Swanson Environmental Strategies

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MEMORANDUM

To: **Yvonne Orengo, ALT UK**

From: **Stella Swanson**

Date: **August 6, 2019**

Re: **Uranium in Water**

Introduction

This memorandum provides additional information regarding uranium concentrations in drinking water near the QMM Ilmenite mine in Madagascar. The additional information is in support of the following statements made in the Summary Report "Review of the Release of Radioactive Material from the Rio Tinto/QMM Mine, Madagascar":

"…ALT UK and Swanson believe this report also highlights two significant opportunities for QMM to meet key **Sustainable Development Goals (SDGs)**:

> (1) **Safe drinking water**, which requires Rio Tinto/QMM (a) to accept that management of the risk associated with QMM mine-related uranium concentrations in receiving waters is a priority; (b) to develop and implement a monitoring program that is sufficiently rigorous to discriminate between natural background uranium and mine-related uranium concentrations in water; (c) to manage uranium effluent releases to the receiving environment adaptively, in response to monitoring information; and, (d) to demonstrate that it recognizes the multiple benefits of the provision of safe drinking water to nearby communities in accordance with its corporate commitment to management of human rights risks, including risks to water resources, and to directing benefits to those affected by mining activities (Rio Tinto 2017 Sustainable Development Report – see: http://www.riotinto.com/documents/RT_SD2017.pdf)
>
> **(2) Equitable inclusion** of local stakeholders and affected communities, which includes developing local staff and community capabilities in communications, social engagement and environmental monitoring skills in order to increase understanding among community members, contribute to informed and inclusive decision making, and provide independent monitoring of the mine's radiation levels over the project lifetime, and beyond."

Management of Risk Associated with Uranium Concentrations in Drinking Water

Risk to human health from uranium in drinking water

Radionuclides such as uranium are also chemically toxic, and the allowable concentrations in drinking-water may be determined by a radioisotope's toxicological rather than its radioactive properties (WHO 2012). This memorandum summarizes the data on the chemical concentration of uranium in water rather than the radioactivity associated with those concentrations for two reasons: (1) long-term risk from uranium in drinking water is dominated by chemical toxicity (largely to kidneys) rather than radiation-related effects; and (2) almost all of the QMM uranium monitoring data are chemical measurements rather than radioactivity measurements.

The WHO guideline for uranium based upon its chemical toxicity is 30 μg/L (0.03 mg/L) (WHO 2017). This is the guideline against which monitored uranium concentrations in receiving waters have been compared.

Does the QMM mine cause increased uranium concentrations in local waterbodies used for drinking water?

Uranium naturally occurs in the Anosy region rocks and soils; therefore, it also occurs naturally in rivers, lakes, ponds and groundwater. However, where there is environmental disturbance, such as mining, concentrations can increase, sometimes to levels which are problematic (WHO 2012). QMM regularly collects and analyses water from several locations in the mine site and has the samples analysed for many chemicals, including uranium. The uranium concentrations measured on the site were compared to uranium concentrations from river and lake samples as a way of investigating whether the QMM mining and extraction activities produce enhanced levels of uranium in water on the site.

Monitoring data provided by QMM from 2015-2018 from the mine site as well as the receiving environment (river and lake samples) were examined for average, minimum and maximum uranium concentrations. Interpretation was difficult because in many cases a high analytical method detection limit of <0.642 mg/L was reported whereas in other cases a somewhat lower method detection limit of <0.047 mg/L was reported. [Analytical method detection limits are the lowest concentrations reliably measured by the laboratory. In the case of the QMM data, both reported method detection limits are higher than the WHO drinking water quality guideline of 0.03 mg/L]. Some samples from almost all of the monitoring sites had results reported as less than the method detection limit, depending upon the sampling date. Therefore, the calculation of averages and the identification of minimum and maximum concentrations was confounded. Averages were calculated by assuming that the method detection limit was the uranium concentration in that sample. This is a conservative assumption (i.e., the actual concentration is likely to be lower). Because of the problem with method detection limits, maximum observed concentrations are likely to be a more reliable indication of differences among on-site and off-site uranium measurements.

The QMM mine definitely releases more uranium into water on the site, thus creating an enhanced source of uranium to the Mandromondromotra River and Lac Ambavarano. This conclusion was reached based on the following observations of the monitoring data.

Monitoring data from 2015-2018 show that uranium concentrations in water collected on the mine site were higher than in nearby river and lake water (Table 1 and Figure 1).

- The **average** uranium concentrations in mining basins, mineral separation plant samples and paddocks as well as process water samples ranged from **0.899 to 1.237 mg/L**, with the exception of water sampled from Site WP95 (this site is not indicated on the QMM map of monitoring site locations). **Maximum** concentrations from these sites ranged from **1.513 to 2.029 mg/L**.
- Effluent release points on the site, adjacent to the Mandromondromotra River, had **average** uranium concentrations ranging from **less than the detection limit of 0.642 mg/L to 0.99 mg/L. Maximum** concentrations at effluent release points ranged from **0.353 mg/L to 1.801 mg/L.**
- In comparison, **average** uranium concentrations in lake and river samples ranged from **0.065 to 0.648 mg/L. Maximum** concentrations in river and lake samples were **all less than the upper detection limit of 0.642 mg/L except in Lac Ambavarano** where maximum concentrations were 0.319 mg/L in the middle of the lake (in this case the lower detection limit applied) and 1.073 mg/L near the weir (this is a notable result which should be followed up).

<u>The primary question is whether the water released from the QMM site causes an increase in uranium in river or lake water; unfortunately, this question cannot definitively be answered because there are no uranium monitoring data for sites which are truly upstream of the QMM site.</u> The closest to an "upstream reference site" is Site WS0501 on the Mandromondromotra River adjacent to the north-east boundary of the QMM site. However, this site could still be influenced by site runoff. Nine of the ten samples from this site were less than either the upper or lower detection limits. One sample has a uranium concentration of 0.136 mg/L.

Notwithstanding the lack of true upstream reference sites which could be used to reliably determine natural uranium concentrations in water, the available monitoring data suggest that releases of water from the mine site to both surface and groundwater would have the potential to contribute additional uranium beyond that already present.

Should management of risks from uranium in drinking water be a priority for QMM?

This question can be answered from two perspectives: (1) whether there is confidence that QMM causes increased uranium concentrations in river and lake water; and (2) whether uranium concentrations exceed the WHO drinking water quality guideline.

Confidence that QMM causes increased uranium concentrations in drinking water

The monitoring data from 2015-2018 do not provide sufficient information to support a confident conclusion regarding whether releases of water from QMM result in increased uranium concentrations in river and lake water used for drinking, although there are definitely plausible pathways from the site to river and lake water which could result in additional uranium beyond those due to natural sources. The data support a conclusion that the mining operations produce elevated uranium concentrations in water collected on the QMM site. However, as noted above, data from the receiving environment cannot be interpreted with confidence because of the lack of true reference concentrations. Monitoring should include sites which have very low probability of being affected by the mine (e.g. upstream Mandromondromotra River samples). Furthermore, as noted in the report and summary report, more frequent sampling of river and lake water at more locations is needed. In addition, samples should be sent to a laboratory capable of detecting uranium at much lower concentrations.

Data from Lac Ambavarano, both from the middle of the lake and near the weir, show elevated concentrations relative to other sampling locations

The additional examination of QMM monitoring data supports the statement in the summary report regarding the need for a monitoring program that is sufficiently rigorous to discriminate between natural background uranium and mine-related uranium concentrations in water. Once this monitoring program is in place, QMM will be equipped to manage uranium effluent releases to the receiving environment adaptively, in response to monitoring information.

Do uranium concentrations in river and lake water exceed the WHO drinking water guideline?

All average concentrations in river and lake water exceeded the WHO drinking water guideline of 0.03 mg/L. However, this observation should be interpreted with caution because both method detection limits also exceed the guideline (0.642 or 0.047 mg/L). This illustrates the point raised above; i.e., the need for a sufficiently rigorous monitoring program, including reliable analytical methodology which includes lower detection limits. Uranium can be determined by inductively coupled plasma mass spectrometry (ICP-MS), which has a detection limit of 0.1 μg/l (0.001 mg/L) and a between-run precision of less than 6% (Boomer & Powell, 1987 cited in WHO 2012).

Results for Lac Ambavarano near the weir were of particular note since all but one of the samples were above detection limits with concentrations well above the WHO guideline (about 10-30x). The lake may receive mine-related uranium concentrations via both surface and groundwater pathways. However, more data are required, with additional sample sites, much lower method detection limits, and accompanying data for groundwater as well as surface water entering the lake.

In summary, the priority information items needed to confirm the (a) the degree and extent of exceedances of the WHO guidelines and (b) the relative contribution of QMM discharges to uranium concentrations in water used for drinking are:

- River and lake samples taken from reference and upstream-to-downstream receiving environment sites relative to surface water and groundwater discharge points from the QMM site;
- Uranium analyses which have much lower detection limits.

Rationale for the need to further address uranium in drinking water

Uranium is by no means the primary risk to human health associated with drinking untreated surface water, and creating fear associated with uranium concentrations must be avoided. The WHO (2012) review of uranium toxicity stated that in studies from Finland and Sweden, there were no adverse effects reported, even at uranium concentrations in drinking-water approaching 100 μg/L (0.1 mg/L). The WHO (2011) guideline for uranium is based upon a "no observed adverse effects level" of 637 μg/day, applying an uncertainty factor of 10 and assuming daily water intake of 2 litres.

Concentrations above the guideline value of 30 μg/L do not indicate that there will be health effects; rather, they indicate the need for further investigation. The need for further investigation is indicated by measured concentrations which are as high as 1 mg/L in Lac Ambavarano – 10 times higher than the highest concentrations in the Finnish and Swedish studies used for the determination of the WHO guideline (WHO 2012). Further investigation would include confirmation of the uranium concentrations using rigorous monitoring methods (as noted above), followed by site-specific determination of the range of Total Daily Intake (TDI) rates and subsequent risk to human health. The risk to human health must include all routes of exposure (e.g. fish consumption), not just drinking water.

Rationale for the focus on safe drinking water

Safe drinking water is a human right.

> "Access to safe drinking water is essential to health, a basic human right and a component of effective policy for health protection" …..The United Nations (UN) General Assembly declared in 2010 that safe and clean drinking-water and sanitation is a human right, essential to the full enjoyment of life and all other human rights". (WHO 2017).

Access to safe drinking water in the Anosy region goes well beyond the uranium issue. However, the uranium issue highlights the more general issue of the risks of consumption of untreated water. As stated in the summary report, no matter what the source of uranium in water, uranium concentrations must be addressed. Addressing uranium in drinking water can also reduce risks from microbiological and other chemical risks. Provision of safe drinking water would be in accordance with Rio Tinto's corporate commitment to management of human rights risks including risks to water resources, and to directing benefits to those affected by mining activities (Rio Tinto 2017 Sustainable Development Report).

Consideration of methods for the provision of safe drinking water in the Anosy region must acknowledge the practical limitations associated with rural areas of a developing country. It is recommended that a combination of simple, household-based water treatment and education regarding sanitary practices be used.

Household-based filtration systems can include intermittently operation slow sand filtration or rapid granular, diatomaceous earth, biomass and fossil fuel–based (granular and powdered activated carbon, wood and charcoal ash, burnt rice hulls, etc.) filters (WHO 2012). Effectiveness varies considerably with media size and properties, flow rate and operating conditions, and some options are more practical than others for use in developing countries.

It is strongly recommended that Rio Tinto/QMM collaborate with organizations experienced in the provision of household-based filtration systems, such as the Centre for Affordable Water and Sanitation Technology (CAWST) https://www.cawst.org/. CAWST is a Canadian charity and licensed engineering firm which addresses the global need for safe drinking water and sanitation by building local knowledge and skills on household solutions people can implement themselves. CAWST's core strategies are:

- Make water knowledge common knowledge;
- Build the capacity of public sector organizations;
- Start with household water treatment;
- Lead with education and training; and,
- Identify barriers to implementation and ways to overcome them.

Household filtration systems not only remove bacteria, viruses and parasites but can be designed to include materials which remove metals, including uranium. For example, clay ceramics may be effective in removing uranium (Florez et al. 2017).

Education and training in the provision of safe drinking water will require equitable inclusion of local stakeholders and affected communities. As stated in the summary report, this inclusion can include development of environmental monitoring skills, including skills related to the proper collection of samples for uranium analysis.

<u>In summary, it is possible to address the issue of uranium in drinking water and the broader issue of safe drinking water through the use of household-based filtration systems as well as education and training. This would be entirely consistent with Rio Tinto's sustainability commitments and would not require expensive, technical, and difficult-to-maintain water treatment.</u>

Conclusions

QMM mining activity is a source of enhanced uranium concentrations.

- Monitoring data show that the QMM mine definitely releases more uranium into water on the site, thus creating an enhanced source of uranium to the Mandromondromotra River and Lac Ambavarano.

- The primary question is whether the water released from the QMM site causes an increase in uranium in river or lake water; unfortunately, this question cannot definitively be answered because there are no uranium monitoring data for sites which are truly upstream of the QMM site.

- Notwithstanding the lack of true upstream reference sites which could be used to reliably determine natural uranium concentrations in water, the available monitoring data suggest that releases of water from the mine site to both surface and groundwater would have the potential to contribute additional uranium beyond that already present.

- The additional examination of QMM monitoring data supports the statement in the summary report regarding the need for a monitoring program that is sufficiently rigorous to discriminate between natural background uranium and mine-related uranium concentrations in water. Once this monitoring program is in place, QMM will be equipped to manage uranium effluent releases to the receiving environment adaptively, in response to monitoring information.

Uranium Concentrations in river and lake water samples exceed the WHO drinking water guidelines of 0.03 mg/L, usually by substantial margins.

- The exceedances of the WHO drinking water quality guideline in river and lake water indicate the need for additional investigations which include the use of laboratories which provide much lower detection limits for uranium. Once additional monitoring data are collected, the risk associated with mine-related uranium concentrations in drinking water should be estimated.
- The priority information items needed to confirm the (a) the degree and extent of exceedances of the WHO guidelines and (b) the relative contribution of QMM discharges to uranium concentrations in water used for drinking are:
  - River and lake samples taken from reference and upstream-to-downstream receiving environment sites relative to surface water and groundwater discharge points from the QMM site;
  - Uranium analyses which have much lower detection limits.
- Uranium is by no means the primary risk to human health associated with drinking untreated surface water, and creating fear associated with uranium concentrations must be avoided.
- Concentrations above the guideline value of 30 μg/L do not indicate that there will be health effects; rather, they indicate the need for further investigation. The need for further investigation is indicated by measured concentrations which are as high as 1 mg/L in Lac Ambavarano

Safe drinking water is a human right.

- Access to safe drinking water in the Anosy region goes well beyond the uranium issue. However, the uranium issue highlights the more general issue of the risks of consumption of untreated water.
- Addressing uranium in drinking water can also reduce risks from microbiological and other chemical risks.
- It is highly recommended that Rio Tinto/QMM collaborate with organizations such as the Centre for Affordable Water and Sanitation Technology CAWST which are experienced in the provision of simple, household-based filtration systems as well as education and training. This collaboration would be entirely consistent with Rio Tinto's sustainability commitments.

Table 1. Summary of Uranium Monitoring Data from 2015-2018. Data provided by QMM. See Figure 2 for location of sites.

Process Water	**Site ID**	**Mean Uranium Concentration**	**Minimum Uranium Concentration**	**Maximum Uranium Concentration**	**Number of Samples**	**Comments**
Mine Basins/Dredging Ponds	BASMIN	1.115	<0.047	1.748	99	
Mineral Separation Facility	MSP01	1.24	0.824	1.513	11	
Mineral Separation Facility	MSP02	1.237	0.744	1.489	11	
Mineral Separation Facility	MSP03	1.095	<0.047	2.029	85	
Onsite storage basins	Paddock 3	1.144	<0.047	1.804	97	
Onsite storage basins	Paddock 6	1.096	<0.047	1.766	91	
Onsite storage basins	Paddock 7	1.12	<0.047	1.764	91	
Effluent Release Points	WMC603	0.99	<0.047	1.801	89	
Effluent Release Points	WMC604	0.301	<0.047	0.353	7	
Effluent Release Points	WMC703	0.593	<0.047	2.007	39	
Effluent Release Points	WMC704	<0.642	NA	NA	12	All samples <0.642
Effluent Release Points	WMC803	0.252	<0.047	0.864	54	
Effluent Release Points	WMC804	<0.642	NA	NA	13	All samples <0.642
Effluent Release Points	WMC900	0.373	0.352	0.389	3	
Process Water	WP95	0.065	<0.047	<0.642	146	All but 15 samples either <0.047 or <0.642
Process Water	WP097A	0.96	<0.047	1.976	138	
Between Paddock 6 and MSP03	WW0126	0.899	<0.047	1.68	50	
Receiving Environment						
SE of site, N of Lac Besaroy	WS0103	0.266	<0.047	<0.642	6	5 samples either <0.642 or <0.047

Lac Besaroy (?)	WS0203	0.197	<0.047	<0.642	6	2 samples either <0.642 or <0.047
Lac Ambavarano near weir	WS0701	0.648	0.319	1.073	4	
Méandre River	WS301	0.202	<0.047	<0.642	6	
Lac Ambavarano mid-lake	WS0603	0.169	<0.047	0.397	5	
Mandromondromotra River d/s of WMC803 discharge	S42	0.378	<0.047	<0.642	10	
Mandromondromotra River d/s of WMC703 discharge	S43	0.302	<0.047	<0.642	7	All samples either <0.642 or <0.047
Mandromondromotra River d/s of WMC603 discharge	S44	0.065	<0.047	0.187	10	DL=<0.047 for all sampling times. 5 samples <0.047
Mandromondromotra River at northern site boundary	WS0501	0.353	<0.047	<0.642	10	9 samples either <0.642 or <0.047. 1 sample at 0.136

Figure 1. Mean Uranium Concentrations from 2015-2018 on the QMM Site and in the Receiving Environment

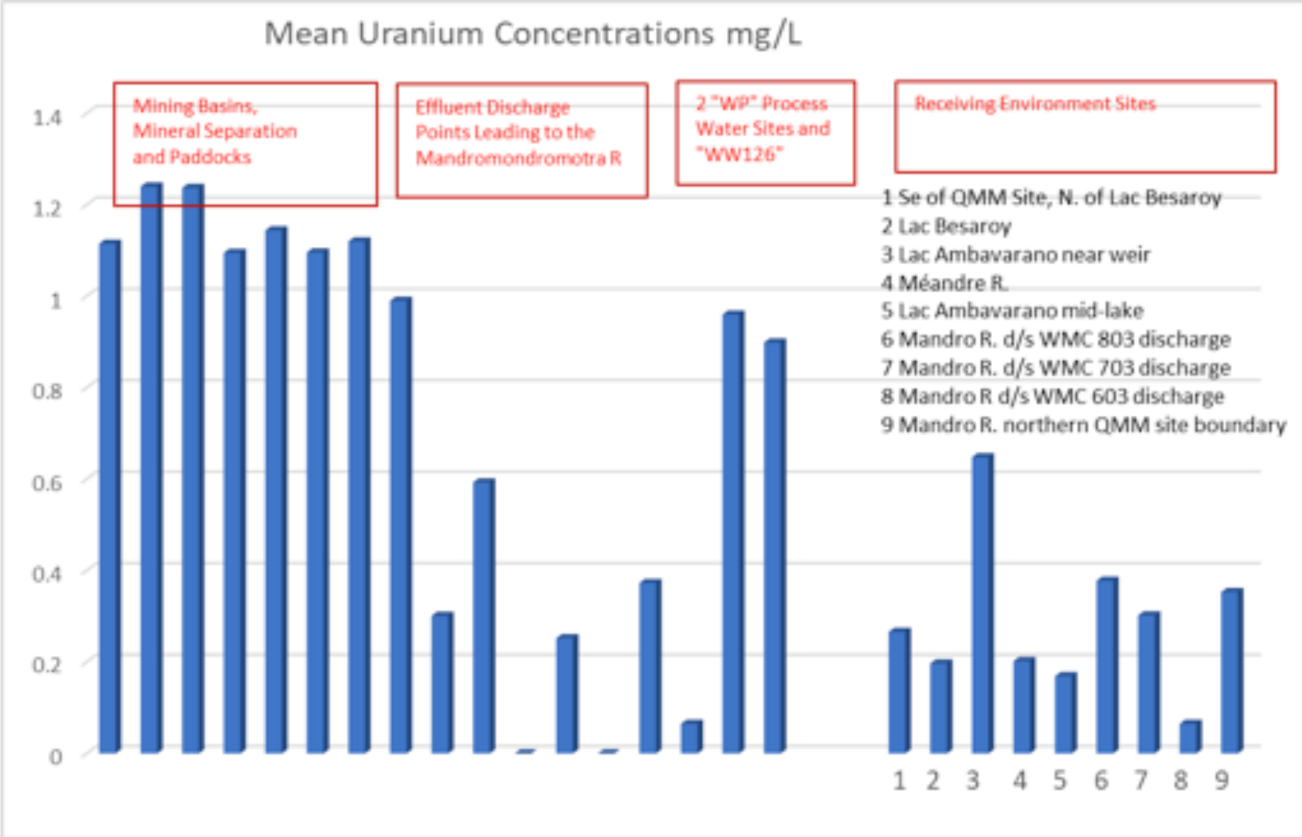
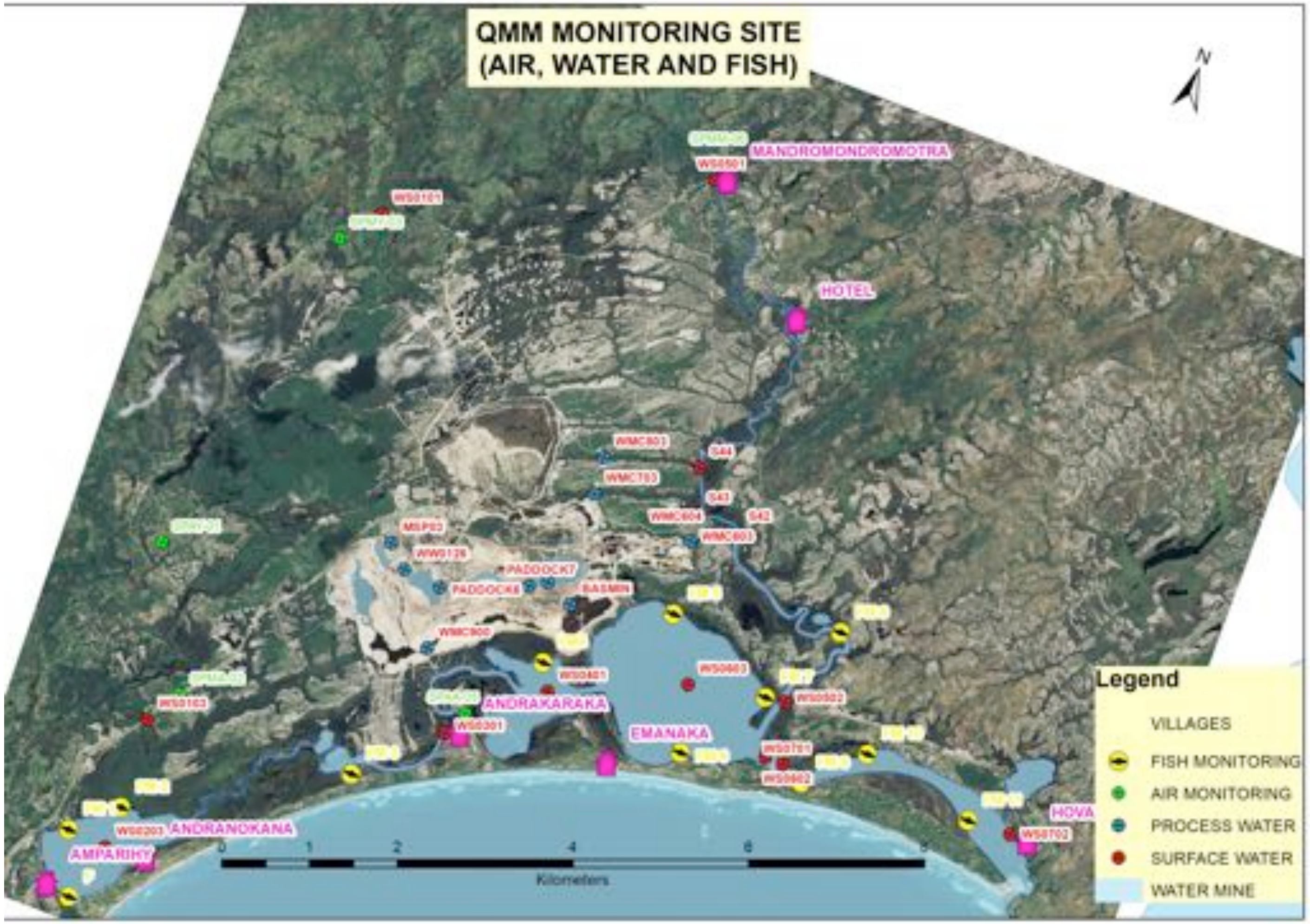

Mean Uranium Concentrations mg/L
Mining Basins, Mineral Separation and Paddocks
Effluent Discharge Points Leading to the Mandromondromotra R
2 "WP" Process Water Sites and "WW126"
Receiving Environment Sites
1 Se of QMM Site, N. of Lac Besaroy
2 Lac Besaroy
3 Lac Ambavarano near weir
4 Méandre R.
5 Lac Ambavarano mid-lake
6 Mandro R. d/s WMC 803 discharge
7 Mandro R. d/s WMC 703 discharge
8 Mandro R d/s WMC 603 discharge
9 Mandro R. northern QMM site boundary
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1 2 3 4 5 6 7 8 9

Figure 2. QMM Monitoring Sites



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