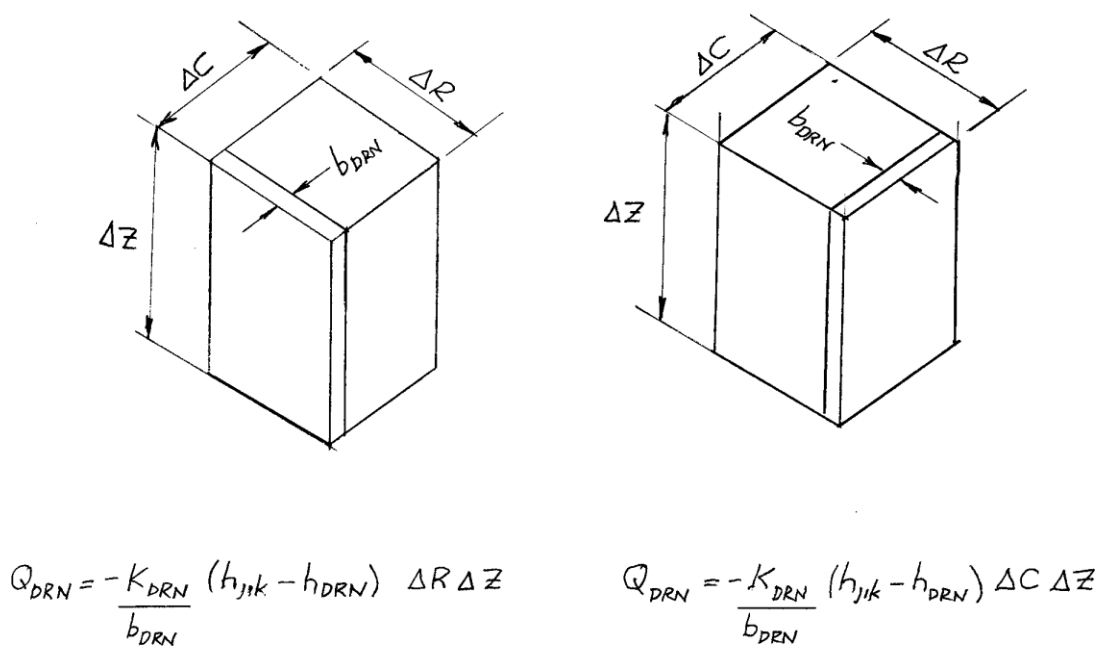
Proposed Milton Quarry East Extension
JART COMMENT SUMMARY TABLE – Groundwater Modelling

Please accept the following as feedback from the Milton Quarry Joint Agency Review Team (JART). Fully addressing each comment below will help expedite the potential for resolutions of the consolidated JART objections and individual agency objections. **Additional, new comments may be provided once a response has been prepared to the comments raised below and additional information provided**.

	JART Comments (May 2022)	Reference	Source of Comment	Applicant Response 2022	JART Response
Report/Date: Geology and Water Resources Assessment Report December **2021**			**Author: GHD**		
1.	What do “drain bottom sediments” and the “thickness of drain cell bedding material” mean in the context of the MODFLOW Drain Package representing a seepage face along the Niagara Escarpment? Our conception of the application of the Drain Package for a seepage face is illustrated in Figure 1. Is our conception similar to the approach embedded in Equation (F1)? $C = \frac{KLW}{M}$ What stages were assigned for the MODFLOW Drain Package representing the seepage face along the Niagara Escarpment?  **Figure 1. Conceptual models for the Drain Package applied to represent seepage faces**	Page F9	S.S. Papadopulos & Associates Inc.	It is noted that these boundary conditions remain far from the area of interest and do not materially affect the simulated results for the proposed MQEE. In the context of the MODFLOW Drain Package representing a seepage face along the Niagara Escarpment, the “drain bottom sediments” and “thickness of drain cell bedding” are just treated as inputs required by Groundwater Vistas to calculate conductance as shown in Equation (F1). As described by Anderson et al., (2015)[1], conductance is difficult to measure in the field and is strongly affected by local heterogeneity. In practice conductance is estimated during model calibration. Consistent with Anderson et al., (2015), conductance was initially set based on grid cell dimensions and the permeability of the aquifer material and conductances were subsequently adjusted during model calibration to reproduce observed groundwater elevations, flow directions, and flow rates. The hydraulic conductivity, length, width, and drain bed thickness are only retained for Groundwater Vistas as they are required by Groundwater Vistas to calculate conductance to write the MODFLOW drain package. Drain cell stages are approximately 0.2 m above the top of Cabot head (bottom of the model domain) to represent the seepage face along the Niagara Escarpment.	**RESOLVED.**

[1] Anderson, M., W. Woessner, and R. Hunt. (2015) Applied Groundwater Modeling – Simulation of Flow and Advective Transport 2nd Edition

2.	Do the available groundwater level data support the assumption that groundwater divides coincide with topographic watershed boundaries? Is it possible to conceive of a reality check for the results shown in Figure F6.1? For example, is it feasible to prepare a map with contours of ground surface elevations at the same as Figure F6.1?	Page 9	S.S. Papadopulos & Associates Inc.	Topographic elevations and watershed divides are presented on Figure 2.6 of the Geology and Water Resources Assessment Report (GWRA) (GHD, 2021) at approximately the same scale as shown on Figure F6.1. In general, the topographic highs match the groundwater highs (or no flow streamlines) as further supported by Figure 2.8 of the GWRA, which presents regional groundwater flow derived from historical water well records. In general, the interpreted groundwater elevation contours intersect the watershed divide at right angles supporting that the groundwater flow divide corresponds to the watershed boundary.	**RESOLVED.**
3.	Comparing Figures F6.4a and F6.4b, and Figures F6.5a and F6.5b, there are substantially more water level targets for the July 2010 calibration conditions than the 2017 average conditions. Intuitively, we would have expected the other way around, with additional monitoring being installed through time. Is there an explanation why there are 203 targets for July 2010 conditions (Figure F6.5a) but only 31 targets for July 2017 conditions (Figure F6.5b)?	Page F9	S.S. Papadopulos & Associates Inc.	In practice, the injection rates at recharge wells are adjusted until target water elevations are met at trigger wells (i.e., trigger wells are the compliance points for measured water levels). In this modelling scenario, a similar procedure was completed whereby the injection rates were input and adjusted such that the total injection rate, recirculation to the quarry, and simulated water levels at trigger wells provided a reasonable representation of observed conditions. Therefore, the purpose of the Average Annual 2017 simulation was to verify that the parameter values determined through the July 2010 calibration would match observed flow rates and water levels at trigger well locations in 2017. The key changes in 2017 relative to July 2010 include the substantial extraction of the North Quarry and West Cell, progression into the East Cell, and operation of the expanded Water Management System. The focus of this simulation was to confirm that the simulated injection rates matched the observed rates, simulated groundwater elevations in the immediate vicinity of the quarry (i.e., trigger well locations) were comparable to observed levels, and that simulated recirculation to the quarry was comparable with observed quarry inflow rates. These objectives were readily achieved with a reduced set of targets in the immediate vicinity of the recharge system and quarry excavation.	**RESOLVED.**

4.	What are the "scaled absolute residuals" reported in Figures F6.5a and F6.5b?	Page F9	S.S. Papadopulos & Associates Inc.	The scaled absolute mean is the absolute residual mean divided by the observed head range. There is a typo on Figure F6.5b in which the residual mean divided by the observed head range was presented as the scaled absolute residual rather than the absolute residual mean divided by the head range. The correct scaled absolute residual is 0.02 for Figure F6.5b.	**RESOLVED.**
5.	Referring to Figure 6.6, are Model Layers 1 and 2 assigned the same hydraulic conductivity values? It is indicated in the text that Model Layers 1 and 2 are simulated as mostly being dry. Do the yellow and salmon areas denote the areas where the layers are not dry?	Page F9	S.S. Papadopulos & Associates Inc.	Figure 6.6 presents the calibrated hydraulic conductivity in Model Layers 1 and 2. Model Layers 1 and 2 are assigned the same hydraulic conductivity zones and hydraulic conductivity values. Dry model cells are not shown on Figure F6.6. Therefore, the yellow and salmon areas do not denote areas where the layers are not dry. Yellow and salmon colours denote the different hydraulic conductivity values and are shown for both wet/dry cells across the model domain. As described on Figure F6.6 the salmon coloured areas denote an assigned hydraulic conductivity value of 20 m/day and the yellow coloured areas denote an assigned hydraulic conductivity value of 3.5 m/d. The white (blank) areas correspond to no-flow cells within the model.	**RESOLVED.**
6.	It is not clear whether the hydraulic conductivity values inferred through calibration are consistent with independent estimates from the Site. At a minimum, we request an assessment of the consistency between the values inferred through calibration and the values listed on Table 6.1 of the GWRA report. On page 31 of the GWRA report reference is made to pumping tests conducted at TW1-80, a well that is indicated to be close to the proposed East Extension. Are the hydraulic conductivities inferred through calibration consistent with the estimate of 1.4×10-3 cm/s developed by matching the Thiem solution to the combined responses of all monitoring wells?	Page F9	S.S. Papadopulos & Associates Inc.	A continuously variable hydraulic conductivity distribution is assigned in model layer 3 to represent the Amabel formation. The minimum, average, and maximum assigned hydraulic conductivity values are 5.7e-6, 1.45e-3, and 4.2e-3 cm/s, respectively. Both the minimum and maximum values are within the range of hydraulic conductivity values (from 1e-2 to 8.1e-7 cm/s) presented in Table 6.1. The average hydraulic conductivity value of 1.45e-3 cm/s is consistent with the estimate of 1.4e-3 cm/s developed by matching the Thiem solution to the combined responses of all monitoring wells at TW1-80.	**RESOLVED.**
7.	Referring to Figure 7.1, it is indicated that 150 constant head boundary condition cells are used to represent WMS recharge wells. "The fixed head of the recharge wells was calibrated to prevent or minimize drawdown in their vicinity relative to the base case (July 2010 conditions)." It is not clear what this means. Since the cells are assigned fixed head conditions aren't the drawdowns at the cells – and near them – by definition zero?	Appendix F	S.S. Papadopulos & Associates Inc.	The drawdown is not evaluated at the recharge well locations, rather it is evaluated at trigger well locations (i.e., compliance points). Constant heads are adjusted to minimize drawdown at trigger well locations, not recharge well locations. In practice, as the quarry extraction advances, WMS recharge rates are increased to maintain measured water levels at trigger well locations that are located beyond the recharge wells. A similar approach was taken to simulate the expansion of the quarry. The expanded quarry limits are represented and the constant head elevations are increased (thereby increasing simulated WMS recharge rates) to maintain groundwater levels at the trigger well locations.	**RESOLVED.**

				Figure F7.3 and F7.6 demonstrate that there is an increase in groundwater elevations at some recharge well locations relative to the existing quarry full extraction and rehabilitation conditions as intended to compensate for drawdown caused by dewatering and mining the east extension thereby minimizing drawdown at trigger well locations.	
8.	Referring to Figures 7.3 and 7.6, are we correct in understanding that the changes are calculated as follows? As shown in the two slides attached to this letter, it is not obvious from spot checks that this is how the results are calculated. <u>Figure 7.3</u> Change = Simulated Layer 3 water levels for the approved existing quarry fully extracted - Simulated Layer 3 water levels for the approved existing quarry + MQEE fully extracted <u>Figure F7.6</u> Change = Simulated Layer 3 water levels for the approved existing quarry rehabilitation - Simulated Layer 3 water levels for the approved existing quarry + MQEE rehabilitation	Page F9	S.S. Papadopulos & Associates Inc.	The changes are calculated opposite to your understanding. The change is calculated as described below for Figures F7.3 and F7.6 <u>Figure F7.3</u> Change = Simulated Layer 3 water levels for the approved existing quarry + MQEE fully extracted - Simulated Layer 3 water levels for the approved existing quarry fully extracted <u>Figure F7.6</u> Change = (Simulated Layer 3 water levels for the approved existing quarry + MQEE rehabilitation) – (Simulated Layer 3 water levels for the approved existing quarry rehabilitation) See response to the two attached slides below to clarify the calculations.	**RESOLVED.**
9.	We request clarification of the comparisons of the flow calibration targets reported on Table F6.3. • For the comparison of July 2010 conditions, is there a reason why the total recharge flows are not reported? • For the comparison of 2017 average conditions, the reported simulated recharge flows for the North Quarry and the West Cell are the same as the targets, to four significant figures. This strikes us as implausible; however, the same values are reported on Table F7.1. Are the simulated values in fact identical to the targets? • For the 2017 average conditions the total of the reported recharge flows is 4863 L/min. However, when we add the individual reported recharge flows we obtain 5045 L/min. Is this check conceptually wrong? Are we missing something?	Page F9	S.S. Papadopulos & Associates Inc.	• The totals could have been included in Table F6.3 for ease of comparison. A supplementary version of Table F6.3 showing the totals has been provided attached to this response. • Yes, for the 2017 condition the simulated flows are identical to the target values. In some cases, well boundary conditions were initially specified at measured flow rates to determine the head value required to reproduce observed flow rates. Emphasis was placed on replicating the flow values as the purpose of the annual 2017 condition which was to verify that the model with the observed (target) recharge rates would reproduce observed groundwater elevations at trigger well locations and that recirculation (groundwater inflow to the quarry) was consistent with measured inflows. • Thank you for bringing this to our attention. The Excel formula has been corrected and a revised table showing the corrected total is provided in the appended Tables F6.3 and F7.1. This typo does not affect the findings of the impact assessment.	**RESOLVED.** The supplementary version of Table F6.3 and the corrected version of Table F7.1 are added to the project documentation.

	• For the 2017 calibration it appears that the simulated wetland recharge flows differ substantially from the observed flows. Are time series of recharge flows available to assess whether the simulated values are within the ranges of the observations?			• Wetland water elevations and flow rates have been provided for Wetlands V2, W7, and W8 for calendar 2017. See Figures 1, 2, and 3 appended to this response. As shown on Figures 1 through 3 the recharge flows vary significantly throughout the year and the simulated values are within the range of average weekly flowrates for each wetland. The difference between 2017 simulated and average annual observed flows can be attributed to nearby recharge well operations and groundwater/surface water interactions. In some instances/time periods, the wetlands are supported by nearby groundwater recharge rather than direct diffuse discharge. This is evident in the hydrographs for Wetlands W7 and W8 (Figures 2 and 3) where water levels are maintained for extended periods with little or no top-up. These conditions are replicated by the model and result in relatively low simulated diffuse discharge rates at Wetlands W7 and W8. Refinement of these local scale interactions could have been pursued; however, this was identified to be an interim condition that would not be present under full extraction conditions. Under full extraction conditions the surface water system is above the connected groundwater flow system (water table). This condition was documented in the 2021 Annual Water Monitoring Report. At 2021 year-end, full extraction conditions have essentially been achieved in the vicinity of the on-Site wetlands. The total observed diffuse discharge to the wetlands was 650,000 m^3 in 2021, providing a good match when compared to the simulated 680,000 m^3 for full extraction conditions. It should be noted that while a suitable match has been achieved between observed and simulated conditions, the adaptive management approach does not rely on the simulated results for wetland mitigation. Ultimately the success of the wetland mitigation activities is guided by monitoring, operational experience, and ongoing evaluation	

				and review of real-world conditions related to water and ecology considerations in accordance with the AMP.	
10.	On Table 7.1, what do the values associated with the "Approved Extraction Flow Target Flow Target" refer to?	Page F9	S.S. Papadopulos & Associates Inc.	The row identified was erroneously included in the final report and is not relevant. There is no "Approved Extraction Target Flow" with respect to the predictive simulations. The row has been removed for the appended supplemental Table 7.1.	**RESOLVED.** The appended supplemental Table F7.1 is added to the project documentation.
11.	<u>Model file requests</u> In their summaries of model results, GHD have helpfully indicated the names of the groundwater models. To confirm that the model results are reproducible, we request the Groundwater Vistas and MODFLOW input files for the following models. We also request that the files include the MODFLOW listing files (files typically with extension .LST) for each model. • 2023_v032.272 • 2023_v032.274 • EEFE_v032.325 • EEFE_v032.425	Page F9	S.S. Papadopulos & Associates Inc.	It is noted that the performance of the proposed mitigation relies on the proven Water Management System and Adaptive Management Plan and does not rely on modelling or simulated results. The pursuit of nuances in model results will have little or no impact on the real-world success of the project. Dufferin asks that all additional simulations and review be conducted by GHD upon request to limit additional work products. To this end, no model files have been provided; however, Dufferin remains committed to working cooperatively and will review and provide responses to all reasonable requests, including real-time simulations by GHD in conference with SSPA.	**RESOLVED.** On August 5, 2022 the proponent's hydrogeology consultants met with the JART peer reviewer. Ahead of the meeting the proponent's transmitted copies of the MODFLOW Output Listing files for the four simulations indicated. The groundwater models were re-run and it was confirmed that the results matched those in the listing files. This confirms that the model results presented in the GWRA Report are reproducible.
12.	**Appendix – Change calculations** Change calculation #1			The values selected in the comment for change calculation #1 are incorrect due to approximating head values from the coarsely spaced contours on Figures F7.1, F7.2, and F7.3. Please see appended Figures 4, 5, and 6 showing more finely spaced contours to clarify the calculation. Figures 4, 5, and 6 correspond to a zoomed in view around the East Extension for Figures F7.1, F7.2, and F7.3, respectively.	**RESOLVED.** The appended Figures 4, 5 and 6 are added to the project documentation.
13.	Change calculation #1			The values selected in the comment for change calculation #2 are also incorrect due to approximating head values from the coarsely spaced contours on Figures F7.4, F7.5, and F7.6. Please see appended Figures 7, 8, and 9 showing more finely spaced contours to clarify the calculation. Figures 7, 8, and 9 and correspond to a zoomed in view around the East Extension for Figures F7.4, F7.5, and F7.6, respectively.	**RESOLVED.** The appended Figures 7, 8 and 9 are added to the project documentation.

Appendix – Change calculations

Change calculation #1

Approved existing quarry fully extracted – Approved existing quarry + MQEE fully extracted

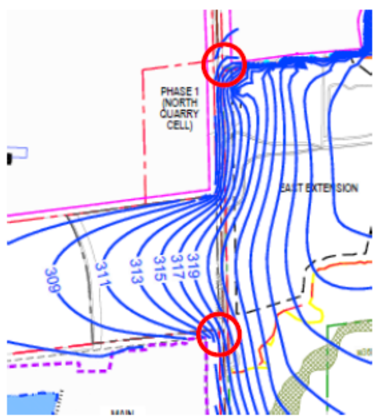


Figure F7.1

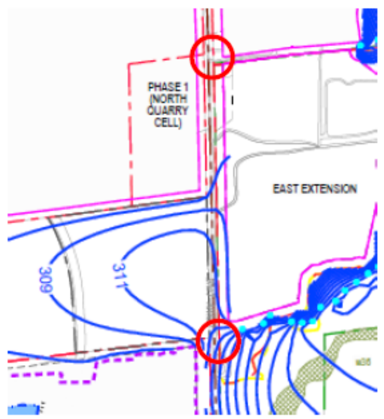


Figure F7.2

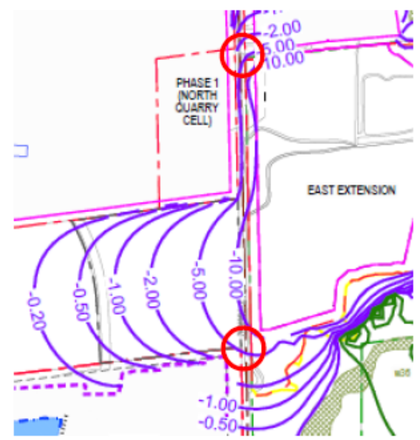


Figure F7.3

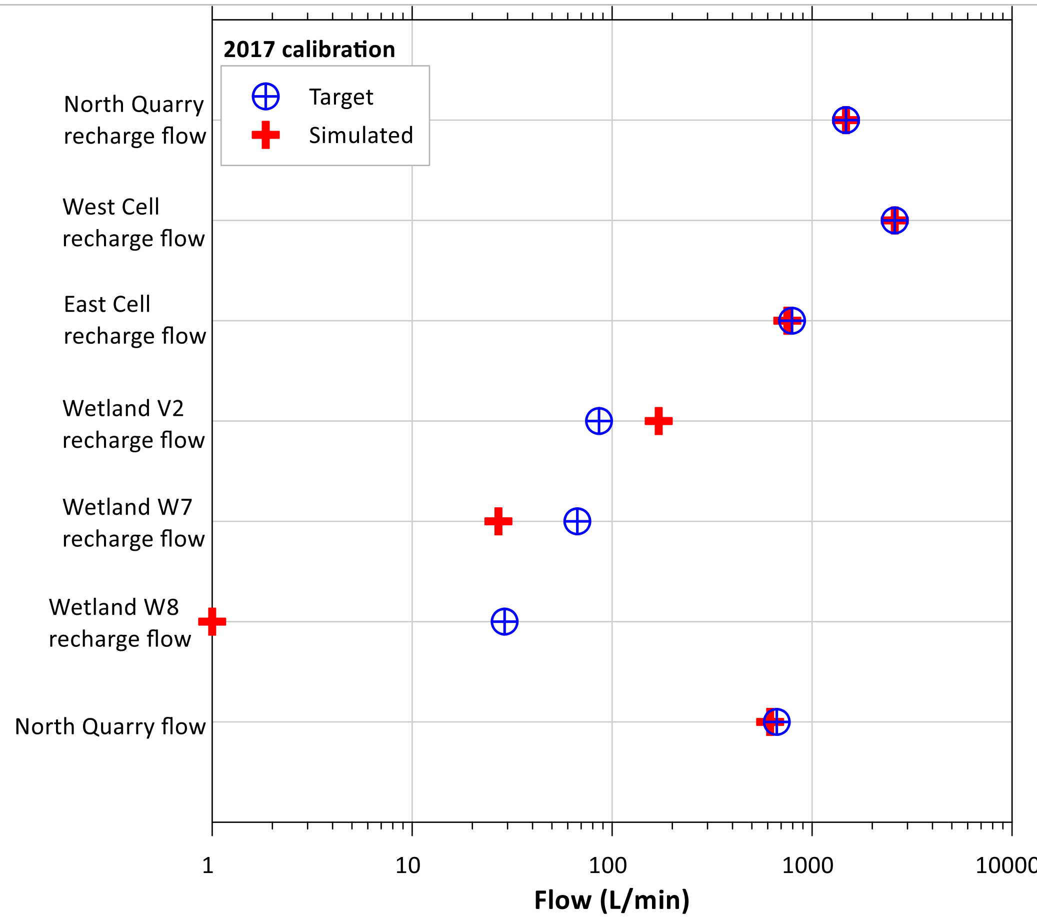
Upper point: 307 masl - ? = 5.0 m

Lower point: 319 masl – 311 masl = 5.0 m (?)

	JART Comments (June 27, 2022)	Reference	Source of Comment	Applicant Response 2022	JART Response
Report/Date: Geology and Water Resources Assessment Report December **2021**			**Author: GHD**		
	<u>Supplemental Questions Received June 27, 2022</u>				
14.	Am I correct in understanding that for pre-extraction conditions there is runoff of 60 mm/yr from the 15.9 ha footprint of the MQEE to lower land (I presume that is east and south of the MQEE)?	Page F9	S.S. Papadopulos & Associates Inc.	Yes, runoff is estimated to be 60 mm/yr. No, runoff from the extraction footprint does not head east and south. As described in the GWRA (Section 5 and specifically Section 5.4) "As presented on Figure 5.2 [of the GWRA], the majority of the proposed MQEE extraction area (84%) currently drains to the south towards Wetland W36. With a small area (14%) in the northwest corner draining west towards Town Line and the existing North Quarry."	**RESOLVED.**
15.	Am I correct in understanding that for pre-extraction conditions there is runoff of 60 mm/yr from the 15.9 ha footprint of the MQEE to lower land (I presume that is east and south of the MQEE)?	Page F9	S.S. Papadopulos & Associates Inc.	The runoff rate provided (566 mm/yr) is for dry quarry areas within the excavation footprint. As suggested, all "runoff" is captured by the quarry sumps and circulated to the Reservoir.	**RESOLVED.**
16.	For interim conditions, what does the runoff in parentheses represent for the infiltration term? Am I correct in understanding that none of the precipitation that falls into the quarry can infiltrate through the floor? Is that because it is assumed that the base of the quarry is impermeable (Cabot Head Shale) and remains impermeable regardless of what activities happen on top of it?	Page F9	S.S. Papadopulos & Associates Inc.	The parentheses indicate that little or no infiltration occurs as the majority of this component is runoff. The detailed water budget calculations provided in Appendix G do include a small vertical leakage component (< 10 mm/yr) to conservatively account for water loss through the quarry floor to the underlying formations.	**RESOLVED.**
17.	For final rehabilitated conditions (quarry lake), what does the runoff term of 194 mm/yr represent? I must be misinterpreting it as runoff from the lake to its surroundings. What does it really represent?	Page F9	S.S. Papadopulos & Associates Inc.	This runoff/surplus is excess water in the system – I,.e. precipitation minus evaporation. In reality, this water will likely overflow through the hydraulic control structures and return to the Reservoir for storage. The surplus can then be used for quarry lake top-up or discharged directly to the Hilton Falls Reservoir Tributary.	**RESOLVED.**
18.	For final conditions, am I correct in understanding that no water leaks out of the quarry to the groundwater system?	Appendix F	S.S. Papadopulos & Associates Inc.	Water does leak to the groundwater flow system under final conditions. These leakage rates are presented in Table F7.1. Flows from the West Cell, East Cell, and East Extension are negative due to the support provided to the surrounding groundwater flow system. The North Quarry also "leaks" to the groundwater system; however, it receives support from the East and West Cells, and net flow is positive. The leakage to the surrounding groundwater flow system is essential for passive support of the aquifer and downgradient water resources. This assessment simply identifies the total surplus	**RESOLVED.**

				of water available to the natural environment. The surplus under the rehabilitation condition would likely overflow through the hydraulic control structures and return to the Reservoir. This surplus could then be used for quarry lake top-up or discharged directly to the Hilton Falls Tributary.	

	JART Comments (December, 2022)	Reference	Source of Comment	Applicant Response	JART Response
Report/Date: Geology and Water Resources Assessment Report December **2021**			**Author: GHD**		
	<u>Supplemental Questions on the Modelling</u>				
19.	It is indicated on page 5 of Appendix F that the overall calibration of the MQEE Model for the July 2010 data set "is comparable to the Pre-Extraction and 5-Year Review models, although some calibration residual statistics have increased slightly as a result of the much larger number of targets." It is not clear to us why the July 2010 set of calibration targets for the MQEE model is larger than it was for the Pre-Extraction and 5-Year Review models. Were additional targets found for July 2010 conditions when the MQEE model was being developed?	Page F9	S.S. Papadopulos & Associates Inc.		
20.	The simulation of 2017 average conditions is referred to as a "calibration verification". It is not clear whether this is a true verification of the calibrated model. Were any model parameters were adjusted between the July 2010 calibration and the simulation of 2017 conditions, apart from the specification of average annual groundwater elevations for each of the 31 Trigger Wells adjacent the Northern Cells (North Quarry, West Cell, and East Cell)?	Page F9	S.S. Papadopulos & Associates Inc.		
21.	Referring to Table F6.3, the simulated recharge flow to the North Quarry for 2010 conditions is about 75% of the observed inflow (926 L/min vs. 1222 L/min). On page 15 of Appendix F it is indicated that this difference is attributable to higher actual recirculation relative to "the ideal conditions simulated by the model." Doesn't this imply that there is something missing in the groundwater model such that recirculation is not simulated correctly?	Page F9	S.S. Papadopulos & Associates Inc.		
22.	A comparison of the flows reported on Table F6.3 suggests a close match to the three flow targets reported for July 2010. The corresponding results for average 2017 conditions are shown in the plot below. In contrast to the results for 2010, in our opinion the matches to the flow targets for 2017 average conditions are problematic. First, the reported simulated recharge flows for the North Quarry and the West Cell are identical to four significant figures. This strikes us as implausible. Are we missing something fundamental in the comparison? Second, the simulated wetland recharge flows differ substantially from the observed flows. Are time series of recharge flows available to assess whether the simulated values are within the ranges of the observations?	Page F9	S.S. Papadopulos & Associates Inc.		



2017 calibration
Target
Simulated
North Quarry recharge flow
West Cell recharge flow
East Cell recharge flow
Wetland V2 recharge flow
Wetland W7 recharge flow
Wetland W8 recharge flow
North Quarry flow
1
10
100
1000
10000
Flow (L/min)

	JART Comments (November, 2022)	Reference	Source of Comment	Applicant Response	JART Response
Report/Date: Geology and Water Resources Assessment Report December **2021**			**Author: GHD**		
	<u>Comments/Questions on the Impact Assessment Analyses</u>				
23.	The impact assessment for the MQEE is unusual. For the scenario of active operations, it is assumed in the assessment that the existing mitigation measures have been extended and are functioning as designed. The mitigation of potential impacts is builtinto the scenarios considered in the impact assessment. In our opinion, this is a reasonable approach during the period of active operations. However, the approach *presumes* that there will be active mitigation beyond the end of operations when the lakes are filling and after the lakes have attained their final planned levels. In our opinion, the fundamental difference between the MQEE impact assessment and "standard practice" needs to be highlighted.	GWRA Section 10	S.S. Papadopulos & Associates Inc.		
24.	Whether or not this is regarded as a remote possibility, we consider it appropriate to ask, What are the likely impacts if the MQEE proceeds but the existing mitigation measures are not extended? The results of additional analyses will assist the JART in understanding the nature of the additional responsibilities and in understanding why the additional mitigation measures proposed for the MQEE are required. We recommend that the following scenarios be analyzed. a. End of interim conditions: Approved Existing Quarry Fully Extracted, MQEE fully extracted, no extension of existing mitigation measures b. Final rehabilitated conditions: Lakes in the Approved Existing Quarry, expanded East Cell Lake incorporating the MQEE, no extension of existing mitigation measures	GWRA Section 10	S.S. Papadopulos & Associates Inc.		
25.	Are we correct in understanding that because the AMP for the existing quarry provides comprehensive measures for all private wells in the area of the Milton Quarry, no additional provisions specific to the MQEE are required?	GWRA Section 10	S.S. Papadopulos & Associates Inc.		
26.	The potential long-term impacts for final rehabilitated conditions are shown in Figure 10.2 of the GWRA Report. It appears from the figure that some of the mitigation measures are operating, but it is not exactly clear which ones. The diffuse discharges at wetlands U1 and W36 are indicated. The network of recharge wells is also shown in the figure; however, comparing the contours of groundwater levels in Figures 10.1 and 10.2 it appears that not all of the recharge wells are active in the simulation of final rehabilitation conditions (no groundwater mounding is evident in the groundwater level contours south of the East Extension.	GWRA Section 10	S.S. Papadopulos & Associates Inc.		

27.	The potential changes in groundwater levels in the Amabel Formation for interim conditions (existing quarry and MQEE fully extracted) are shown in GWRA Figure 10.1 (also Figure F7.3). For wetland U1, the water level in the rock beneath the wetland is predicted to decline by 10.0 m. For wetland V2, the water level in the rock beneath the wetland is predicted to decline by up to 5.0 m (the predicted hydraulic gradients are very steep). Are there data from other areas of the site that confirm that diffuse discharge is sufficient to maintain wetlands even when the water level in the underlying rock is depressed substantially?	GWRA Section 10	S.S. Papadopulos & Associates Inc.		
28.	3. For final rehabilitated conditions, the results presented in Figure 10.2 suggest that for wetland U1, there may be a long-term decline of between 0.2 m and 2.0 m of the water level in the rock beneath the wetland. A decline in the water level in the rock of 1.0 m is predicted along the southern limits of wetland V2. Will seasonal diffuse discharge to the wetlands be sufficient to mitigate the effects of the permanent drawdown in the underlying rock?	GWRA Section 10	S.S. Papadopulos & Associates Inc.		
29.	Beyond wetlands U1 and V2, the recharge wells are predicted to cause increases in groundwater levels. Are we correct in understanding that the results beyond the recharge wells is the basis for the indication on page 69 of the GWRA that "There are no areas influencing water resources where the groundwater level is not maintained or raised under these representative simulation conditions"?	GWRA Section 10	S.S. Papadopulos & Associates Inc.		
30.	It is indicated in the GWRA Report that "It is possible that limited seasonal groundwater recharge may still be required to the east of the East Cell", although it is not indicated what "limited" might mean. Has any attempt been made to quantify the potential recharge requirements?	GWRA Section 10	S.S. Papadopulos & Associates Inc.		

31.	The current planned final lake levels include assigning the North Quarry Lake a level of 318.5 m AMSL, consistent with the approved rehabilitation plans for the existing quarry. Our understanding is that the final lake level for the North Quarry Lake is still to be decided. A lower level of 315.5 m AMSL has been proposed. Will this difference in final lake levels affect the predictions of water requirements for mitigation during final rehabilitated conditions?	GWRA Section 10	S.S. Papadopulos & Associates Inc.		
32.	Referring to Appendix F, Figure F7.4, are we correct in understanding that for the currently approved final rehabilitation condition for the existing quarry that a level of 333.0 m for the East Cell Lake is not sufficiently high to fully mitigate all the wetlands? Is this the explanation for the inclusion of WMS recharge wells on the east side of the East Cell even in the absence of the MQEE?	Appendix F	S.S. Papadopulos & Associates Inc.		
33.	It is assumed implicitly in the modelling analyses that once final lake levels are attained, conditions will not change. In his karst characterization (GWRA, Appendix E; page 5), Dr. Worthington indicates that a relevant consideration for longterm injection of water through recharge wells is the possibility that "…there may be excessive dissolution of the bedrock over time that may cause solutional enlargement of fractures that increase rates of seepage and hence increase the mitigation effort required to maintain protection of water resources". Although Worthington's warning may be addressed on page 46 of the GWRA Report, we recommend that the proponent indicate formally that Dr. Worthington's concern should be discounted for the MQEE.	GWRA Section 7 and Appendix E	S.S. Papadopulos & Associates Inc.		
34.	The groundwater modelling analyses are limited to steady-state analyses. The results of the simulations do not provide any guidance of the likely duration of the evolution from interim conditions to fully-rehabilitated conditions. However, estimates of the duration of lake filling are presented in the main text and Table 10.4 of the GWRA Report. It was not initially clear to us how the lake filling times were estimated. Subsequent exchanges with the consultants for the proponent have clarified the analyses of final lake filling. In our opinion, the details in the follow-up exchanges are sufficiently important that this material be included as part of the formal documentation for the proposed MQEE.	GWRA Section 10 and Appendix G	S.S. Papadopulos & Associates Inc.		

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<tr><td>35.</td><td>We have reviewed the water budget calculations. In our opinion the analyses are appropriate and the results are reasonable. Subsequent exchanges with the consultants for the proponent clarified the calculations. We recommend that the materials in the follow-up exchanges be included as part of the formal documentation for the proposed MQEE.</td><td>GWRA Section 10 and Appendix G</td><td>S.S. Papadopulos & Associates Inc.</td><td></td><td></td></tr>
<tr><td>36.</td><td>It is assumed in the impact assessment that during active operations of the MQEE, the existing mitigation measures have been extended and are functioning as designed. Therefore, a key question in the impact assessment is whether there is sufficient water to support the mitigation measures. Our review of the results of the water budget calculations summarized on GWRA Table 10.2 suggests there will be sufficient water to support mitigation during interim conditions.

• Estimated available annual surplus, interim extraction condition for the approved existing quarry: a value of 1,311,804 m^3 is reported.
• Estimated available annual surplus, interim extraction condition for the approved existing quarry + MQEE: a value of 1,335,887 m^3 is reported.

Recognizing that the two values of the likely average annual surplus are reported with too much precision, the results of the water budget calculations suggest that the surplus will actually be higher with the addition of the MQEE. Is our understanding correct? What accounts for the additional water during operation of the MQEE?</td><td>GWRA Section 10 and Appendix G</td><td>S.S. Papadopulos & Associates Inc.</td><td></td><td></td></tr>
<tr><td>37.</td><td>The impact assessment includes predictions of the year in which final lake filling will be complete. The predictions on Table 10.3 suggest that adding the MQEE to the East Cell Lake will extend lake filling by 2 to 3 years, depending on the assumed climate conditions. [The units “m^3/yr” shouldn’t be there.] The MQEE is predicted to have negligible impact on the time required for final lake filling. The results of the analyses also suggest that the assumed climate conditions, that is, assumptions regarding climate change, are likely to have limited influence on the predictions of lake filling. How do the assumed annual rates of precipitation and evapotranspiration change between the three assumed climate conditions?

<table><tr><th>Assumed climate conditions</th><th>Currently approved lake filling final date</th><th>Lake filling final date with addition of MQEE</th></tr><tr><td>1981-2010</td><td>2042</td><td>2045</td></tr><tr><td>Predicted 2050s</td><td>2043</td><td>2045</td></tr><tr><td>Predicted 2080s</td><td>2043</td><td>2045</td></tr></table></td><td>GWRA Section 10</td><td>S.S. Papadopulos & Associates Inc.</td><td></td><td></td></tr>
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