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Robert E. Moran, Ph.D.
Michael-Moran Assoc., LLC
Water Quality/Hydrogeology/Geochemistry
Golden, Colorado, U.S.A.
remwater@gmail.com

Mining Water: the San Cristobal Mine, Bolivia
Executive Summary.

- Minera San Cristobal (MSC) presently extracts between about 42,000 and 50,000 cubic meters per day of ground waters to supply their process and other needs. Such extraction volumes will continue for roughly 20 years and may even increase.

-Almost none of the local water which falls as rain or snowfall actually recharges the local aquifers. Hence, extracting such large water volumes are *not sustainable development* in any realistic sense. This represents *mining of water*. These actions guarantee an increase in the local and regional competition with other existing and potential water users.

-Such extreme extraction rates ensure that large areas of the local aquifers will be dewatered for many decades after the MSC activities cease. As such, many other potential water users will be unable to make use of these resources.

-Water which comes to the surface at local springs and seeps also flows into the shallow aquifer at numerous locations at the margins of the basin. As such, the springs are hydrogeologically connected to the shallow aquifer. Likewise, ground waters can move between the shallow and deep aquifers. Thus, pumping large volumes of ground water from the deep aquifer ultimately draws some of the shallow aquifer water downward, lowering the surface water elevation. Because the waters of the springs and shallow and deep aquifers are all ultimately interconnected hydrogeologically, many local and regional springs and wetlands will dry up as a result of the long-term pumping by MSC.

-Long-term pumping by MSC will cause water levels to decline in the shallow aquifers and to reduce pressures in the deeper aquifer. Given the inadequate network of monitoring wells and piezometers that presently exist, it is not possible to determine the depth or lateral extent to which the local and regional water tables will decline.

-Flows within the local surface waters will be reduced by long-term MSC ground water extraction. This will reduce flows into the Salar de Uyuni.

-Chemical contaminants present in the waste rock piles, the tailings lagoon sediments, and the open pit walls will cause some degree of long-term contamination to local ground waters. The sediments immediately below the tailings lagoon are not absolutely impermeable to long-term seepage.

-The historical water quality data collected by MSC and their consultants are of questionable quality and are not usable to develop a quantitative baseline. This is true for both the water quality data presented in the Environmental Impact Assessment (EIA) and those data collected subsequently. Thus, MSC has not compiled an actual water quality baseline database. The water quality data presented in the EIA and subsequent studies do not provide a reliable standard against which future changes in water quality can be judged.

-Information used to prepare the EIA (Knight Piesold, 2000) is almost 10 years old. Many of the activities and impacts described in the EIA are no longer relevant when compared to what is actually occurring at the MSC facilities.

-It is clear that the mining industry has an especially-favored economic and strategic relationship with the Bolivian government. As such, inherent conflicts-of-interest exist when an agency such as the Ministry of Environment and Water attempts to regulate the environmental and water use issues at MSC.

-Government oversight of water use and environmental aspects: It seems obvious that no Bolivian regulatory agency presently conducts adequate technical review and enforcement of water extraction and related environmental issues at the MSC. Whatever inspections have been performed are largely cosmetic and fail to investigate actual technical aspects of hydrogeologic issues and their impacts.

Recommendations and Guidelines for Future Action.

-The general public needs a source of technical support to assist them in integrating and interpreting the available hydrogeologic information. Provide funds necessary to allow a group that is technically and financially-independent of MSC to play such a role.

-In the MSC region, the volumes of available waters (ground and surface waters, springs) and reliable information on their water qualities need to be collected by some scientific group that is structurally and financially "independent" of the mining company. This same group should compile and evaluate the usability of all existing "baseline" data. This group must have the confidence of the general public.

-Develop an expanded monitoring network of wells and piezometers to determine the actual vertical and lateral extent of water level declines. These decisions should be performed by the independent group noted above, in conjunction with the representatives of MSC.

-Develop an actual “baseline” data set for [pre-operational] water levels, spring locations, and water chemistry using all of the reliable data. Ideally these activities would be performed by a technical group independent of MSC.

-Monitoring wells located down-gradient from the tailings lagoon should be monitored to verify actual seepage amounts and water quality. If excessive volumes of seepage are detected, seepage pump-back systems could be installed.

-Encourage the government to develop regulations that set limits on the unacceptable extraction and wasting of ground and surface water by MSC (and other mining and industrial activities). These policies should consider water as a public / communal resource, and any extraction must be sustainable over the long-term without generating unacceptable impacts to other nearby water users.

Encourage the government to develop practices / regulations that require MSC to measure and publicly-report all uses of water at their facilities, at least quarterly. These practices / regulations should require that an appropriate arm of the Bolivian government is mandated to review such data and verify the adequacy of data collection in the field numerous times per year.

Because water is the most valuable resource in such arid settings, Bolivian officials must develop *enforceable* procedures for requiring MSC to limit its water use and contamination. Such procedures might include requiring mine operators to pay a significant price for use of various volumes of water, but in no case should non-sustainable extraction of the resource be permitted.

These policies would require that MSC and the independent scientists mentioned above would conduct detailed studies to define the volumes of surface and / or ground water available for extraction within the project region and would provide estimates of the volumes of water available for long-term, sustainable development. Collection and interpretation of such information should be performed jointly by the company, their consultants and an independent technical team representing civil society and the government. Obviously all such water information would be available to the general public and the members of this independent technical team.

-Attempts to quantify the actual surface and ground water resources available need to focus on the collection of measured data. The use of computer simulations should be minimized and used only as secondary tools.

-Promote greater participation of the general public in discussions with mining companies regarding actual, measured impacts to water resources and other environmental impacts.

-Encourage the Bolivian regulatory authorities to develop legislation that requires all mining companies, existing and future, to demonstrate that they have some form of viable *financial assurance* to allow payment for future, unforeseen environmental and resource impacts. In Canada, the U.S.A., and most of Western Europe, such financial assurance takes the form of a financial bond or environmental insurance, which is purchased from and held by a party independent of the mining company.

New regulations developed by the Bolivian government should not allow consultants for the mining companies to calculate the quantities of money to be held as the bond. Such amounts need to be calculated by parties independent of the mining industry. Likewise, independent parties should determine the schedules for release of the bond monies to the companies.

1.0 Introduction.

Purpose and Scope. The present efforts are intended to evaluate the *water-related impacts* of a large, open-pit silver-zinc-lead mine, Minera San Cristobal (MSC), in the high, very dry altiplano of southwestern Bolivia. This evaluation was done considering the broader context of the numerous present and future users of the extremely limited volumes of fresh water available from all sources in this region. My activities in Bolivia were conducted between August 8 and 23, 2009; the observations and opinions that follow are the product of the following activities:

- Review of many of the most relevant reports prepared by MSC and their consultants, obtained from the Ministry of Environment and Water (M. E&W), La Paz. These reports were initially reviewed by a Portuguese hydrologist, Dr. Helena Amaral, at my direction, while she worked three months with CGIAB, (Comisión de Gestión Integral de Aguas de Bolivia, Commission for the Integrated Management of Bolivian Waters). Dr. Amaral prepared summaries of these documents and data which were provided to me in July 2009. I reviewed these summaries and many other related documents in the U.S.A., La Paz and Uyuni (see References).
- review of professional literature related to southwest Potosi and the MSC (see references);
- meetings with Dr. Jorge Molina of the University of San Andres, various members of the Geological Survey of Bolivia (SERGEOTECMIN), and the Minister of Environment and Water and several of his staff;
- meetings and interviews with various laboratory staff at the Technical University of Oruro and SpectroLab, Oruro---the latter having been involved in the preparation and analysis of portions of the MSC water samples;
- a site visit and meetings with the senior staff of Bolivian National Lithium Project;
- a visit / inspection of the MSC mine facilities and surroundings [conducted August 16-18, 2009], the last two days as part of team from the Ministry of Environment and Water together with representatives of some local municipalities.
- meetings with members of FRUTCAS (see below) and other civil society groups in the region.

In addition, my comments are informed by more than 37 years of applied hydrogeologic and geochemical experience at hundreds of mines and other industrial and resource facilities around the world. This experience has been gained working for private investors, industrial clients, tribal and citizens groups, NGO's, law firms, and governmental agencies at all levels.

These efforts were performed at the request of CGIAB (Comisión de Gestión Integral de Aguas de Bolivia, Commission for the Integrated Management of Bolivian Waters) and FRUTCAS (Federación Regional Única de los

Trabajadores Campesinos del Altiplano Sud-- Regional Farmers Federation of the Southern Altiplano). My activities were funded by the Municipality of Colcha K (Potosí, Bolivia), CESU--(Centro de Estudios de la Universidad de San Simón, Cochabamba), and Global Green Grants Fund, U.S.A.

Members of CGIAB, FRUTCAS and some of the local municipalities accompanied and assisted me in the activities described above. *Nevertheless, the observations and conclusions presented herein are entirely my own.*

Introductory Note. After several unsuccessful attempts, MSC ultimately allowed me to visit the mine site as part of an official "inspection" team composed of staff from the Ministry of Environment and Water, myself, two members of local municipalities, and a member of CGIAB. However, MSC was reluctant to allow open technical discussions between myself and their technical staff and consultants, using their actual data. Their repeated response was: "All of our technical data are publicly available." MSC controls the entire flow of information concerning their mine and processing facilities. They collect their own production and monitoring samples, and select the information they wish to provide to the Bolivian government. Apparently the M. E&W makes no effort to require MSC to supply complete data, *interpreted through time*, nor do they attempt to make such evaluations themselves. My observations and conclusions below were made using the sources described above, but were limited by the reluctance of MSC to allow substantive review of actual data with their technical staff (see Appendices).

Background. The San Cristobal Mine [Minera San Cristobal (MSC)] is a large open-pit silver-zinc-lead mine, in the high, very dry altiplano of southwestern Bolivia that began active operations in the third quarter of 2007. It is currently intended to have an active life of about 20 years, but this may change with future fluctuations in metals prices and new ore discoveries.

The mining and processing facilities are located in what used to be the old village of San Cristóbal and the small historical mines of Toldos, Animas, Tesorera and Jayula. The old village was founded during the 16th century and used to serve as a rest place on the route between Potosí and the Pacific Ocean. The old village was relocated within the present MSC project area, and is now referred to as the new San Cristóbal village (about 650 persons). Culpina K is the other village located within the MSC project area, and it remains in place.

Elevations in this region are between approximately 3800 and 4500 meters in elevation (12,460 to 14,760 feet) and receive only about 150 to 200 mm in a year of average precipitation [about 6.0 to 8.0 inches per year], but recent years are reported to have severely reduced precipitation. The elevations, extremely strong sunlight (especially extreme ultraviolet radiation), and strong winds cause evaporation rates to be much higher than the rainfall, between about 1300 and 1700 mm per year (51.2 to 67.0 inches per year)--roughly 8 to 10 times the average precipitation. As such, very small quantities of rainfall or snowmelt have actually entered the ground waters per year. *Most* of the ground waters being extracted are considered to be **"fossil waters"**, that is rainfall which fell after the last glacial periods more than 10,000 years ago (Molina, 2007, Chaffaut, 1998).

SERGEOTECMIN reports that no significant recharge has occurred in the basins from which MSC is taking ground water in the last 6 years.

The economy of this southwest Bolivian region revolves predominantly around the raising of llamas and other related camelids, growing and exporting quinoa, mining, and tourism.

Bolivia has a long history of traditional metal mining, during both pre-colonial and subsequent centuries, most of which was *underground mining*. Mining has been one of the main sources of gross revenue to the Bolivian economy, and still is. Large percentages of many Bolivian communities generally support the operation of metal mines especially in areas where few other sources of income are available. Modern metal mining mostly involves construction of immense *open pits* created using explosives and mechanical equipment with much greater impacts than traditional mining. It is common to have open pits that are 1 to 2 km across and 300 to 400 meters deep.

Many citizens near the mine have begun to have concerns about the drying-up of various seeps, springs and wetlands that feed their livestock, about declines in the water levels of existing private wells, about possible contamination of ground and surface waters by mining wastes, poisoning of flamingoes and other birds, and possible impacts to the nearby Salar de Uyuni, the largest salt flat in the world, a tremendous tourist attraction and the greatest source of tourist dollars in the region. These fears combined with the difficulty locals have in accessing reliable, independent sources of information concerning the mine's activities have led to much speculation about the possible impacts to water resources.

In addition, the Bolivian government has begun construction of a pilot plant to develop the techniques necessary to extract valuable lithium and potassium and other commercial chemical compounds from the brines of the Salar. This pilot project is presently State-owned and operated, and intended to provide numerous jobs and other economic benefits to the region---and would also rely on the waters that flow into the Salar. It is the previously-mentioned fears and increasing interest in the regional waters that have led to these present investigations.

Mine Operations Summary.
The following summary is based on information presented in the EIA (Vol. 1, p. 1-83), which is now almost 10 years old. It is normal for many of the details to change throughout the life of any metal mine.

It is projected that MSC will ultimately remove about *240 million tons of silver-zinc-lead ore* from an open pit mine that will be about 1.6km by 1.3 km in area. The final depth is unknown. Explosives and massive mechanical machinery are used to remove the rock thus forming the pit. Most of the rock removed from the pit will be waste of two categories:
--*waste rock*: the slightly-mineralized rock containing metal concentrations too low to be of economic value; approximately *511 Million tons of waste rock* will be stored in piles on the site [generated at 70,000 tons per day] over 20 years. [Waste rock is sometimes misleadingly labeled *esteriles* in Latin America, which implies that these rocks contain nothing---which is incorrect. They contain concentrations of almost any metal or metal-like element plus other non-metal compounds---all of which can be released into the environment—either in contaminated water or dust.]
--*tailings*: ore (economically-valuable rock) is conveyed from the pit to the processing plant where it is crushed and milled and enormous quantities of water and process chemicals are added to allow the extraction of the valuable metals in the form of a concentrate (EIA, V. 1, p. 20-23). Tailings are the wastes which leave the plant and are about 50% solids and 50% liquids— a mixture of rock particles, process chemicals and contaminated water. Tailings contain significant concentrations of trace and minor constituents (see EIA, Table 42) and an average of 4% sulfur minerals. The EIA estimates that *240 million tons of tailings* will be produced and deposited in the *unlined* tailings lagoon over 20 years.

While fresh tailings from the plant are alkaline [expected pH about 10.0 (EIA, V.1, pg. 132)] due to the lime used as a processing reagent, they contain enough pyrite to potentially generate **acid drainage** in the long-term. Chemical reaction rates of the lime are more rapid than those for the pyrite, thus gradually the pH declines with time. Contaminants can be mobilized in either acid or alkaline solutions. *All of these wastes would remain on the site forever.*

The economically-valuable product produced at the plant are the silver-zinc-lead concentrates, which are transported via train to Chile, and further exported to other countries (Europe, Asia and Australia) for smelting.

MSC reportedly pumps and uses approximately 42,000 to 50,000 cubic meters per day of ground water for processing and other mine-related purposes, and is likely to require additional quantities to meet their future mineral processing needs. MSC claims that they presently recycle roughly 18 percent of the tailings water for reuse in the plant, and hope to increase this to 50 percent at some indefinite time in the future. No data on the actual, measured volumes of water pumped or recycled were seen in any of the reports reviewed.

Hydrogeology: Review of Molina (2007) and discussions with technical staff at SERGEOTECMIN indicate the southern altiplano contains numerous basins that are filled with about 200 m of unconsolidated sediments of Quaternary age which are saturated with ground water. Normally roughly the upper 50 meters form a shallow aquifer of Pleistocene sediments, filled predominantly with melt water from the last glacial periods---greater than 10,000 BP (before present). These shallow aquifers contain relatively high quality water, usable for human consumption, irrigation (quinoa), livestock watering (Llamas, alpacas, sheep), etc.

The deeper aquifers usually extend from about 50 m to at least 200 m below the land surface. Compared to the shallow aquifers, they have finer-grained sediments, longer residence times for the waters, and are *progressively saline with depth*. This pattern is typical of the aquifers near many post-Pleistocene saline lakes in the western U.S.A., Chile, Australia, the Middle East, etc. *The basins from which MSC is presently extracting ground water have these* *characteristics.* Much of the deeper water is unsuitable for domestic purposes, irrigation or livestock watering. These sediments are believed to be recharged by run-off through coarse alluvial fan-like material at the foot of the Cordillera Oriental. Direct recharge through the surface of the altiplano is believed to be very limited due to high evaporation and the low permeability of the superficial sediments (Dames and Moore, 1967).

The shallow aquifer at the MSC well fields is unconfined, while the deeper is confined and even artesian (flows at the surface) in places. All available evidence indicates that ground waters can move between the two aquifers under the influence of this long-term, high-volume pumping.

MSC operates two groundwater well fields: the main one located in the drainage basin of the Jaukihua River, 9 km south of the concentration plant, and the secondary located in the drainage basin of the Rio Grande de Lipez, 10 km southeast of the concentration plant. Because MSC needs additional process water, they have begun exploration and testing in a third area. Also, MSC states that they currently recycle roughly 18 % of the tailings waters. Water recycling was not considered economical and/or environmentally advantageous in the EIA.

Village Domestic Waters. The intense groundwater pumping currently impacts the former ground water supplies for the local villages; hence MSC provides them with alternate sources. According to the 6th TEMR [Trimestral Environmental Monitoring reports] – Mine Construction Phase, August 2006 (period May - July 2006), Attachment 1, the following amounts are supplied (or are intended to be):

▪ **Community of San Cristobal:**
- Montes Claros spring: collection and distribution of 73,500 L/d.
- Spring from the old San Cristobal village, 30,000 L/d.
- Jalanta river, 180,000 L/d.

▪ **Culpina K:**
- Oveja Chanca spring: collection and distribution of 50,000 L/d.
- Jawilcha spring: construction of additional water supply, 120,000 L/d.

▪ **Vila Vila:**
- Chacuata spring: collection and distribution of 50,000 L/d.
- Misky Uno and Markahui springs: preserved as freshwater supply.

It is unclear that all of these alternative distribution systems actually function.

<u>**2.0 Observations / Concerns / Uncertainties.**</u>

Reporting. MSC has presented numerous reports to the Bolivian government since before 2000 to the present. One is the enormous Environmental Impact Assessment (Knight Piesold, 2000) composed of 5 volumes and appendices that contain at least 2500 pages. These reports / studies easily include more than 5000 pages of text and figures, in which site conditions and practices change continually between these various documents. They are often composed of unclear and **disorganized verbal descriptions and poorly defined and described tables and figures**. In most cases, there is little or **no significant**

interpretation of the cumulative data presented through time. As a result it is frequently impossible for an informed reader to adequately understand what is being described or what impacts have occurred by reading the documents available from the Ministry of Environment and Water. It is clear that MSC has made these documents public, but has no intention of actually explaining the details to any audience—either the public or the government.

It appears that these **documents are only available to the public at one location in all of Bolivia**—the Ministry of Environment and Water in La Paz. Hence access to these documents is obviously not adequate for the general public.

Water Quantity. MSC presently extracts ground water from the lower aquifer via pumps in at least two well fields at an average rate of between **42,000 and 50,000 cubic meters per day.** Different pumping volumes were reported (verbally) to our team by the senior MSC staff and the drilling consultants constructing and testing a new water exploration well (August 2009). Various technical reports prepared by MSC and their consultants report rates between 40,000 and 42,000 cubic meters per day.

At an extraction rate of 40,000 cubic meters per day, MSC is extracting roughly 14,600,000 cubic meters per year. If one assumed a mine life of 20 years, this would amount to roughly 292 million cubic meters of largely fossil ground water extracted in total (disregarding recycling). Total extraction would be much greater if the rate of 50,000 cubic meters per day is correct.

It is clear from all of the reports and the present water exploration activities that MSC believes they **require additional sources of water** for their operations. It also seems likely, based on reports from the drillers and published information, that MSC wishes to reduce the present declines in water levels near some of the local communities. Hence, they are exploring for additional sources of ground water.

It is unclear exactly **how many production wells** are actually being used. Several reports authored by MSC and their consultants state that 10 wells are employed. The MSC staff stated that ten were available for ground water extraction, but that less normally functioned in any month due to corrosion and mechanical problems. The latest MSC monitoring report presented to the Ministry of Environment and Water (July 2009), Table 5 (Agua Campo de Pozos), reports data from 16 different wells.

According to numerous studies, the majority of the ground water present in most of the altiplano basins is “fossil” water. This is consistent with my experience in other similar settings, such as the Sultanate of Oman. Hence, the basic question is: If water is extracted at 40,000 to 50,000 cubic meters per day for roughly 20 years, **how much time will be required for the aquifers to recover their pre-**

pumping conditions? That is, how much time will be required after pumping ceases for the shallow aquifer water level to return to its baseline level, and for the deep aquifer to be sufficiently recharged so that it returns to its baseline pressured (confined) conditions? MSC has not answered these questions in any of the documents reviewed. Given all of the uncertainties regarding the hydrogeologic details of this area, it is clear that no one really has a quantitatively-reliable answer. Given that these aquifers receive almost no measurable recharge per year (Molina, 2007; Montgomery & Associates, 2008), we can be assured it will be a very long time. Molina has suggested an optimistic estimate of 60 years following the cessation of pumping.

MSC fails to show in any of the monitoring reports reviewed the **cumulative drop in ground water levels** in areas near the mine since they began extracting water. This would normally be accomplished by showing water level changes on a series of maps. Unfortunately, it appears that many wells that existed prior to mine operation—both private and company wells—no longer exist to allow definite comparisons with pre-operational conditions. It also appears that MSC has an inadequate number of wells / piezometers to adequately define the historical changes in water levels, both locally and regionally.

Because of the limited wells described above and because such long-term water level decline maps have not been presented, it is not possible to state accurately how much the local or regional water levels have actually dropped since MSC began extracting ground water.

Rather than show maps constructed using actual water level measurements, MSC has instead presented maps and data describing **predicted** water levels, based on computer simulations. Such **computer simulations** often have great errors when one returns later and compares predicted versus actual water level declines (Moran 2000). The EIA (Knight Piesold, 2000) stated that **no recycling of process waters would be required**, yet MSC today claims to recycle 18percent of these waters. One must assume that the original underestimation was based on results of the early water balance computer simulations.

MSC consultants have prepared at least two different computer simulations of the predicted ground water level declines: the first prepared by Knight Piesold, (2000) and presented in the EIA; the second prepared by Errol L. Montgomery & Associates, Inc. (May 2008). Interestingly, they yield quite different predictions of the future water levels. Knight Piesold (2000) predicted that the water level would drop 17 m at Culpina K and 15 m at the Grande de Lípez River. [This model clearly overestimated the precipitation and recharge, as is discussed in Molina (2007)]. The Montgomery (2008) predictions are quite different. At a pumping rate of 1450 cu. meters per hour (34,800 cu. meters per day) pumping for 17 yrs., the water level decline is predicted to be:
South wells: max. about 61 m
North wells: max. about 128 m.

[The Montgomery simulation started with the pumping rate at 1800 cu. meters per hour (43,200 cu. meters/ day), but the rate was not sustainable as the wells dried up.]

Montgomery conducted a second computer simulation using a pumping rate of 600 cu. meters / hour (14,500 cu. meters / day) for 17 years, which yielded the following declines:
North wells: max. about 18 m
South wells: max. about 28 m
Pumping 600 cu. meters per hr. is likely sustainable for 17 yrs, but mine operations require more water.

Again, neither MSC nor Montgomery present graphically the extent of the actual water level declines throughout region since about 2000.

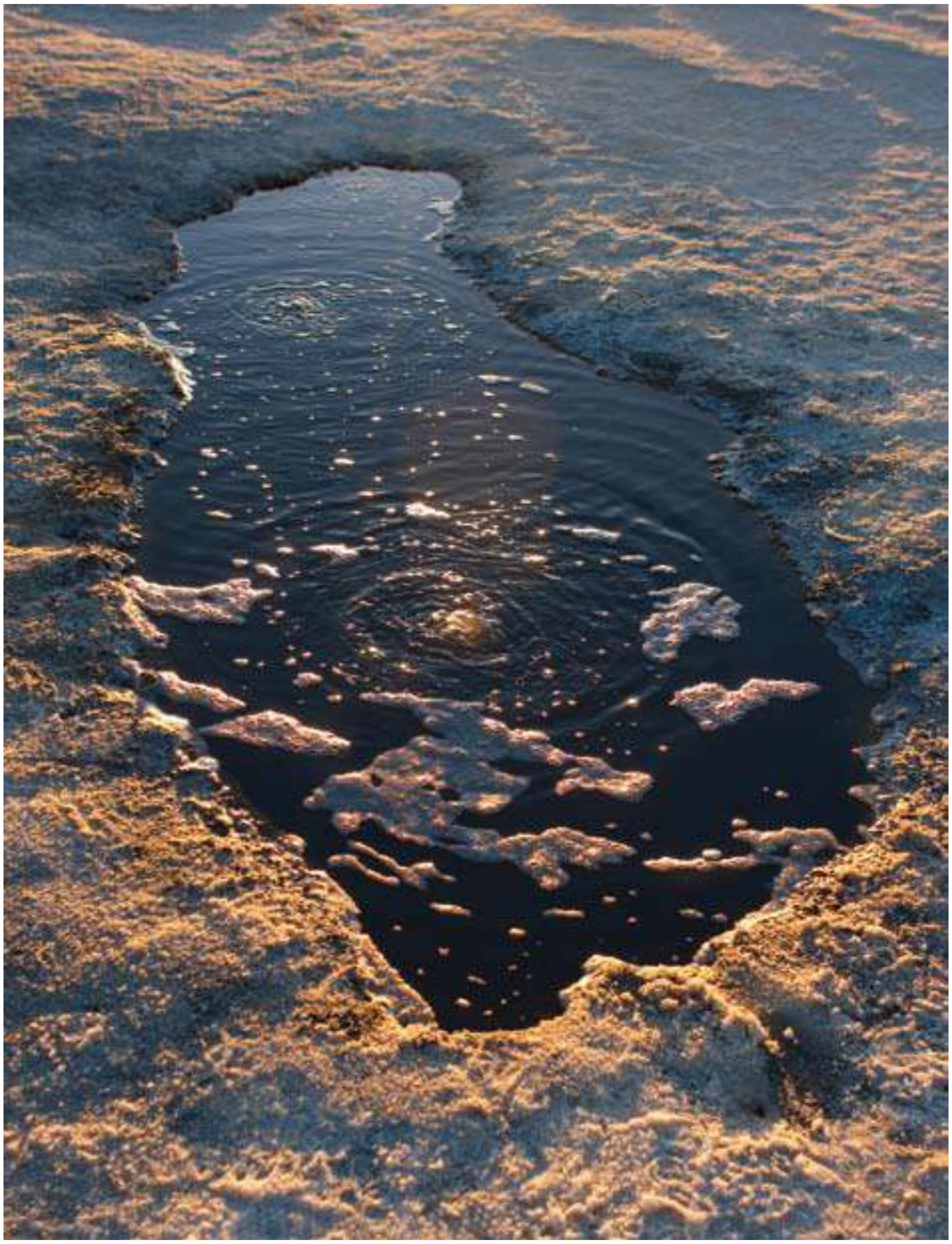
MSC extracts process water from the **deep aquifer**, generally below 50 meters depth. However, such pumping over the long-term will cause leakage of water from the shallow aquifer into the deeper aquifer (roughly 50 to 200 meters depth). This is confirmed by statements made by Knight-Piesold in the EIA, by conclusions of the technical staff at SERGEOTECMIN, and by experience with other similar situations. Leakage from the shallow aquifer into the deeper aquifer will result in long-term declines in the local and regional water table. Long-term, this leakage is likely to cause changes in the water quality of both aquifers in the well field regions.

Extraction of such massive quantities of ground water will clearly cause **declines in the water table** regionally, out to some significant, but undefined radius from the well fields. MSC does not monitor wells or piezometers at distances far enough from the existing well fields in order to reasonably define how far away the future water level drops will extend.

Surface Waters.
Given the locations of the existing well fields, it is likely that, long-term, pumping from the deep aquifer will cause **leakage of surface waters** into the upper aquifer, thereby reducing flows in both the **Rio Jaukihua and the Rio Grande de Lipez.** Such reductions in surface water flow would ultimately reduce flows to the **Salar de Uyuni**. Surface flows into the salar are saline, but they currently provide an environment for birds, especially flamingoes, and other wildlife.

Springs / Wetlands.
Such long-term ground water use will also cause many **springs and seeps** to dry up. Some local citizens have complained that this is already happening in certain locations. Given the recent years of unusually low precipitation, it unclear that MSC ground water extractions are the main cause for such declines in spring flow. Nevertheless, it is obvious from experience in numerous similar ground water-surface water systems in desert regions that ultimately the springs

are interconnected with the aquifers despite the argument that the springs surface at higher elevations than the aquifers. After long-term, high-volume pumping, the flows of such springs generally reduce or disappear.



Unfortunately, MSC and their consultants did not conduct an actual, detailed evaluation of the existing seeps and springs in the local and regional areas. Such baseline evaluations of seeps and springs are routinely preformed at prospective mine sites in developed countries, and usually include mapping the exact locations of these seeps and springs, measuring or estimating the volumes of flow (often quarterly throughout a year), making field measurements of temperature, conductivity and pH, and collecting water quality samples for analysis at a laboratory (also often quarterly for a year)—prior to operations.

Such detailed baseline evaluations should have been performed as part of the EIA activities, or at least prior to the commencement of ground water pumping. MSC's consultant, Knight-Piesold, has likely conducted hundreds of similar studies and they know that such baseline seep and spring surveys should have been performed.

Like the springs, the high elevation **wetlands** [bofedales / humedales] that provide pasture for the llamas and vicuna, etc. will likely be impacted and many will dry up.

Precipitation / Evaporation. Both the precipitation and evapotranspiration data used by MSC in their EIA, (Knight Piesold, 2000) are inadequate for use in reasonably evaluating the available water resources. MSC repeatedly claimed to have 10 years of local precipitation data, but never showed them to our team.

The 10th TEMR – (Closure Mine Construction Phase, August 2007 (May – August 2007) Appendix 2: meteorological data 1998-2007) apparently contains such data, but we have not reviewed the details or adequacy of these data.

Water Quality / Waste Issues.
MSC has argued that all of the shallow ground water in the area prior to project initiation had water quality unsuitable for use by humans, livestock, or for irrigation. Local residents argue this is not true; they previously drank and used it. Unfortunately, the pre-operational baseline data collected by Knight Piesold are inadequate to clearly demonstrate that relatively high quality water existed prior to operations in most areas.

Discussions with members of regional municipalities and SERGEOTECMIN indicate that some **fresh water is (and was) available within the shallow aquifer** prior to commencement of mine operations. This was further confirmed in discussions with the senior staff of the Bolivian Lithium Project. Water for human consumption presently comes from a roughly 50 meter-deep well in the community of Rio Grande**,** about 18 km from the Lithium Project site and less than 30 km from the nearest MSC well fields. It is likely that the MSC ground water extraction will also consume or impact some of the fresh waters originally present in the upper 50 meters of the local sediments.

Based on discussions with both MSC and SpectroLab staffs, the **water quality samples** were (and are) collected by MSC staff and are supposed to be received at SpectroLab in Oruro within 24 hours after collection. Samples are later filtered at the lab and, when necessary, preservatives are added, prior to analysis. Even if samples have actually been received at SpectroLab within 24 hours---and it seems unlikely given the transportation difficulties---this procedure is guaranteed to give incorrect results, which are likely to yield low concentrations.

These are chemically-complex waters which begin to change chemically within minutes after being collected. That is why internationally-approved procedures (for example see: U.S. Geological Survey, 2008) require that samples be filtered in the field with preservatives subsequently added in the field. If such samples require 24 or more hours before filtration, many of the iron, aluminum, manganese, calcium, etc. compounds begin to come out of solution and form chemical sediment particles—precipitates which settle to the bottom or onto the walls of the sample bottles. These precipitates have electrical charges on their surfaces which attract many of the other trace elements. Thus, at SpectroLab, these particles plus the attached trace elements are filtered out of the samples---prior to the addition of preservative (acid) and subsequent analysis. This would mean that the components in these particles would not be analyzed and the concentrations reported by the lab would be lower than if both filtration and acidification had occurred in the field.
Clearly, such lab results are not useful for making quantitative comparisons to any water quality standards or criteria---regardless of whether results come from SpectroLab in Oruro or ACTLABS in Canada.

MSC has failed to present an organized, statistically-valid, summary of **baseline water quality** data for all relevant surface and ground waters. Such data are routinely collected during the year before regulators give approval for the projects to go forward, and they are routinely presented as part of the EIA. The MSC EIA contains sections that have been called “baseline” water quality [i.e. EIA, v. 4, Append. 1, Tables 7 & 8, EIA, v.3, Append. G], but they lack the necessary numerical / statistical details to be useful as an actual baseline. For example, there is no way to know the actual number of individual analyses that were used to calculate an average, median, minimum, maximum, etc. Also, there is no way to determine whether the data in these tables came from filtered or unfiltered samples [i.e.: Do the data represent Dissolved or Total concentrations?]. Other “baseline” data have apparently been collected in later years, but all of these data sets have never been combined into summarized, pre-mining baseline water quality tables for the following: springs, shallow aquifer, deep aquifer, surface waters.

Without such detailed baseline data, there is no viable way to demonstrate that mining activities have actually changed the water quality---either presently or in the future. Likewise, there is no reasonable basis on which to state that existing water quality is within baseline conditions---as is frequently claimed in the MSC monitoring reports.

It is far more appropriate to compare existing and future MSC water quality to the various international water quality standards and guidelines presented in Table 1.0 than to the unreasonably lax standards of the World Bank, as is frequently done in most of the MSC reports.

Ground Water Quality: As noted above, long-term, high volume pumping from the deeper aquifer is likely to cause leakage of the shallow aquifer water into the deeper aquifer. This process plus the water level declines in the shallow aquifer are likely to degrade water quality in both aquifers (see EIA, V.1, pg.135). In the shallow aquifer, as the water level declines, the coarser-grained sediments are dewatered causing the later dewatering to yield greater percentages of chemical solutes from the finer-grained sediments---which normally contain higher concentrations of dissolved chemicals. The dewatering also changes the geochemical conditions in the sediments around the well thus the chemistry of the waters entering the well change through time.

Surface Water Quality / Ground Water Impacts: Similar metal mines around the world routinely generate the following impacts to nearby surface waters: increased sediment loads; spills of process reagents, gasoline, diesel and other fuels and greases; release of nitrates and ammonia from blasting compound residues into waters; release of acids (naturally-produced and process compounds), contaminated drainages from pit walls, waste rock, ore stockpiles, pit lakes and tailings into surface and ground waters; release of alkaline, contaminated seepages from the fresh tailings and other alkaline process chemicals. It is incorrect to assume that only acid waters cause increased concentrations of minor and trace constituents. When waters or wastes have a pH greater than about 8.5, they readily mobilize many of the oxyanions present in metal ores, such as: arsenic, antimony, molybdenum, selenium, uranium, vanadium, etc.

Geochemical testing of MSC waste rock and tailings indicates that acid drainage will likely develop when adequate water is available. The EIA (p. 131-132, 158) reports that acid drainage will likely form increasing concentrations of aluminum, arsenic, cadmium, cobalt, copper, iron, manganese, nickel, lead, antimony and zinc.

Water Treatment. There is some uncertainty as to whether water provided by MSC to the neighboring towns for human consumption (and some portions of the recycled process water) is treated or not. The monitoring reports (MSC, July 2009 monitoring report, pg.14, sect. 7.1.6) say that a **reverse osmosis treatment plant** is used for such purposes. However, when asked, Mario Velasco of MSC reported that no such treatment plant had been constructed.

It is also unclear whether ground water used as plant process water must be below some salinity or total dissolved solids threshold to be adequate for processing purposes. Our team received conflicting answers regarding this issue.

Tailings Lagoon. Long-term, the **unlined** tailings lagoon is likely to leak and release some volume of contaminants into the nearby shallow ground waters. Furthermore, the EIA predicts that roughly 25,000 cubic meters per day of tailings waters will overflow from the unlined lagoon. MSC has made repeated statements that the sediments below the tailings are impermeable. Nevertheless, all sediments and even dams and synthetic liners leak to some degree over time.

Monitoring wells located down-gradient from the tailings lagoon should be monitored to verify actual seepage amounts and water quality. If excessive volumes of seepage are detected, seepage pump-back systems could be installed.

Contrary to practices in the developed world, existing Bolivian laws do not require tailings impoundments to be constructed with any form of engineered liner.

Concluding Remarks.

- Bolivia has an extensive history of water disputes and conflicts; some of the more notorious include: demonstrations in Cochabamba in 2000 over attempts to privatize the public water supply by the U.S. company Bechtel; attempted legislation to allow transport and sale of Bolivian waters to Chile; capture of spring waters originating in Bolivia on the Chilean side of the border near Silala, which are then transported many tens of kilometers to be used at Chilean mining sites—and the resulting repeated attempts at international agreements.

- The extremely weak Bolivian mining and water laws encourage mining companies to expropriate all available water in their concession areas. In addition, mining companies are not required to pay any form of market price for the water they use, which further encourages wastage and accumulation of the scarce water in this one sector—to the detriment of the farmers, livestock owners, municipalities, and other potential water users (see Moran, 2002).

- Water in such a harsh environment is clearly the most valuable commodity. However, because water for Bolivian mine operations has no real price, any attempt at conducting a cost-benefit analysis, as is often done in environmental impact analyses, is a useless exercise (Moran, 2002). Under such extreme environmental conditions, it is reasonable to regulate water as a "national" resource, with some form of price.

- The present use of massive volumes of ground water at the MSC operations can not seriously be referred to as **sustainable development.** It is extraction with a short-term perspective which will clearly preclude the use of these same waters for other purposes for many decades in the future.

Southwest Potosi contains many other mineral resources which have and may be developed as Bolivian-State operations, and which might provide actual sustainable development. These include:
-large deposits of antimony and other polymetallic deposits which have been developed in the past;
-massive deposits of lithium, potassium, boron and other salts in the Uyuni Salar with tremendous potential;
-salt and sodium sulfate are currently exploited in the Uyuni Salar (Molina, 2007).
In addition, the Salar is the major tourist attraction for the region, bringing in significant sustainable revenue.

The mine generates significant revenue to the central and regional governments, but much of these revenues is actually refunded to the company. Few of these revenues go to provide long-term support for the local communities that are actually impacted.

- Much of the general public mistrusts technical information and opinions that are collected and paid for by the companies that stand to profit from their own opinions. Furthermore, the company information provided to the Bolivian government is largely not integrated and interpreted to show patterns through time.

Many experts argue that the continuing financial crisis in much of the world was partly caused by the increasing self-regulation, self-reporting and weak regulatory enforcement throughout the financial sector. Similar patterns are present in the relationships between Bolivian mining operations and regulators.

- *Financial assurance*. At present, Bolivia does not require mining companies to provide any form of financial assurance to protect the State and society from unforeseen, long-term water (resource) and environmental impacts. In developed countries, most metal mining companies are required to purchase a financial bond or environmental insurance, which is purchased from and held by a party independent of the mining company. MSC has apparently agreed to provide alternative supplies of water to some local, impacted communities. However, if this company were to cease operations unexpectedly (i.e. bankruptcy), the sources of funds necessary to supply these alternative water supplies (or any other needed expenses) would be unavailable. The same is true after the anticipated life-of-mine ends. There will be no cash flow to fund necessary activities. Because it will be, as a minimum, many decades before the aquifers return to their original conditions once the pumping has ceased, it is reasonable to ask: Who will pay for supplying the alternative sources of water?

The post-closure phase is the longest in the overall life cycle of any mine. Nevertheless, it is the phase when the least hydrogeological information is available. Studies in the U.S.A. (Kuipers, 2000) have found that billions of dollars (U.S.) of State and federal funds have been required to pay for unforeseen water supply and contamination problems resulting from closed mining impacts.

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Appendix 1: Political Process Details:
1-Government oversight of water use and environmental aspects: It seems obvious that no Bolivian regulatory agency presently conducts adequate technical review and enforcement of water extraction and related environmental issues at the MSC. Whatever inspections have been performed are largely cosmetic and fail to investigate actual technical aspects of hydrogeologic issues and their impacts.

2-The government environmental oversight that does occur is predominantly intended to protect the interests of the mining company rather than those of the local communities or civil society in general.

3-Site Visit: Our team spent months attempting to arrange a visit to the MSC. The overall conclusion is that MSC would have preferred to avoid allowing a site visit by an *experienced* observer. Some of the details include:
-in May 2009, Dr. Amaral of CGIAB attempted to receive approval for a site visit; she was refused;
-late July 2009, CGIAB staff attempted to arrange a site visit; no responses from MSC;
-Aug. …2009, the CGIAB staff sent an email to the offices of Golden Minerals, parent company of MSC, requesting approval of Dr. Moran to review original MSC documents [most were originally written in English] in their offices in Golden, Colorado, U.S.A. [Dr. Moran lives within 10 km of the Golden Minerals offices.] No response from the staffs of either Golden Minerals or MSC.
-Aug. 3, 2009, Dr. Moran goes to Golden Minerals offices, leaves business card, asks that the General Manager, Mr. Jerry Danni or one of his staff contact him via phone. No substantive response.
-Aug. 10-11, 2009: meetings with the Minister of Environment and Water and his staff to arrange some form of site visit meeting. Sra. Mariel Rodriguez Lafuente arranges to have Moran be part of an official "inspection" team from the ministry. Site visit would occur on Aug. 17-18, 2009.
-Aug. 10, 2009: CGIAB team plus Moran, Ministry staff and members of two of the local municipalities attended organized presentations at MSC followed by visits to various parts of the mine facilities. Despite repeated requests to review actual MSC data with the company technical experts---as opposed to accepting company verbal statements as "truth"---MSC made certain that no actual data or publically-available figures were ever shown or used to allow actual technical dialogue. This pattern of formalized / legalistic interaction was actively encouraged by Sra. Mariel Rodriguez of the Ministry throughout the day. [The ministry representatives made no attempt to interact directly with myself or the representatives of civil society. Instead, they were flown to the site on an MSC

airplane; they lodged at the MSC mine facilities and interacted only with the MSC staff.
-Aug. 11, 2009: The morning had been scheduled for a continuation of the field “inspection”, but instead, all participants were required to attend organized presentations by MSC staff and a consulting geologist [……….] explaining why no problems existed with seepage from the tailings deposit and status of the current MSC ground water model predictions. Again, all attempts to have technical dialogue using the actual MSC data were diverted until MSC asked for a break in their organized sessions, after which they agreed to allow some substantive technical discussions. At this point, Sra. Rodriguez of the M. of M & W, attempted to prevent such discussions. At this point Moran asked that we end the “organized” presentations and the site visit as nothing substantial was being accomplished. Later in the afternoon the group reconvened for about 2 hours to formalize some official documents agreeing that a Ministry “site inspection” had occurred.

4-The Bolivian government clearly knows there is a problem with too much water being extracted at MSC. Apparently they have put pressure on the company to find new sources of ground water. This has resulted in the present (August 2009) water exploration program which was on-going during our visit.

Based on information from the water exploration drilling crew, the company is presently using about 50,000 cubic meters / day and still needs more. The same sources stated that the company was required to drill a new test well; conduct a 24-hour pump test; and prepare a report, all within one month. They further commented that: the well diameter was too small; the capacity of the test pump was too low; the aquifer test duration was too short. Hence, this exercise will not realistically answer the long-term questions concerning the volumes of ground water available, the vertical and lateral extent of water level declines and whether long-term pumping will cause leakage through the neighboring hard rocks to produce impacts from one basin to another. Clearly a much larger scale, longer-term aquifer test is required to shed light on these questions. It seems imperative that an independent party should be overseeing these investigations.

Table 1.0. INTERNATIONAL WATER QUALITY GUIDELINES

Parameter	Units	IFC Precious Minerals[1]	World Bank Guidelines[2]	US EPA	US EPA Aquatic Life[3]		Canada Agricultural[4]		Canada[5]	Canada[6]	Bolivia[7 8] (Selected Constituents)	
		Mine Effluents	Open Pit Mining	Drinking Water[9]	Acute	Chronic	Irrig.	Livest	Drinking Water	Freshwater Aquatic Life	Discharge Waters	Receiving Waters[10]
pH	Units	6.0-9.0	6.0-9.0	6.5-8.5	6.5	9			6.5-8.5	6.5-9.0	6.9	6.0-8.5
TDS	mg/l			500			500-3500	3000	500			1000
Tot Susp Solids	mg/l	50	50								60.0	
Turbidity	NTU											<10.0
COD	mg/l	250	250									
Bioch Ox Dem	mg/l	50	50									
Oil+Grease	mg/l	10									10	Absent
Total N	mg/l	10	10									5
Total Phos	mg/l	2	2									0.4 (Ortho)
Sodium	mg/l								200			200
Chloride	mg/l			250			100-700		250			250
Cl, tot res	mg/l				0.019	0.011						
Sulfate	mg/l			250				1000				300
Sulfide	mg/l	1	1			0.002					2.0	0.1
Nitrate	mg/l			10 (as N)				100	10(N)	13		20
Nitrite	mg/l								1			<1.0
Ammonia (as N)	mg/l				0.002 to 0.325	0.032 to 0.049				0.019	4.0	0.05
Flouride	mg/l	20	20	4.0 (2.0)			1.0	1.0-2.0	1.5	0.12		0.6-1.7
Aluminium	mg/l			0.05-0.2	0.75	0.087	5.0	5.0	0.1	0.005-0.1		0.2
Antimony	mg/l			0.006					0.006		1.0	0.01
Arsenic	mg/l	0.1	0.1	0.05(0.01)	0.34	0.15	0.10	0.025	0.005	0.005	1.0	0.05 (Tot.)
Boron	mg/l								5			1.0
Cadmium	mg/l	0.1	0.1	0.005	0.002	0.00025	0.0051	0.08	0.005	0.000017	0.3	0.005
Chromium,hex	mg/l	0.1	0.1		0.016	0.011	0.008	0.050		0.001	0.1	0.05 (Tot.)

Parameter	Units	IFC Precious Minerals[1]	World Bank Guidelines[2]	US EPA	US EPA Aquatic Life[3]		Canada Agricultural[4]		Canada[5]	Canada[6]	Bolivia[7,8] (Selected Constituents)	
		Mine Effluents	Open Pit Mining	Drinking Water[9]	Acute	Chronic	Irrig.	Livest	Drinking Water	Freshwater Aquatic Life	Discharge Waters	Receiving Waters[10]
Chromium (tot)	mg/l			0.1					0.05		1.0 (+3)	
Copper	mg/l	0.5	0.5	1.3(1.0)	0.013	0.009	0.2-1.0	0.5-5.0	1	0.002-0.004	1.0	0.05
Iron(tot)	mg/l	3.5	3.5	0.3		1	5		<0.3	0.3	1.0	0.3 (Sol.)
Lead	mg/l	0.1	0.1	0.015	0.065 0.025	0.0025	0.20	0.10	0.01	0.001-0.007	0.6	0.05
Manganese	mg/l			0.05				0.2	<0.05			0.5
Mercury	mg/l	0.01	0.01	0.002	0.0014	0.00077		0.003	0.001	0.000026	0.002	0.001
Molybdenum	µg/l						10-50	500		73		
Nickel	mg/l	0.5	0.5		0.47	0.052	0.2	1.0		0.025-0.15		0.05
Selenium	mg/l	0.1	0.1	0.05		0.005	0.02-0.5	0.05	0.01	0.001		0.01
Silver	mg/l	0.5	0.5	0.1	0.0032	0.0019				0.0001		
Thallium	mg/l			0.002						0.0008		
Uranium	µg/l			30			0.01	0.2	20			0.02 (Tot.)
Zinc	mg/l	2	2	5	0.12 0.12	0.12	1.0-5.0	50.0	5	0.03	3.0	0.2 (Pest.)
Alpha, Gross	picoCi/L			15								0.1 (Bq/L)
Radium	picoCi/L			5								
Cyanide (total)	mg/l	2(0.20)	1		0.022	0.0052			0.2	0.0005		0.02 (form?)
Cyanide(free)	mg/l		0.1	0.2							0.2	0.02 (form?)
Cyanide WAD	mg/l	0.5 (0.05)	0.5									
Chlor,tot resid	mg/l	0.2	0.2									
Phenols	mg/l	0.5	0.5							0.004	1.0	
Fecal Coliform	MPN/100ml	400	400						<5	100		
Tot. Colif.									<5	1000		
Temp (increase)		<3°C	<3 C								±5.0°C	±3.0°C (receptor)
Salinity (change)		<20%	<20%									

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http://www.epa.gov/waterscience/pc/revcom.pdf
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