

Comparison of post-closure regulatory frameworks in Australia and South American countries

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Abstract

Within mine closure planning, post-closure is the stage that follows the implementation of the Closure Plan, which includes monitoring and verification of emissions and effluents and, in general, the monitoring and control of all conditions resulting from the implementation of the measures and activities of the Closure Plan (Government of Chile 2012, Decree 41 that approves the Mine Closure Regulation of Mine Closure Law Chile). The post-closure stage has a fundamental role in proving that the physical and chemical stability of a mine site is maintained over time, as well as protecting the health and safety of people and the environment. In this way, post-closure seeks to identify deviations in these components in time, as well as the implementation of the necessary maintenance activities to avoid the degradation of the closure works.

Globally, the criteria for defining post-closure activities changes depending on the legislation of each country or region according to: the maturity of the environmental, mining and closure legislation; the way in which these legislations evolve; the economic development of the country or region, the available monitoring and maintenance technologies, among other factors.

The objective of this paper is to compare closure regulations of different jurisdictions that host medium and large-scale mining. The purpose of this comparison is to identify the similarities and differences with respect to post-closure monitoring and maintenance activities required by closure legislation, and to analyse the relative maturity level of post-closure practices at these jurisdictions.

In this way, the mining regulations associated with post-closure in Australia and South American countries (e.g., Bolivia, Brazil, Chile, Colombia, Ecuador and Peru) will be presented at first. Subsequently, different relative maturity levels will be defined with respect to post-closure activities according to post-closure aspects, such as existence of specific legislation for mine closure, and enforceability of the post-closure program and duration of the post-closure stage. Finally, a post-closure maturity level is assigned to each jurisdiction's legislation, based on the previously defined maturity levels.

Keywords: *post-closure, regulation, monitoring, maintenance*

1 Introduction

The Chilean closure law N°20,551 defines post-closure as the stage that follows the execution of the closure plan, which includes the activities of monitoring and verification of emissions and effluents and, in general, the follow-up and control of all those conditions that result from the execution of the measures and activities of the closure plan, to ensure the physical and chemical stability of the site over time, as well as the safeguarding of life, health, safety of people and the environment (Government of Chile 2012).

The objective of this paper is to compare closure regulations of different jurisdictions that develop medium and large-scale mining, specifically, with respect to post-closure monitoring and maintenance activities. The purpose of this comparison is to identify the similarities and differences with respect to post-closure monitoring and maintenance activities required by closure legislation, and to analyse the relative maturity level of post-closure practices at the different jurisdictions analysed.

The jurisdictions chosen for this comparison are Australia (Western Australia and Queensland), Bolivia, Chile, Colombia, Ecuador, Minas Gerais (Brazil) and Peru.

2 Methodology

The methodology used in this paper consists of three main steps:

1. A review of the relevant legislation in each of the jurisdictions mentioned was performed. Verifying the existence of environmental, mining and post-closure requirements for each jurisdiction. The existence of support guides for such legislation was also verified, which is helpful in some cases to understand the way in which the post-closure stage is implemented.
2. Definition of different relative maturity levels are defined regarding to post-closure activities and considering different aspects of the post-closure stage. For this purpose, after collecting all the post-closure information from each of the jurisdictions, different aspects are defined for the relative maturity of the legislation related to the post-closure stage, such as: existence of specific legislation for mine closure, enforceability of the post-closure program, duration of the post-closure stage, definition of completion criteria, and definition of post mining land use. A relative maturity assessment equation is defined according to the afore mentioned aspects.
3. Finally, based on the information gathered on the post-closure legislation of each jurisdiction, each of them is ranked by its corresponding, previously defined, relative maturity levels, and a General Relative Maturity Level is calculated through the equation defined previously.

3 Data

The information on the legislative framework for the post-closure stage collected for each of the jurisdictions of focus is presented below.

3.1 Legislation review by jurisdiction

3.1.1 *Western Australia*

The state of Western Australia (WA) has two pieces of legislation that regulate mine closure, which correspond to The Mining Act 1978 (Government of Western Australia 1978) and The Environmental Protection Act 1986 (Government of Western Australia 1986).

The Mining Act 1978 outlines the law as it relates to mining, and for incidental and other purposes. The Environmental Protection Act 1986, on the other hand, provides for the prevention, control and abatement of pollution and environmental harm, for the conservation, preservation, protection, enhancement, and management of the environment and for matters incidental to or connected with the foregoing.

In addition, some guidelines are available to assist in the implementation of the above-mentioned laws: (1) Statutory guidelines for mine closure plans (2020), (2) Mine Closure Plan Guidance - How to Prepare in Accordance With the Statutory Guidelines (2020), (3) Guidelines For Preparing Mine Closure Plans (2015) and (4) A Framework for Developing Mine-Site Completion Criteria in Western Australia (2019).

3.1.1.1 *Statutory guidelines for mine closure plans*

The Statutory Guidelines for Mine Closure Plans (2020) is the guideline approved by the Director General, Department of Mines, Industry Regulation and Safety on 31 January 2020 under section 700 of the Mining Act 1978. It identifies the form and content of information required in a mine closure plan. Thus, in relation to post-closure, the guide indicates mine closure plan must include:

- A monitoring framework to monitor the progress of the closure implementation strategies for achieving closure outcomes and completion criteria
- Description of proposed post-closure monitoring
- A description of the monitoring methodology

3.1.1.2 Mine closure plan guidance

In addition, Mine Closure Plan Guidance (2020) detail the mandatory form and content of information required in a mine closure plan. The purpose of this guidance document is to assist applicants in preparing mine closure plans to meet Western Australian regulatory requirements. Thus, in relation to post-closure, the guide indicates:

- There must be a sufficient timeframe nominated to undertake monitoring and maintenance until it can be demonstrated that closure outcomes and completion criteria have been met.
- Completion criteria have been defined in the mining context as agreed standards or levels of performance that indicate the success of rehabilitation and enable an operator to determine when its liability for an area will cease.
- In the early stages of the project or where detailed information on closure performance is not available, a minimum post closure monitoring period should be provided for in the mine closure plan, usually in the order of 10 years.

3.1.1.3 Guidelines for preparing mine closure plans

The Guidelines for Preparing Mine Closure Plans (2015) provided guidance on the preparation of mine closure plans to meet Western Australian regulatory requirements until the implementation of the Mine Closure Plan Guidance (2020). Thus, in relation to post-closure, the guide indicated the following information with regard to its monitoring and maintenance program: (1) appropriate detail on the monitoring framework to be implemented for each of the closure criteria, (2) use of recognised or acceptable monitoring methodologies and standards, (3) monitoring that takes into account the wider receiving environments, receptors and exposure pathways, (4) monitoring using appropriate quality control systems and procedures in sampling, analysis and reporting of results, (5) referencing trends against expected or predicted performance based on agreed closure criteria, (6) contingency strategies if monitoring data indicates key environmental indicators move outside agreed closure criteria, and (7) post-closure monitoring to continue until agreed completion criteria has been demonstrated to be met.

3.1.1.4 Framework developing mine-site completion criteria in WA

The intent of the Framework for Developing Mine-Site Completion Criteria in Western Australia (2019) is to support the development and implementation of completion criteria and associated monitoring programs as outlined in the Guidelines for Preparing Mine Closure Plans (DMP and EPA 2015). Completion criteria are defined as agreed standards or level of performance that indicate the success of rehabilitation and enable an operator to determine when its liability for an area will cease.

The Department of Mines, Industry Regulation and Safety (DMIRS) and the Environmental Protection Authority (EPA) require the following information to be included in a Mine Closure Plan:

- Completion criteria that will be used to measure rehabilitation success
- Completion criteria that will demonstrate the closure objectives have been met
- Completion criteria developed for each domain which consider environmental values

The aim of the Framework is to provide greater consistency for mining companies to develop risk-based completion criteria and monitoring.

The framework identifies six key components in the development of, and assessment against, completion criteria: (1) selection of post-mining land uses (PMLUs); (2) aspects and closure objectives; (3) selection of references; (4) selection of attributes and risk-based prioritization; (5) development of completion criteria; and (6) monitoring.

3.1.2 Queensland

The state of Queensland has three pieces of legislation that regulate mine closure, which correspond to The Mineral Resources Act 1989 (Government of Queensland 1989), The Environmental Protection Act 1994 (Government of Queensland 1994) and The Mineral and Energy Resources (Financial Provisioning) Act 2018 (Government of Queensland 2018).

The Mineral Resources Act 1989 sets out limited objectives and is largely focused on the procedures for granting and regulating mineral and coal resource tenure and mining equipment. Its principal objectives are *encourage environmental responsibility in prospecting, exploring and mining*, and *encourage responsible land care management in prospecting, exploring and mining*.

The Environmental Protection Act 1994 (the 'EP Act') is a key element of Queensland's environmental legal system. Its objective is to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains ecological processes (ecologically sustainable development). Under the EP Act, environmental protection policies are developed to cover specific aspects of the environment. There are approved policies for the air environment, acoustic environment, and for water and wetland biodiversity.

In addition, the EP Act has a key role in setting and administering land rehabilitation principles. In 2018, it introduced new requirements for progressive rehabilitation and closure plans (PRC plan) for large or complex mines. The EP Act also requires that all resource activities must have financial security requirements in relation to rehabilitation in place, prior to the activity commencing on site. For large mining operators, the amount of financial security that must be paid is reassessed every five years, if not before, to ensure the payment reflects the level of disturbance on site.

The Mineral and Energy Resources (Financial Provisioning) Act 2018 does not expressly address mine closure in any of its objectives, but it states the intention to *encourage responsible land care management in prospecting, exploring and mining*. Whilst 'mining' is not defined, 'mine' is defined to mean carrying on an operation *for the purpose of extracting a mineral from its natural state*. This Act introduced the Financial Provisioning Scheme, which supports the management of the financial security for rehabilitation paid by resource companies.

In addition, some guidelines are available to assist in the implementation of the above-mentioned laws: (1) Guideline: Progressive rehabilitation and closure plan for mined land (2019) or Guideline PRC plan, and (2) Guideline: Rehabilitation requirements for mining resource activities (2018).

3.1.2.1 Guideline: Progressive rehabilitation and closure plan for mined land

The Guideline PRC plan (2019) assists applicants in developing a PRC plan as part of a site-specific application for a new mining activity and for existing environmental authority holders who are required to develop a PRC plan under section 754 of the EP Act. The PRC plan contains two sections. The PRCP schedule – an enforceable section which sets out the rehabilitation milestones that are to be achieved by when through-out the life of the operation. The Second is the rehabilitation planning part. The rehabilitation planning part of a PRC plan must contain a monitoring and maintenance program that identifies and describes the monitoring systems that will be carried out to demonstrate when the milestone and milestone criteria specified in the PRCP schedule section have been achieved. The program must include, where relevant to the milestone and milestone criteria (but not limited to): (1) Schedule of monitoring, reporting and review for each milestone; (2) description of methodologies and standards, which could include field-based assessments and the application of new remote sensing, GIS and other relevant emerging technologies; (3) monitoring that enables the repeatable collection of relevant statistically valid data; (4) monitoring using appropriate quality assurance and data management processes and systems regular analysis of site data including multi-year comparison trends and benchmarking against analogue/reference sites; (5) contingency strategies if monitoring data indicates milestone criteria are not being met; (6) post-closure monitoring to ensure

milestone criteria has been demonstrated; and (7) intent of monitoring reports, such as provision of results and key findings.

3.1.2.2 Guideline: Rehabilitation requirements for mining resource activities

The Guideline: Rehabilitation requirements for mining resource activities (2018) provides information on both progressive and final rehabilitation requirements for large or complex resource projects operating in Queensland under the EP Act. The guideline also explains how the administering authority will assess whether progressive or final rehabilitation for either new or established mining projects is satisfactory. Assessment will be based on the accepted rehabilitation objectives for each domain within the mine site and monitoring of indicators to demonstrate that the completion criteria have been met and are likely to be sustained for an acceptable period.

3.1.3 Perú

Peru has four pieces of legislations that regulate mine closure, which correspond to Unified Text of the General Mining Law (1992), National Environmental Impact Assessment System Law 27.446 (2001), Mine Closure Law 28.090 (2003), and General Environmental Law 28.611 (2005).

The Law 27.446 imposes the requirement to submit a mine closure plan as part of the environmental and social impact assessment process.

In addition, the Mine Closure Law 28.090 has eight supreme decrees, of which the most important one related to closure corresponds to DS 033-2005 EM that establishes procedures for the elaboration and submission of mine closure plans.

Of the previous legislations, the one that most refers to post-closure is DS 033-2005-EM. Below are the articles related to post-closure.

3.1.3.1 DS 033-2005-EM - ARTICLE 24 Mandatory closure, maintenance, and monitoring plan

In all the facilities of the mining unit, the mining activity owner is enforced to implement the closure measures established in the approved Mine Closure Plan, as well as to maintain and monitor the effectiveness of the measures implemented, both during its execution and in the post-closure stage.

The monitoring program (location, frequency, elements, parameters and conditions to be monitored) will be proposed by the mining activity owner and approved by the authority, which will be specific according to the characteristics of each area, work or facility and must be carried out until the physical and chemical stability of the mining components subject to the Mine Closure Plan is demonstrated.

3.1.3.2 DS 033-2005-EM - ARTICLE 31 Post closure

Once closure of the areas, workings and facilities used by a mining unit has been completed, the mining holder must continue to develop the corresponding effluent and emissions treatment, monitoring, maintenance, or surveillance measures, in accordance with the Mine Closure Plan approved by the competent authority. The execution of engineering and infrastructure construction works for environmental rehabilitation are not included in the post-closure stage.

The post-closure stage will be in charge and under the responsibility of the operator of the mining activity for a period of no less than five years after the conclusion of the execution of the Mine Closure Plan. This period could be extended until the mining activity operator demonstrates, through the implementation of post-closure activities, that physical and chemical stabilization of mine wastes or components has been achieved. In this case, an amount at present value will be deducted from the guarantees corresponding to the projected additional post-closure time that is necessary or in perpetuity as required, so that the State, directly or through a third party, will be responsible for maintaining the established post-closure measures. The remaining amounts of the guarantee will be returned to the operator.

3.1.3.3 DS 033-2005-EM - ARTICLE 63 Financing and maintenance of post-closure measures

The value of the measures that must continue to be executed after the post-closure period, which is under the responsibility and liability of the mining holder, in accordance with the provisions of Article 31 of these Regulations, shall be determined as net present value and, if applicable, shall be established to perpetuity. To determining the value, measures to be executed for more than thirty (30) years shall be considered as perpetual.

3.1.4 Chile

The state of Chile has the following legislation related to mine closures: Law 19,300 that approves the law on general bases of the environment (Government of Chile 1994), and Law 20,551 (Government of Chile 2012c) that regulates the closure of mine sites and facilities. These laws have their own regulations, which are approved by Decree 40 and Decree 41 respectively.

Law 19,300 establishes a general framework for regulating the right to live in a pollution-free environment, the protection of the environment, the preservation of nature and the conservation of the environmental heritage. It also regulates environmental management instruments such as the Environmental Impact Assessment System, among others. The regulation of Law 19,300 establishes the rules that will regulate the Environmental Impact Assessment System and Community Participation in the Environmental Impact Assessment process.

Law 20,551 requires all mining sites to have a closure plan approved by the Service, prior to the start of mining operations, which must contain all the facilities of the site. The regulations of the closure law establish the rules that regulate the closure of mining sites and mining facilities, in accordance with the precepts of Law 20,551. In addition, it complements the regulatory framework established in Law 20,551 for the purposes of its implementation.

In addition, some guidelines are available to assist in the implementation of the above-mentioned laws: (1) Guidance for the description of copper and gold-silver mining development projects in SEIA (2017), (2) Methodological guide for the presentation and updating of closure plans subjected to the general application procedure (Methodological Guide for Closure Plan) (2020), (3) Methodological Guide for Chemical Stability of Mining Sites and Facilities (2015), and (4) Methodological Guide for Evaluation of the Physical Stability of Remaining Mining Facilities (2018).

The objective of the Methodological Guide for Closure Plan is to provide guidelines and orientations to the owners of mining companies and to the National Service of Mining and Geology (SERNAGEOMIN), for the preparation, presentation and evaluation of mining site closure plan projects, and their updates, subjected to the General Application Procedure of Law 20,551. Regarding post-closure it indicates that:

- A summary table with the post-closure measures committed to in the sectoral permits must be presented.
- A general summary table (in editable format) must be submitted that includes all the facilities at the site indicating the post-closure measures committed. This summary table should indicate for each monitoring element, the name of the facility, reference of the measure, type of monitoring, description of the monitoring, monitoring points, monitoring periodicity and duration.
- Post-closure schedule: A schedule detailing the execution of post-closure measures for each facility must be submitted. In addition, an editable Gantt chart type table must be submitted showing at least the post-closure measures, execution period and frequency for each of the facilities and/or site (must consider monitoring and maintenance measures in perpetuity).

3.1.5 *Bolivia*

As indicated in the Methodological Guide on Mine Closure (, CEPAL, 2020) in Bolivia, mine closure regulation is subject to the environmental regulatory framework, which is mainly constituted by the Environmental Law N°1,333 (1992); Supreme Decree N°24,176 that regulate the Environmental Law (1995), the General Regulations on Environmental Management (modified and complemented by DS 26,705), the Regulations on Environmental Prevention and Control (modified and complemented by DS 26,705), and the Environmental Regulations for Mining Activities (DS 24,782; 1997).

Thus, the Environmental Regulation for Mining Activities (DS 24782 of 31/08/1997) rules mine closure activities in its Title VII. All mining operators are obliged to submit to the closure rules by the Regulation.

The Regulation requires a Closure and Rehabilitation Plan for the Area, which must be approved prior to the start of operations. Article 67 requires, among others, post-closure actions, which are the stability control of waste accumulation's structure and the flow monitoring of: drains, channels of closed reservoir, dams or landfills and of seepage monitoring wells.

The Regulation considers that post-closure is a three-year period after the implementation of closure activities (article 69). This period purpose is maintaining emissions and discharges within the limits established in the regulations of the Environmental Law, as well as to ensure that there are no signs of instability in waste accumulations. For this purpose, the mining concessionaire or operator must submit to the Environmental Authority an audited report on actions, their evaluation and the state of the area of operations.

In the Mining and Metallurgy Law (N°535 of 27 May 2014) there is only one article referring to closure. Article 221 details the obligation of all mining holders to make accounting provisions in their projects to cover the closure of their operations.

3.1.6 *Colombia*

As indicated in the Methodological Guide on Mine Closure (A. L. Morales y M. Hantke Domas, CEPAL, 2020), Colombia has the following legislation related to mine closures: Law N°2,811 of 1974 Renewable Natural Resources and Environmental Protection Code, Law N°99 of 1993 National Environmental System, Law N°685 of 2001 Mining Code, and Law N°1333 of 2009 that imposes sanctions on the offender when carrying out remediation works ordered by the environmental authority.

Additionally, Colombia has four decrees related to mine closure: Decree N°2,820 of 2010 Regulates Title VIII of Law N°99 of 1993 on Environmental Licensing, Decree N°933 of 2013 which refers to events in which environmental authorities may impose environmental restoration and rehabilitation measures to achieve appropriate mine closure, Decree N°1,076 of 2015 Environmental Regulatory, Decree 1073 of 2015 Mine Regulatory Administrative Sector of Mines and Energy.

The Mining Code states with respect to mine closure:

- Article 45 provides the subscription of a concession contract between the State and a private entity, which regulates, among other things, the closure or abandonment of the corresponding works.
- Article 84 indicates that the concessionaire, to start its operation stage, must submit a 'Work Program' to the granting authority, which must include a plan for the operation, closure and installations and infrastructure abandonment.
- Article 204 indicates the Mining Code obliges the concessionaire to submit an environmental impact study for its mining project.

Decree 1076 of 2015 states that three months before the decommissioning and abandonment phase, the concessionaire must submit a study to this effect. If the environmental authority authorises this phase, the licensee must submit a policy covering the costs of the activities described in the decommissioning and

abandonment plan, which must be constituted in favour of the competent environmental authority. The renewal must be carried out annually for three more years after the end of this phase. This three-year period is the post-closure phase in Colombia. From an environmental perspective, post-closure is only guaranteed for up to three years after the dismantling and abandonment of the deposit.

3.1.7 Minas Gerais (Brazil)

The State of Minas Gerais (Brazil) has the following legislation related to mine closure: (1) ANM Resolution 68 (2021), and (2) COPAM Normative Deliberation N°. 220 (2018).

ANM Resolution sets the rules regarding the Mine Closure Plan, and indicates that every mining project must have a Mine Closure Plan (Article 2), which is defined as: a set of procedures for the decommissioning of the mine area after mining activities, including the demobilization of temporary support structures for mining and beneficiation operations, the physical and chemical stability of the remaining structures and their monitoring, as well as the enabling of the area for a new mineral exploitation or other future use.

In addition, ANM Resolution Article 5 indicates that projects in the process of applying for a mining permit or with mining activity that has not yet begun, must provide the following information in regard to post-closure:

- Main monitoring and maintenance actions planned in the area
- Physical-financial schedule of the Mine Closure Plan (PFM), integrating pre-closure, closure and post-closure actions

In the same way, ANM Resolution Article 6 indicates that the Mine Closure Plan for mines in closure by exhaustion, besides the elements of Article 5, must contain the following contents regards to post-closure:

- Maintenance and monitoring actions for the remaining structures after the enterprise is closed.
- Guidelines for adapting the area to the foreseen future use.

For its part, ANM Resolution Article 7 indicates that operating mines do not add more post-closure related content.

3.1.8 Ecuador

As indicated in the Methodological Guide on Mine Closure (A. L. Morales y M. Hantke Domas, CEPAL, 2020), Ecuador has the following legislation related to mine closure: Mining Law N°. 45 of January 29th, 2009; Environmental regulations for mining activities, Regulation on safety and health at work in the mining industry, Regulation to the Organic Environmental Code, and Organic Environmental Code.

There is no law which regulates mine closure. However, Article 186 of the Organic Environmental Code states that a closure and abandonment plan must be implemented, which will be linked to the environmental management plan.

For its part, the Mining Law refers to closure, either to define it as a phase of the mining activity (Article 27), which must be included in the Service Contract of the mining service provider (Article 40) or in the Mining Exploitation Contract (Article 41).

The Environmental Regulations for Mining Activities details the management of mine closure. In its chapter 10, referring to the specific technical-environmental provisions for closure and abandonment, it states regarding the monitoring of closure activities (Article 127): An adequate period of monitoring should be included in the closure planning. Monitoring should be designed to demonstrate that the proposed compliance criteria and conditions are met and that the site is safe, stable and has achieved the planned closure objectives. Such conditions should be demonstrated for a period of five years after the cessation of mining and closure of the mine or as long as the Ministry of Environment foresees according to the nature of the project.

3.2 Definition of relative maturity levels by aspect

To define the relative maturity of the legislation of the jurisdictions under study, different aspects of importance for post-closure were chosen and are defined below.

3.2.1 Specific mine closure legislation

The existence of specific legislation that regulates mine closure is considered important for the relative maturity of the post-closure stage, because in jurisdictions where there is specific closure regulation, it is possible to regulate post-closure issues more precisely, for example, by requiring specific content in the closure plans, such as monitoring frequencies and duration of the post-closure stage, among others.

In addition, as indicated in the Asia-Pacific Economic (APEC) Cooperation Mining Task Force (2018) in its document Mine Closure Checklist for Governments (MCCG), the regulations will reach out to broader topics, *providing a clear pathway through post-closure and relinquishment*, ideally.

The relative maturity associated with this item has been assessed and is shown in Table 1 below.

Table 1 Specific mine closure legislation

Value	Description
1	Jurisdiction does not have any legislation applicable to mine closure
2	Jurisdiction does not have specific closure legislation but has environmental or mining legislation that applies to closure
3	Jurisdiction has specific closure legislation

3.2.2 Post-closure duration

It is considered that a mature post-closure jurisdiction should require that the duration of the post-closure phase depends on the results of the closure measures that have been implemented. Providing an incentive for mining companies to ensure that the closure measures implemented are effective and demonstrate the physical and chemical stability of the facilities.

A rigid post-closure stage duration does not encourage the operator to ensure the physical and chemical stability of the mine site post-closure.

Moreover, MCCG (2018) indicates that the duration of the post-closure monitoring period should be addressed based on site-specific risks, rather than adopting a blanket duration of five or 10 years, which is likely to be excessive in some cases and insufficient in others.

The maturity associated with this aspect has been assessed as shown in Table 2.

Table 2 Post-closure duration

Value	Description
1	Jurisdiction without a specific duration of the post-closure stage
2	Jurisdiction requires a specific duration for the post-closure stage
3	Jurisdiction requires that the post-closure stage last until it is demonstrated that the 'completion criteria' have been met.

3.2.3 *Post-closure program*

The post-closure program specifies information on how the mine holder will ensure the physical and chemical stability of the site over time, as well as the safeguarding of life, health, safety of people and the environment. Generally, a post-closure program provides information on the description, frequency, duration, locations, and compliance indicators for post-closure activities. Therefore, it is considered that a jurisdiction with a relatively high level of maturity should require a post-closure program. The maturity associated with this aspect has been assessed as shown in Table 3.

Table 3 Post-closure program requirement

Value	Description
1	Jurisdiction does not require post-closure program
3	Jurisdiction requires post-closure program

3.2.4 *Definition of completion criteria*

Completion criteria are defined as agreed standards or level of performance that indicate the success of rehabilitation and enable an operator to determine when its liability for an area will cease. In this way the mining holder can ensure the physical and chemical stability of the site over time.

For its part, MCCG (2018) indicates that mine closure policy should ensure that effective progress toward closure objectives is demonstrably made by: (1) monitoring closure works against agreed-upon closure milestones expressed as criteria to be met at a specified time, and (2) providing sufficient post-closure monitoring until all closure criteria are met and relinquishment is formalized.

In addition, MCCG (2018) indicates that in the closure and post closure period, the management and monitoring will, among others, evaluate the success of closure measures.

Therefore, the definition of completion criteria is an important indicator of the relative maturity of a jurisdiction.

The maturity associated with this aspect has been assessed, as shown in Table 4.

Table 4 Definition of completion criteria

Value	Description
1	Jurisdiction does not require completion criteria definition
2	Jurisdiction requires completion criteria definition, but a methodology for their definition is not indicated
3	Jurisdiction requires completion criteria definition and there is a methodology for their definition

3.2.5 *Definition of Post mining land use (PMLU)*

Post mining land use is a term used to describe a land use that occurs after the cessation of mining operations (Western Australian Biodiversity Science Institute 2019).

As indicated in the International Council on Mining and Metals (ICMM) Good Practice Guide (2019), a clear definition of the post-closure land use greatly facilitates closure planning. When the post-closure land use is understood, it aids not only the definition of the closure vision and site-specific closure objectives, but also the selection of closure activities and the definition of success criteria. Therefore, more appropriate completion criteria will be defined when post-closure land use is considered.

Thus, the definition of a PMLU is closely related to the implementation of post-closure activities, as the completion criteria will depend on the post-closure use of the land.

In addition, MCCG (2018) indicates that with the evolution of modern concepts around sustainable development, it may not be sufficient to simply attempt to return the land to the pre-mining conditions, nor is that always the most practical goal.

The maturity associated with this aspect has been assessed, as shown in Table 5.

Table 5 Definition of post mining land use (PMLU)

Value	Description
1	Jurisdiction does not require PMLU definition
2	Jurisdiction supports the definition of a PMLU, but it is not a requirement.
3	Jurisdiction requires PLMU definition

3.3 General relative maturity level (GRML)

To define the General Relative Maturity Level (GRML) of the jurisdictions studied, an equation is considered using the values obtained for each of the aspects indicated in the previous section. For this calculation, the aspect ‘Specific mine closure legislation’ is considered the most relevant. Therefore, the sum of the values obtained for the rest of the aspects will be multiplied by the value obtained from the existence or not of mine closure legislation. Equation (1) below shows how the relative maturity level of each legislation is calculated.

$$GRML = A \cdot (B + C + D + E) \tag{1}$$

where: *GRML* = General Relative Maturity Level, *A* = Specific mine closure legislation value, *B* = Post-closure duration value, *C* = Post-closure program value, *D* = Definition of completion criteria value, *E* = Definition of PMLU value.

4 Results

The results obtained for each jurisdiction assessed, in terms of their relative maturity levels by aspect, are presented below in Figure 1 and Figure 2.

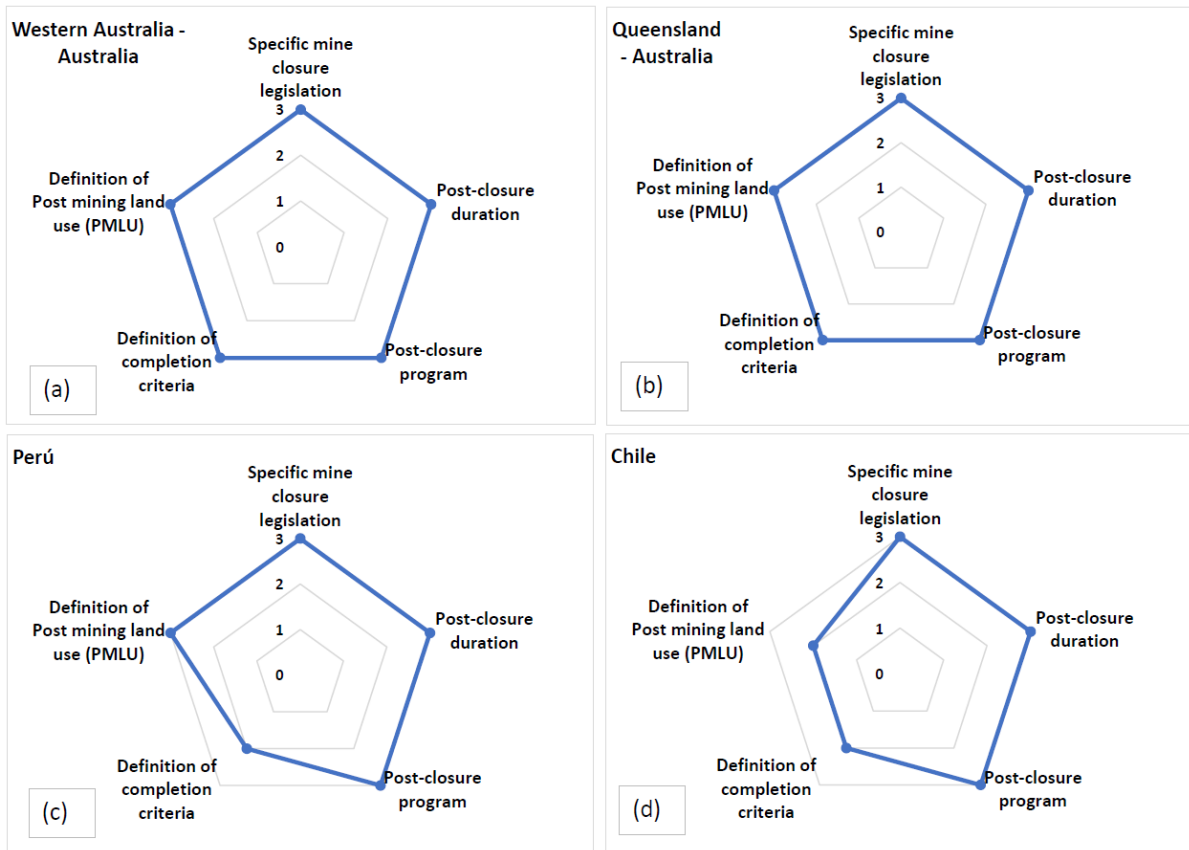


Figure 1 Relative maturity levels by aspect (a) Western Australia, (b) Queensland, Australia, (c) Peru, (d) Chile

Figure 1 shows that the jurisdictions of Western Australia and Queensland, Australia achieve the highest relative maturity values in all aspects studied. Peru reaches the highest maturity values in all aspects, except for the definition of completion criteria, where it reaches maturity level 2 as it does not propose a methodology for its definition. Meanwhile, Chilean legislation reaches the highest maturity values in all aspects, except for definition of post-mining land use and definition of completion criteria, in which it does not propose a methodology for their definitions.

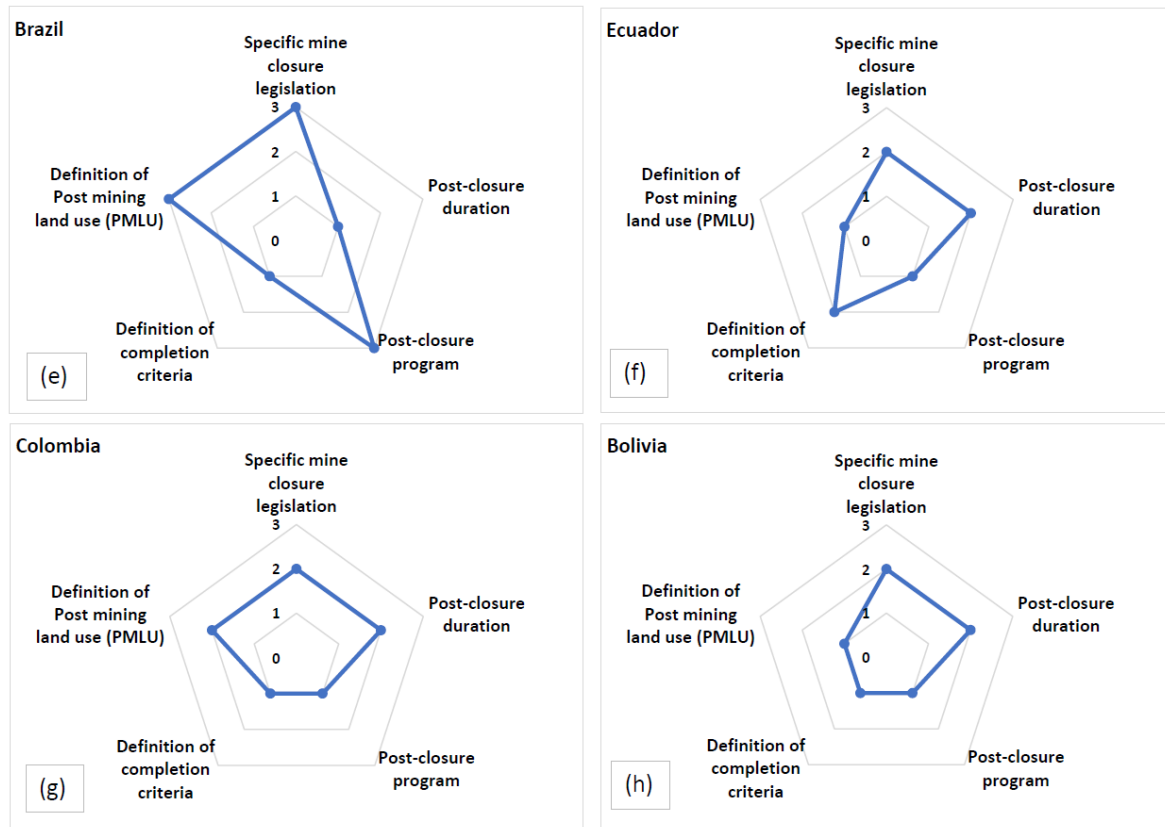


Figure 2 Relative maturity levels by aspect (e) Brazil, (f) Ecuador, (g) Colombia, (h) Bolivia

Figure 2 shows that the jurisdictions of Ecuador, Colombia and Bolivia achieve the lowest relative maturity values in at least two aspects. Meanwhile, Brazil (Minas Gerais) achieves the highest relative maturity value in three aspects, corresponding to specific mine Closure legislation, post-closure program and definition of post mining land use.

Finally, the results obtained for each of the jurisdictions assessed in terms of the general relative maturity level (GRML) are presented in Figure 3 below.

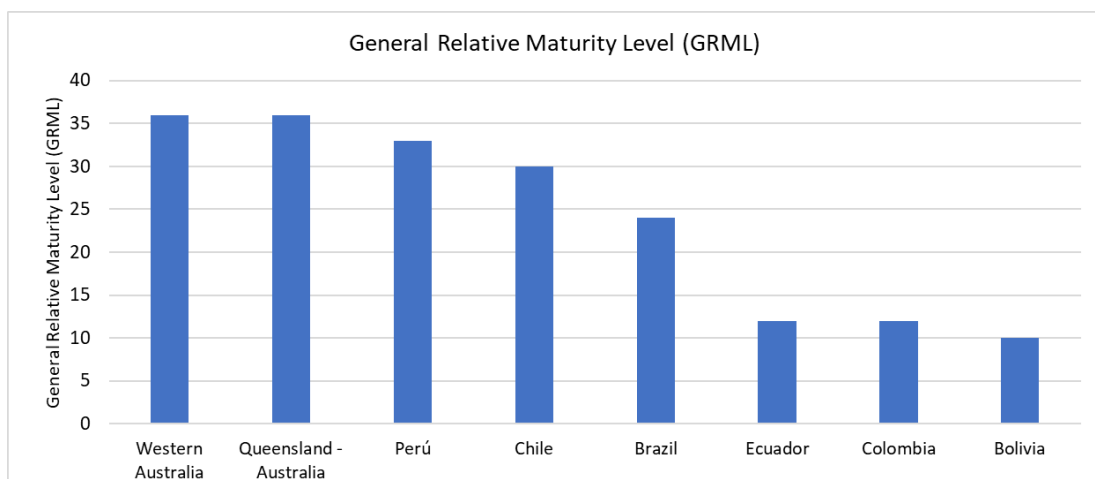


Figure 3 General relative maturity level results

5 Conclusion

The regulations of different jurisdictions were compared with respect to post-closure monitoring and maintenance activities. Through this comparison, similarities and differences were identified with respect to the post-closure activities required by each legislation. In addition, the relative maturity level per aspect was determined for each of the jurisdictions, as well as their GRML. It is important to note that the maturity level of post-closure policies may not reflect the maturity level of mine closure policies overall.

Four groups were identified from the comparison made and the determination of different levels of maturity:

1. The first group corresponds to the legislation of Western Australia and Queensland Australia, which obtained the highest values for the relative maturity levels by aspect and for the GRML. This is to be expected as these legislations date back to the 1970s and 1980s, so they have had time to evolve over time. In addition, the economic, social, and cultural differences between Australian jurisdictions and South American countries cannot be ignored.
2. The second group is composed of the legislation of Peru and Chile, which correspond to jurisdictions that have more recent specific closure legislation (2003 and 2012, respectively). They are based on more mature legislation such as that of Australia. These jurisdictions are at an advanced level of maturity, and well on their way to achieving the higher GRML values.
3. The third category is the jurisdiction of Minas Gerais (Brazil), which has very recent specific closure legislation (2021), so there are still some gaps to reach the group composed of Chile and Peru. These gaps correspond specifically to the definition of the duration of the post-closure stage and the definition of completion criteria.
4. Finally, a group consisting of Bolivia, Colombia and Ecuador was identified. This group of jurisdictions has the lowest GRML values. The main differentiator with respect to the rest of the jurisdictions studied is the lack of specific closure legislation. Nevertheless, in these jurisdictions closure is regulated by environmental legislation, in such a way that there are aspects covered in an intermediate way, such as the requirement of a specific duration for the post-closure stage, as well as the definition of post-mining land use (Colombia) and the definition of completion criteria (Ecuador).

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References

- A. L. Morales y M. Hantke Domas 2020, Methodological Guide for Mine Closure, Economic Commission for Latin America and the Caribbean (CEPAL), Santiago.
- APEC Mining Task Force 2018, Mine Closure Checklist for Governments, APEC Secretariat, Singapore.
- Brazilian Ministry of Mining and Energy 2021, ANM Resolution N°68 that Provides for the rules regarding the Mine Closure Plan, Brazil
- Chile Foundation and SERNAGEOMIN 2015, Methodological guide for chemical stability of mining sites and facilities, Chile.
- COPAM 2018, Normative Deliberation N°. 220 that establishes guidelines and procedures for the temporary suspension of mining activities and mine closure, among others, Brazil.
- Department of Mines, Industry Regulation and Safety 2020, Mine Closure Plan Guidance - How to prepare in accordance with Part 1 of the Statutory Guidelines for Mine Closure Plans, Australia
- Department of Mines and Petroleum, and Environmental Protection Authority 2015, Guidelines for Preparing Mine Closure Plans, Australia
- Department of Mines, Industry Regulation and Safety 2020, Statutory Guidelines for Mine Closure Plans, Australia
- Environmental Assessment Service 2017, Guidance for the description of copper and gold-silver mining development projects in SEIA, Chile.

- Government of Bolivia 1992, Environmental Law N° 1,333, Bolivia
- Government of Bolivia 1995, Supreme Decree N° 24,176 that regulate the Environmental Law, Bolivia.
- Government of Bolivia 1997, Supreme Decree N° 24,782 the Environmental Regulations for Mining Activities, Bolivia.
- Government of Bolivia 2002, Supreme Decree N° 26,705 modified and complemented the General Regulations on Environmental Management and the Regulations on Environmental Prevention and Control, Bolivia.
- Government of Bolivia 2014, Law N°535 of Mining and Metallurgy, Bolivia.
- Government of Chile 1994, Law 19,300 that approves the law on general bases of the environment, Chile.
- Government of Chile 2012, Decree 40 approves regulation on the environmental impact assessment system, Chile.
- Government of Chile 2012, Decree 41 approves the regulation of the closure law of mining sites and facilities, Chile.
- Government of Chile 2012, Mine Closure Law 20,551, Chile
- Government of Colombia 1974, Law N°2,811 of Renewable Natural Resources and Environmental Protection Code, Colombia.
- Government of Colombia 1993, Law N°99 of National Environmental System, Colombia.
- Government of Colombia 2001, Law N°685 Mining Code, Colombia.
- Government of Colombia 2009, Law N°1,333 that imposes sanctions on the offender when carrying out remediation works ordered by the environmental authority, Colombia.
- Government of Colombia 2010, Decree 2,820 that regulates Title VIII of Law 99 of 1993 on Environmental Licensing, Colombia.
- Government of Colombia 2013, Decree 933 by which rules are issued on the formalisation of traditional mining and some definitions of the Mining Glossary are modified, Colombia.
- Government of Colombia 2015, Decree 1073 Mine Regulatory Administrative Sector of Mines and Energy, Colombia.
- Government of Colombia 2015, Decree 1076 Environmental Regulatory, Colombia.
- Government of Ecuador 2009, Decree 119 Environmental regulations for mining activities, Ecuador.
- Government of Ecuador 2009, Law N°. 45 of Mining, Ecuador.
- Government of Ecuador 2017, Law N°0 Organic Environmental Code, Ecuador.
- Government of Ecuador 2019, Decree N°752 Regulation to the Organic Environmental Code, Ecuador.
- Government of Ecuador 2020, Resolution N°. ARCERNR-013 regulation on safety and health at work in the mining industry, Ecuador.
- Government of Peru 1992, Unified Text of the General Mining Law, Peru
- Government of Peru 2001, National Environmental Impact Assessment System Law 27,446, Peru
- Government of Peru 2003, Mine Closure Law 28,090, Peru
- Government of Peru 2005, DS 033-2005 Mine closure regulation, Peru
- Government of Peru 2005, General Environmental Law 28,611, Peru
- Government of Queensland 1989, The Mineral Resources Act 1989, Australia
- Government of Queensland 1994, The Environmental Protection Act 1994, Australia
- Government of Queensland 2018, Guideline Rehabilitation requirements for mining resource activities, Australia.
- Government of Queensland 2018, The Mineral and Energy Resources (Financial Provisioning) Act 2018, Australia
- Government of Queensland 2019, Guideline Progressive rehabilitation and closure plan for mined land (PRC plans), Australia.
- Government of Western Australia 1978, Mining Act 1978, Australia
- Government of Western Australia 1986, The Environmental Protection Act 1986, Australia
- ICMM 2019, Good Practice Guide: Integrated Mine Closure Good Practice Guide 2nd Edition, ICMM, London.
- Pontifical Catholic University of Valparaiso and SERNAGEOMIN 2018, Methodological Guide for Evaluation of the Physical Stability of Remaining Mining Facilities, Chile.
- SERNAGEOMIN 2020, Methodological guide for the presentation and updating of closure plans subjected to the general application procedure – version 2, Chile.
- Western Australian Biodiversity Science Institute 2019, A framework for developing mine-site completion criteria in Western Australia: project report, Australia.