchment hydrology
- Drainage channel bed material and morphology
- Depth to groundwater

- Drainage channel gradient




As outlined in Site 12 Pool – Water Quantity Assessment and Management Report (662NS-5700-RP-WM-002), a reduction in catchment for Site 12 pool is expected owing to the placement of a proposed waste rock dump (WRD). Although the RFI is inclusive of potential site wide impacts, the availability of data and hydrological analysis described below, resulted in the Site 12 Pool catchment being the representative study area for this assessment. The discussion section will indicate the applicability of the analysis to other catchments in the North Star area.

## ANALYSIS APPROACH

The approach taken to determine the potential impact of changes to surface water runoff on groundwater levels was as follows:

- Investigate general trends and dependencies in water level data (both groundwater and surface water)
- Develop relationship between surface water flow and groundwater recharge
- Compare pre-development and post-development recharge for a given rainfall event

This approach required data for groundwater levels, rainfall and surface water flow. At Iron Bridge, only the Site 12 Pool area contains coincident monitoring of sufficient resolution and duration. The locations of monitoring are illustrated in Figure 1 below, with approximately 300 m separating NS-0664 (a groundwater monitoring bore) and IB_SW_Pool12_01 (a location with water level measurements). Rainfall data for Iron Bridge is an amalgamation over time from two gauges located between 4 – 5 km to the west of Site 12 Pool.

The Site 12 Pool catchment has also been the subject of hydrological modelling. *662NS-5700-RP-WM-002* Contains analysis of rainfall and flood frequency analysis, as well as a flow rate comparison for the Pools in the pre and post-development scenarios.

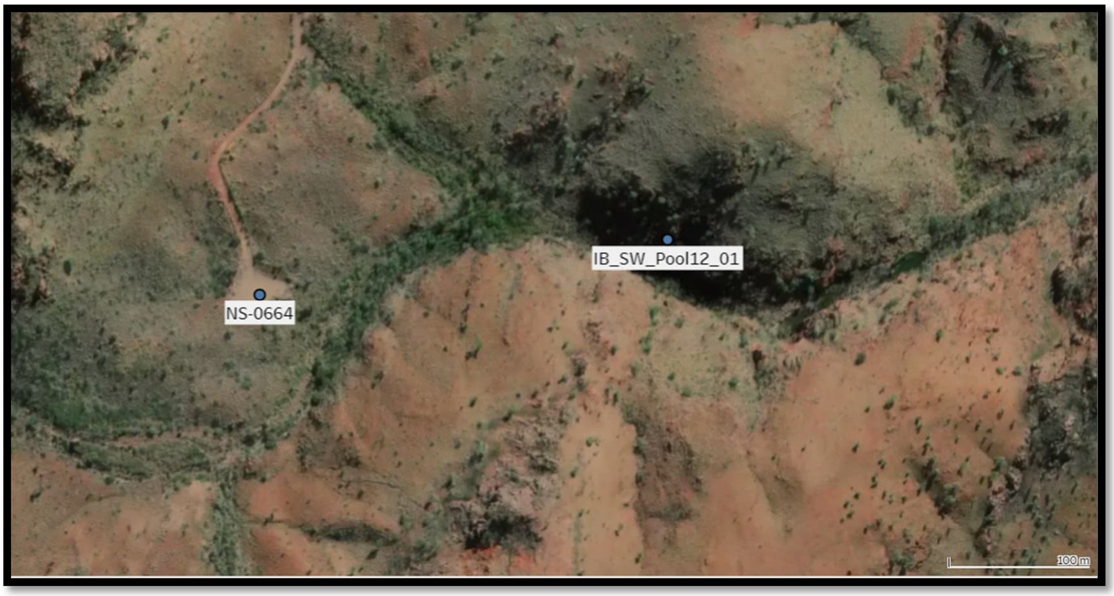



**Figure 1: Aerial image of monitoring locations**

## ANALYSIS OUTCOME

A total of 12 recharge events (defined by a measured hydrograph response) were analysed to determine:

- Rainfall depth (mm) and duration
- Recharge at NS-0664 (mm) and comparative theoretical loss using 8 mm/hr loss model adopted in *Site 12 Pool – Water Quantity Assessment and Management Report (662NS-5700-RP-WM-002)* for flow modelling.
- Peak flow ($m^3/s$) and change in surface water level at IB_SW_Pool12_01

As expected, both streamflow and groundwater recharge displayed a positive, and proportional, correlation with rainfall events (Figure 2). All but three events were noted as occurring in “wet” antecedent conditions, with another event or series of smaller rainfall events in the days prior.

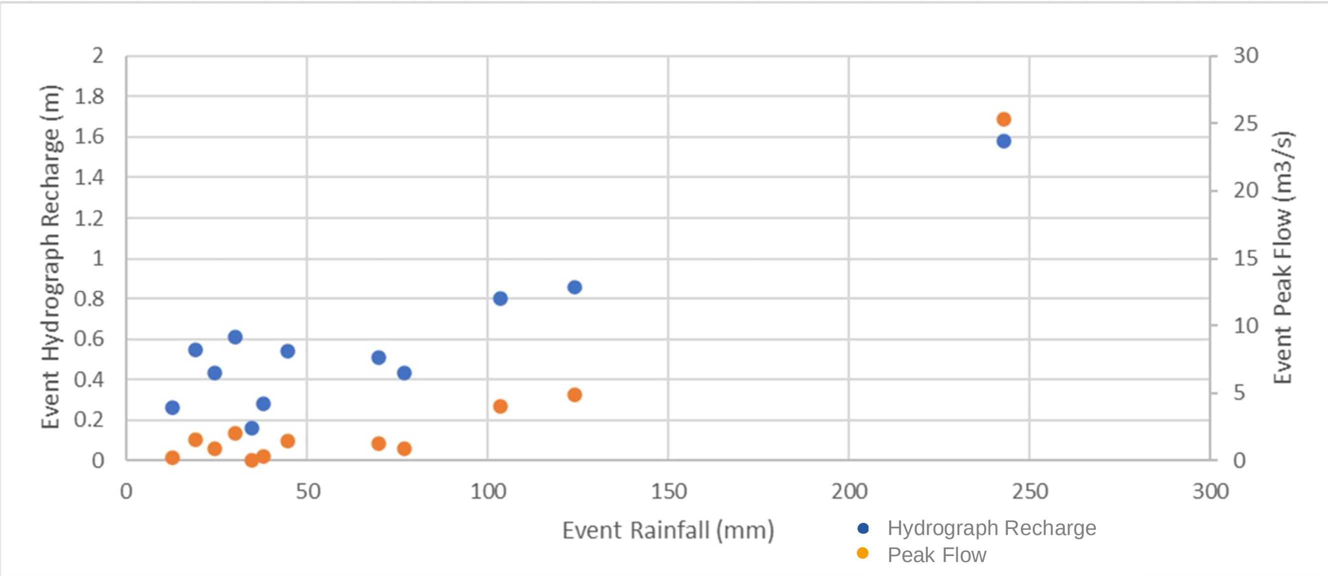



**Figure 2: Recharge and peak flow response to rainfall in the Site 12 Pool area**

A comparison of groundwater recharge and streamflow for the same event suggested, as expected, that the influence of streamflow on recharge would eventually reach an asymptote. This is the point where the aquifer system is around the bore is likely to be unable to accept more recharge. The relationship presented is considered intrinsic for the hydrogeological setting around bore NS-0664. As there is no proposal to alter the immediate area around the bore, the relationship is fit for use in the “post development” scenario of reduced surface water flow from further upstream in the catchment. It is important to note that the available data could not constrain the “best fit” asymptote of recharge for peak flow values above 25 m3/s. The mathematical representation of the relationship adopted for further analysis may over-estimate recharge capacity; this is indicated in Figure 3 below.

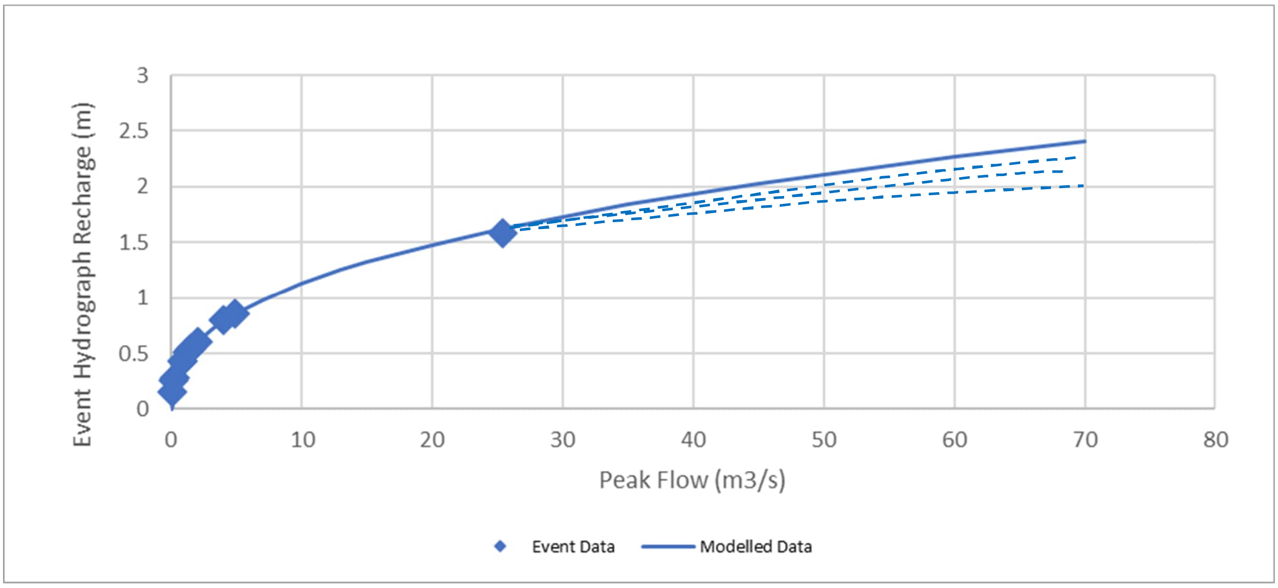



**Figure 3:** **Groundwater recharge as a function of peak flow at Site 12 Pool. Dashed lines indicate uncertainty in extreme flow events not yet captured by field data.**

The next stage of the analysis was to align the recharge and streamflow with a frequency of event, based on the rainfall recurrence intervals from 662NS-5700-RP-WM-002. For selected event frequencies (those with modelled hydrological impacts), the calculated streamflow rates were adjusted by the amounts prescribed in the hydrology assessment (662NS-5700-RP-WM-002), and calculated the resulting recharge from that streamflow. This is plotted in Figure 4 against the pre-development flows/recharge for the same event.

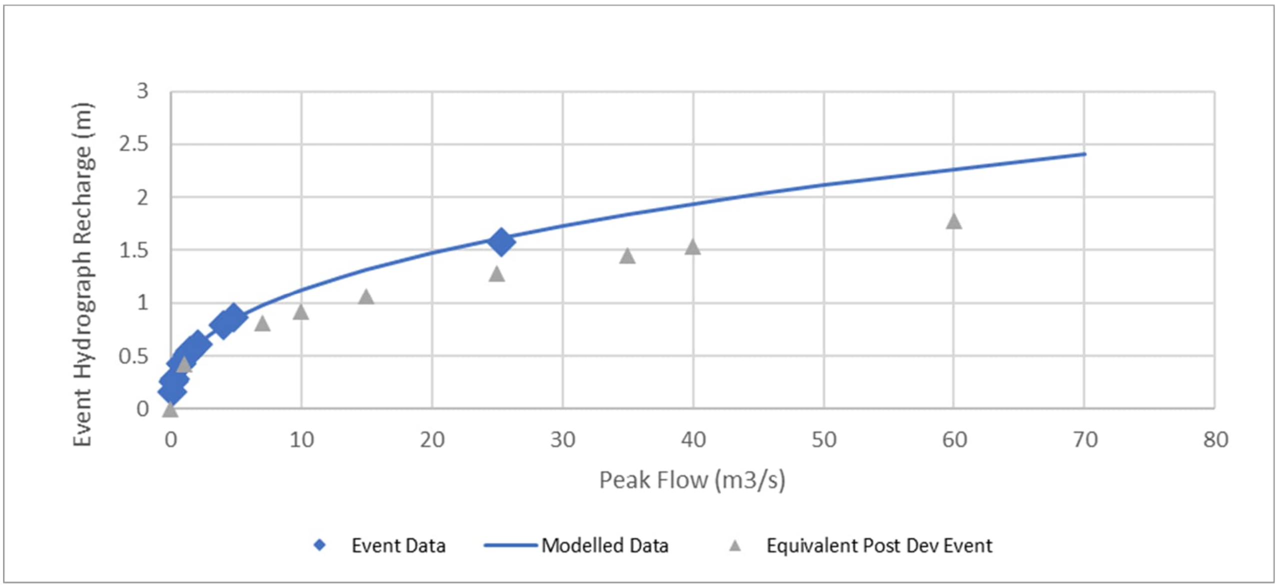



**Figure 4:** **Comparison of pre and post-development recharge for selected recurrence interval rainfall events**

Figure 5 tabulates this theoretical percent reduction in recharge for selected rainfall event frequency. The reduction does depend on the frequency of the event, but reflects the concept that more frequent events are likely to rely on more localised runoff and be less impacted by changes in the catchment further upstream. The outcome of this stage of the analysis suggests an approximate reduction in recharge of 20%, for the reduction in Site 12 pool's catchment expected from the development of the Project.

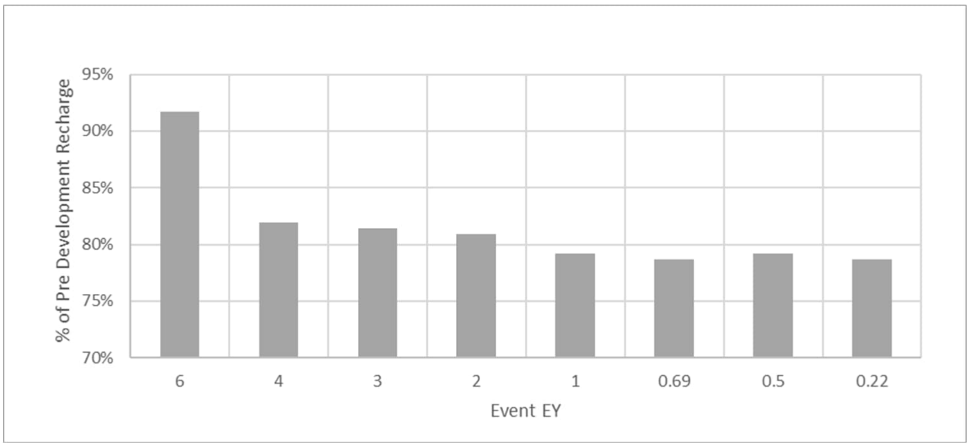



**Figure 5: Theoretical reduction in recharge for different "exceedance per year" events**

## DISCUSSION

The outcomes of the analysis presented is unique to the potential hydrological impacts proposed in the Site 12 pool catchment. However, they may be considered a proxy for other catchments in the Iron Bridge area with similar proposed changes to catchment runoff. The theoretical 20% reduction in recharge is associated with that proportion of aquifer recharge received through infiltration of surface water flow in drainage channels, not total recharge. Applying this reduction factor on total recharge is therefore conservative; however no data is available to quantify how conservative it may be.

The Iron Bridge Mine Area Hydrogeological Assessment (IB-5700-RP-WM-0002) included sensitivity analysis of drawdown for a 30% reduction in total recharge across the entire model domain. This 30% sensitivity scenario is in excess of the potential 20% reduction indicated in the analysis above which, as discussed, is itself already conservative. The potential impacts, risk assessment and proposed management of this reduced recharge scenario have been considered in the hydrogeological assessment and associated groundwater operating strategy (regulated under the RiWI Act). The outcomes of the hydrogeological assessment can be considered inclusive of potential holistic impacts to groundwater levels from catchment changes.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