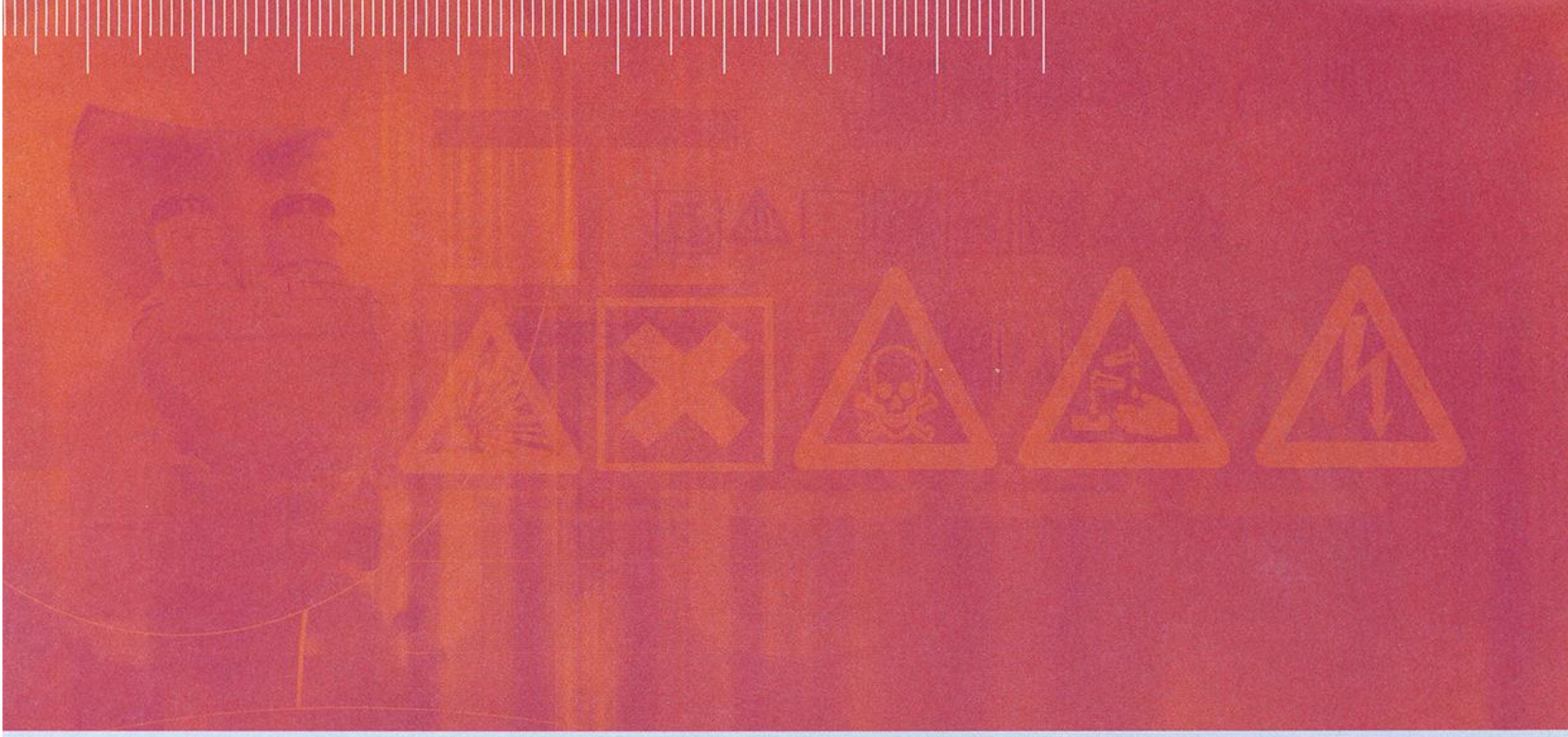


Post-Mining Risk Management in France

DRS-19-178745-02406A 26/03/2019

Cerema GEODERIS INERIS

controlling risks for sustainable development

Post-Mining Risk Management Handbook

Ground and Underground Risks Division

ACKNOWLEDGMENTS

This methodological handbook was developed at the request of the General Directorate for Risk Prevention (DGPR), a division of the Ministry for the Ecological and Inclusive Transition.

It was created under the direction of the French National Institute for Industrial Environment and Risks (Ineris) as part of its missions in support of the Ministry. This document is the result of the work of several different organizations involved in evaluating and managing the residual risks of mining operations, more commonly known as post-mining management: Ineris, Cerema, GEODERIS.

This document is also based on a previous handbook on developing Mining Risk Prevention Plans, which was created under the coordination and scientific direction of Ineris[1].

This document was verified by the Ground and Underground Office of the DGPR with the support of the Post-Mining Divisions.

Directed by: Mr. SALMON (Ineris)

Authors: Mr. SALMON and Mr. FRANCK (Ineris), Ms. LOMBARD and Mr. THIERY (Cerema), Mr. HADADOU (GEODERIS)

Reading committee: Ms. MICHAUT and Mr. ASTIER (B3S), Ms. HANOCQ (Post-Mining Division East), Mr. GIROUD (Post-Mining Division South) and Mr. LEROY (Post-Mining Division West) all contributed their experience and support at various stages in the development of this document.

[1]"L'élaboration des Plans de Prévention des Risques Miniers. Guide Méthodologique. Volet technique relatif à l'évaluation de l'aléa. Les risques de mouvements de terrain, d'inondations et d'émissions de gaz de mine." Ineris Report DRS-06-51198/R01, 05/04/2006.

TABLE OF CONTENTS

1. INTRODUCTION

After having heavily exploited the mineral resources in its subsoil over the course of several centuries, France’s mining sites have gradually shut down. Yet the end of mining activity did not put a stop to the types of phenomena that often affect the surface terrain surrounding former mines. During the period after exploitation has ended, traditionally called “post-mining,” numerous disturbances can develop—sometimes as soon as mining work stops, but sometimes much later.

In addition to ground movement phenomena (subsidence, collapses), former mining sites can sometimes be affected by rising gas, often in dangerous compositions. Moreover, irreversible disruptions in underground water circulation induced by mining can potentially cause disturbances, both in terms of water circulation patterns (flooding in low areas, disruption of waterway flows) and water quality (pollution).

To manage the risks associated with these undesirable events, the State has a number of technical and regulatory tools at its disposal. These tools are used to compile the available knowledge on residual mining risks caused by former mining sites in a given territory, delineate affected areas and define the conditions of construction, occupation and use of soils as well as measures relating to the organization, use or operation of existing property. In France, residual mining risk is unique in that if there is no valid mining title, or if the operator or title holder disappears or fails to act, the French Mining Code renders the State responsible for repairing the damages caused by former mining sites that it authorized in the past.

The purpose of this handbook is to help and facilitate the implementation of these tools. It is intended for all actors who participate in mining risk management (e.g., government organizations, local authorities, consulting firms).

It was designed to be an operational text that will help the reader identify which tools are best suited to local issues. It is supplemented by a technical handbook written specifically on conducting hazard studies (Ineris-DRS-19-178745-02411A).

2. BACKGROUND OF POST-MINING IN FRANCE

2.1 BRIEF HISTORY OF MINING IN FRANCE

Like many other European countries, France has a long-held mining tradition. The extraction and commercialization of raw materials in its subsoil was a decisive contributor to France's development as an industrial power.

In French territory, the earliest evidence of underground mineral resource exploitation (ancient flint mines, salt springs) dates back to the Neolithic age (5th to 3rd millennium B.C.E.). Even before the Roman occupation, the Celts and then the Gallics regularly mined gold and tin (1st millennium B.C.E.). But it was during the Gallo-Roman era that mining truly began to flourish, when silver, lead, copper and iron were all sought out and exploited in turn. At that time, mining activity took place in a multitude of small, local mines scattered throughout the territory (1st and 2nd centuries).

After the fall of the Roman Empire, mining exploration and extraction continued at a slower pace for nearly a thousand years. Under the influence of Central Europe, and in order to meet the growing economic needs resulting from the increasing population and political stabilization, mine prospecting and exploitation began to proliferate once more (11th – 13th centuries). It was during this time that the first coal mining began in the regions of Hérault, Provence and Sarre.

But it was the industrial revolution (17th – 18th centuries) that became the crucial impetus for the development of mining in France. Technological advances helped transform what had previously been essentially an artisan activity into an industrial operation. In addition to the large mining basins (coal, iron, salt, etc.) that would greatly contribute to the wealth of the national economy, the early 19th century also saw a wide diversification of materials being sought and exploited (e.g., oil, manganese, fluorite, zinc).

Mining continued to flourish in mainland France during the first half of the 20th century, primarily driven by the two world wars.

In the aftermath of World War II, the national effort to rebuild the country and reduce France's energy dependency encouraged a mining revival. Coal and lignite production rapidly increased, reaching 60 million tons in 1958, a record year.

Various economic factors, the development of the use of hydrocarbons in energy production, competition from foreign deposits and the depletion of some French deposits gradually led to the decline of mining in France. This decline began in the early 1960s for coal and iron and the early 1980s for other substances, then accelerated since the early 1990s.

The last iron mine closed down in 1995, and the last uranium mining stopped in 2001. Potash mining in Alsace ended in 2003, and the last coal was mined in 2004. The mining industries that remain active in mainland France,[2] aside from deep geothermal deposits, are salt extraction via underground mines or dissolution, bauxite mining and hydrocarbon exploitation.

2 Nickel mining is still very active in New Caledonia. Likewise, there are still substantial gold mines in Guyana.

At the end of the 1990s, in response to various phenomena or nuisances occurring in the areas surrounding former mining sites, including ground movements that caused disturbances in nearby dwellings (mine collapses in Lorraine in 1996, 1997 and 1998 affected over one hundred homes), the French government began to develop tools for managing the consequences of mining cessation in a phase known as “post-mining.”

Furthermore, former mining and industrial areas, which have undergone changes as the mines and related industries have gradually shut down, present serious challenges for planning and developing the layout of the territory, which may be faced with potential risks caused by mining.

Therefore, it is necessary to identify and locate, as precisely as possible, the risks and nuisances that are likely to persist after mining activity has ended in order to be able to determine the possibilities for land development and the operational measures best suited to each context.

2.2 KEY MINING LAWS

The French Mining Code was created in 1956, based on the law of 1810. It was reworked several times and recodified in 2011, resulting in Order no. 2011-91 of January 20, 2011, which is currently in force. A major overhaul of the Mining Code is now in progress.

2.2.1 DIFFERENCES BETWEEN MINES AND QUARRIES

French mining law as we know it today dates from the beginning of the 19^{th} century. In an effort to better manage the mineral resources that were deemed strategic for the nation, the law of 1810 introduced the concept of “concessionable” materials and “non-concessionable” materials.

Concessionable materials include:

- metals (e.g., iron, lead, silver, uranium, gold);
- hydrocarbons, including solids (coal, lignite), liquids (oil) and gases (methane);
- salt, potash, phosphates, etc.

In France mining is the extraction of concessionable materials, while quarries are for extracting non-concessionable materials (mainly construction materials). Thus, it is the nature of the extracted material, not the method of extraction (underground or open-pit) that differentiates mines from quarries.

Since those specific regulations were put in place in 1810, and later codified with the creation of the Mining Code in 1956, the French government has had the power to grant authorizations for mining exploration or exploitation through mining titles (exploration permits and concessions). Mineral substances can be exploited only by the State or by virtue of a concession (L. 131-1 of the Mining Code).

Exploration and exploitation operations are governed by mine policing, the purpose of which is to prevent and stop the damages and nuisances linked to mining and to ensure that operators comply with obligations. Mine policing is done by local police prefects with the assistance of the Regional Directorates for Environment, Town Planning and Housing (DREAL)[3].

The establishment of a concession creates a property right separate from surface property (L. 132-8 of the Mining Code). Machines, shafts, galleries and other "permanent" works are real property (L. 131-4 of the Mining Code), and their ownership is therefore separate from surface ownership (which is attached to the concession).

2.2.2 MINING TITLES

The Mining Code gives enterprises the possibility of:

- carrying out exploration operations by obtaining an exclusive exploration permit, a preliminary prospecting authorization (for sea operations) or a geothermal deposit exploration authorization;
- exploiting a mine by obtaining a concession, even without authorization from the owner of the soil.

Mining titles give their holders recognized property rights but do not authorize the opening of mining works, which is subject to a separate procedure. Mining titles are issued by the Minister of Mines to title holders, who are first required to submit proof of their technical and financial capabilities.

2.2.3 MINING OPERATIONS

As part of the process of opening a new mining operation, an in-depth verification must be conducted on the project's environmental sensitivity and how it has been accounted for based on evidence provided by the mine's operator; requirements are then defined for protecting the site's surrounding environment. Depending on the dangers and risks involved, mining operations must be declared to the prefect or receive an authorization, which is granted after a public investigation is conducted and an impact study is submitted by the applicant. Decree No. 2006-649 of June 2, 2006, on mining work, underground storage works and the policing of mines and underground storage, sets out the regulatory framework for mining operations.

In France, mine policing (monitoring, surveillance and inspection of mining operations) is carried out by engineers and technicians under the orders of DREAL directors. The same departments that police mines also carry out labor inspections in the mines.

2.2.4 PERMANENT CESSATION OF MINING OPERATIONS AND "POST-MINING"

Mining regulations provide for a procedure to end mining operations, as well as measures for preventing mining risks that cannot be eliminated entirely.

[3] The Regional and Interdepartmental Directorate for Environment and Energy in Île-de-France, DEAL in the overseas territories.

These provisions require operators to take all measures necessary to prevent potential risks arising from mining operations (e.g., mine collapses, flooding, pollution caused by effluent discharge). Thus, mining cessation comes with studies on risks (such as those related to ground movements and gas emissions) and hydrological impact, as well as various works to improve safety (e.g., stabilizing waste dumps and slag heaps, demolishing obsolete installations, preventing water pollution risks).

According to the Mining Code, the former mine operator—or, absent that, the concession holder—is responsible for the damages that may be caused by his operations, with no time limit. Nonetheless, if the responsible party disappears or fails to act and cannot ensure that the damages are repaired, the State is the guarantor for repairing the damages and is subrogated to the rights of the victims against the responsible party, in application of Article L. 155-3 of the Mining Code.

Provided that the procedure to end mining operations has been completed, the expiration of the mining title transfers to the State the responsibility of monitoring and preventing major risks such as ground subsidence or accumulation of natural gas. Law no. 99-245 of March 30, 1999, known as the “post-mining law,” reworking the Mining Code, specifically makes the State responsible for risks that persist after mining operations have ended, in the name of national solidarity. When facilities for monitoring and preventing risks remain on former mining sites, the State assumes the responsibility of maintaining them, but is compensated financially by operations that ceased work after that law took effect.

Furthermore, after the risks immediately follow mining have been eliminated or prevented by monitoring facilities (as part of shutting down operations), it is important to manage urbanization in order to prevent new risks from arising. Two regulatory tools have been created:

- conducting and disseminating detailed studies of mining hazards and, if necessary, creating Mining Risk Prevention Plans (PPRMs);
- applying the methodology for managing polluted sites and soils to mining sites and Soil Information Sectors (SIS).

2.3 POST-MINING MANAGEMENT IN FRANCE

While the practice of mining in France is very old, post-mining management[4] has evolved greatly over recent decades. In fact, it was in the late 1990s, after a series of unexpected ground movements that destroyed several tens of homes in the southern part of the iron basin of Lorraine, France, that the decision was made to develop a system for the sustainable management of the consequences of mining activity. The French government set up a group of tools to help ensure the management of post-mining risks. First came the legal tools, with the amendment of the Mining Code to improve long-term risk prevention and allow for the reparation of damages caused by mining. Next were the operational tools: first an independent technical expertise in risk evaluation was developed within GEODERIS; then, via a transfer of the personnel and expertise of the Charbonnages de France (former National Coal Operator), a state-delegated operational management authority on

[4] For mining taking place after the law of 1810.

post-mining (site monitoring and safety) was established under the aegis of the Mine Safety and Prevention Department (DPSM) of BRGM.

INERIS, BRGM and Cerema provide the government with methodological support and are involved in the development of alternative monitoring methods other than visits to galleries or shafts.

The government's role in using these various tools has three objectives: anticipating risk, preventing risk and finally repairing the damages resulting from mining.

In addition to the vast mining regions, particularly for iron and coal, that were industrially developed in the 20th century, there is a multitude of smaller-scale operations (over 5,000 mining titles and over 3,000 municipalities affected), some of them extremely old, scattered throughout France.[5] Mines, the majority which are situated at shallow depths, are likely to cause phenomena of surface instability and/or discharge of pollutants.

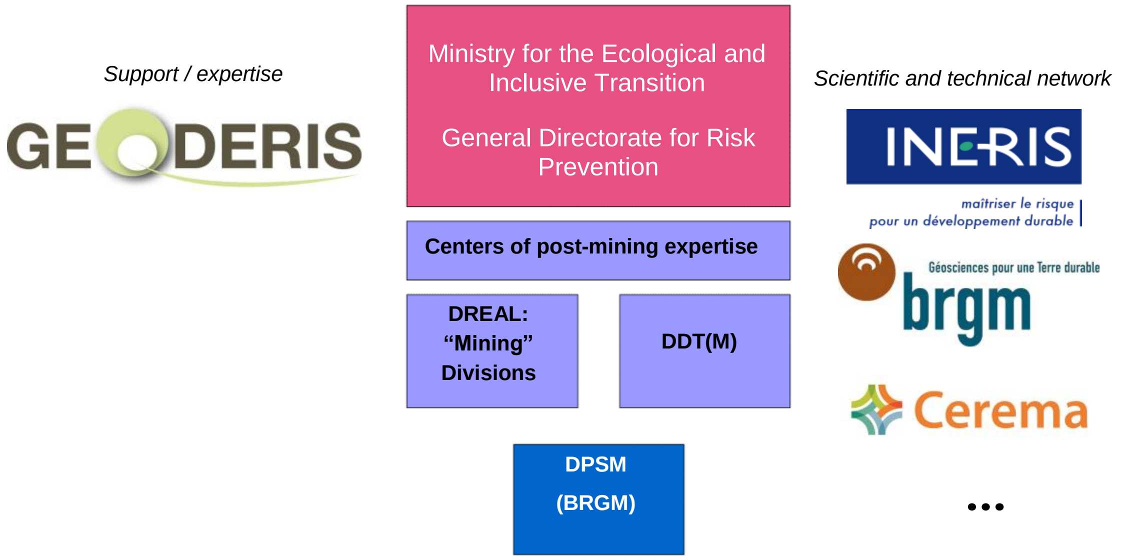


Figure 1: Key players in mining risk management (source: "Mining Risks" Information Session at DREAL)

The key players in the field of post-mining are:

- **DPGR**: the General Directorate for Risk Prevention develops and implements policies on the knowledge, evaluation, prevention and reduction of risks related to human activity and of natural risks;
- **Centers of post-mining expertise**: these centers enable GEODERIS, DPSM and DREALs to collaborate on missions; provide consultation and inter-regional support to DREALs; and act as a liaison between the central administration and the decentralized departments;

[5] Mining companies do not have the status of mining operations under the Mining Code.

- **DREALs**: the Regional Directorates for Environment, Town Planning and Housing form the regional branches of the Ministry for the Ecological and Inclusive Transition;
- **DDTMs**: the Departmental Directorates of Territories and the Sea implement public policies of land-use planning and sustainable development;
- **GEODERIS:** GEODERIS is a Public Interest Group (GIP) formed between BRGM and INERIS that provides assistance and technical expertise on post-mining to the French government (central administrations and decentralized departments, particularly DREALs);
- **BRGM**: the Bureau of Geological and Mining Research is the public institution of reference in the applications of earth sciences in managing the resources and risks of the soil and subsoil;
- **DPSM**: a division of BRGM, the Mine Safety and Prevention Department is the project supervisor delegated by the government (the DREALs).
- **Ineris**: The French National Institute for Industrial Environment and Risks, whose primary mission is to contribute to the prevention of risks caused by economic activities to health, environment and the safety of people and goods. In the context of post-mining, Ineris provides technical support to DGPR in evaluating hazards and risks;
- **Cerema**: The Center of Research and Expertise on Risks, Environment, Mobility and Land Planning is a public institution whose mission is to provide scientific and technical support in developing, implementing and evaluating public policies on land planning and sustainable development, including risk prevention. In the context of post-mining, Cerema provides technical support to DGPR and to decentralized departments in accounting for mining risks in land and urban planning;

3. POTENTIALLY DANGEROUS PHENOMENA IN THE “POST-MINING” PHASE

Phenomena caused by former mining operations may include the following:

- the formation of large residual underground voids, rock faces or deposits of mining residues that can cause **ground movements**, which may endanger the safety of people or cause damages to buildings and infrastructures (cracks, collapses, etc.);
- mines—the largest ones at least—may have contributed to disrupting the circulation of underground and surface water and may have led, sometimes concurrently, to ground subsidence on the surface. When a mine is shut down, the pumping of underground water from the work site also stops; and in the general mining area, there may be a decrease in water consumption by the community and industries in the area. Consequently, the mine closure is accompanied by a rise in the water table level, which has gradually returned to its natural level, partially or completely refilling the reservoirs and voids created by mining, and rejoining the hydrographic network on the surface or topographical low points that may have been created by the mining. These **hydrological and hydrogeological disturbances** may be detrimental to land use or subsoil use;
- the extraction of underground ore contributed to creating a reservoir that may fill up with gas issuing from the exploited rock or from farther away. This gas is a mixture of multiple components with varying content. Under the effects of various mechanisms, mine gas may be directed toward the surface via natural drains (faults, fractures, cracks, etc.) or artificial drains (shafts, galleries, etc.). Mining may also have generated new drains (cracks, crevices) that link underground gas-emitting formations with the surface. These **gas emissions** are potentially dangerous. Furthermore, the natural gases present in the surrounding rock mass are sometimes able to move more freely as a result of destruction caused by mining;
- the extraction or storage of large quantities of solid waste generates physical and chemical instabilities that can cause lasting disturbances in the natural surroundings. One of the causes of post-mining pollution and nuisances is the interaction between mining operations and hydraulic flows, which can lead to contamination of the soil, surface water and groundwater. Surface conditions (air, precipitation) may influence **the discharge into the environment of substances that are potentially damaging or dangerous** to people and/or ecosystems.

The table below describes potentially dangerous phenomena caused by mining.

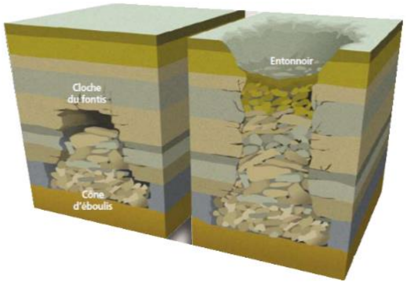
<table>
<tr><th colspan="2">Dangerous phenomena</th><th colspan="2">Description</th></tr>
<tr><td rowspan="2">Mining-induced ground movements</td><td>Localized collapses</td><td>Depending on the initiating mechanism, localized collapses can take the form of “sinkholes,”[6] collapses of shaft heads or gallery heads, or collapses caused by isolated pillar failures.[7]
They are generally characterized by the sudden appearance on the surface of a collapse crater, the diameter of which generally varies from a few meters to several tens of meters.
The dimensions of a localized collapse depend on the size of the void and the nature of the overburden / topsoil that separates the void from the surface.
These phenomena may cause damages to people and structures.</td><td>

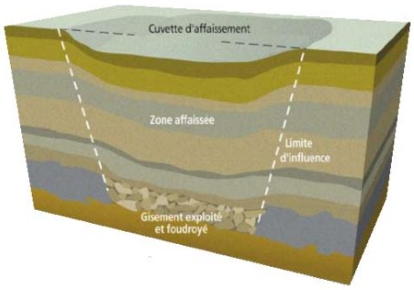
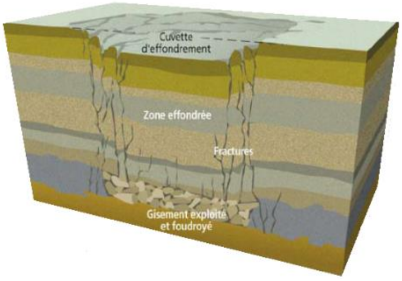
Diagram of a “sinkhole” (source: Graphies, MEDD)</td></tr>
<tr><td>Continuous subsidence</td><td>Continuous subsidence results from the collapse of deep, large-scale underground works. It takes the form of a “bowl[8]” on the surface, several tens to several hundred meters in diameter, with no major breaks.
At the center of the bowl, the land descends vertically.
Along the edges, the land forms into slopes with stretching at the outer edges (causing fractures to open) and shortening at the inner edges (causing bulges to appear).
These phenomena unfold progressively over several days or months, following a dynamic unique to the geological and mining context.
Their consequences generally include damages to buildings located on the surface.</td><td>

Diagram of continuous subsidence (source: Graphies, MEDD)</td></tr>
<tr><td></td><td>Discontinuous subsidence</td><td colspan="2">This phenomenon involves roof failure due to shearing along the support pillars of certain partial exploitations in very specific conditions. The pillars collapse due to overloading, followed by movement of the roof as well as the entire overburden all the way to the surface. Compared to “continuous subsidence,” “discontinuous subsidence” is characterized by the fact that the overburden is mostly rigid and brittle throughout. At the surface, a network of crevices can be observed along the periphery of the panel in question. Given the dynamics of this mechanism, it may be accompanied by one or more seismic tremors.</td></tr>
</table>

[6]Sinkholes are the result of a gradual degradation of the “vault” of a mine gallery, which rises little by little through the overburden until it opens on the surface.

[7]Other localized collapses may result from the ruin of one or more pillars inside an old mine built using the rooms and pillars method. The crater formed on the surface is generally larger than that caused by a sinkhole. Collapses caused by isolated pillar failure are one-time events that are unrelated to the general instability of a mine; rather, they are the result of unfavorable local conditions.

[8]Topographical depression.

Dangerous phenomena		Description	
Mining-induced ground movements	**Generalized collapses**	Generalized collapses are also caused by the collapse of an underground chamber. However, they occur in very specific geological conditions, manifesting themselves by an often dynamic and near-instantaneous collapse of all or part of an exploitation (between the bottom and the surface), thus affecting the stability of surface land over areas that can extend up to several hectares. A seismic tremor may be felt. The part of the collapse affecting the central area may reach several meters in height, or even several tens of meters in the case of collapses of salt dissolution cavities. These phenomena can cause physical dangers and lead to the "irreversible" destruction of property and surface land.	 *Diagram of a generalized collapse (source: Graphies, MEDD)*
	Crevices	In specific cases, mining may lead to crevices in the overburden when subsidence bowls are formed. Some crevices appear on the surface during exploitation, but some do not open or appear until several years later. Crevices take the form of cracks in the soil several decimeters wide and several meters long. The "visible" depth of these crevices is several meters, but the actual depth is unknown.	 *Crevice that appeared in a garden in Cocheren in 2010 (source: GEODERIS)*
	Settlement	Settlement is observed inside mining deposits and sometimes in areas reformed by mine exploitation. In the latter case, settlement is sometimes called "residual movement." It consists of low-magnitude residual movements affecting surface land, both in terms of lowering the land (by several decimeters) and extending the affected surface. Except in specific configurations, its effects are generally limited and are only felt in the most sensitive structures on the surface (very tall buildings for example).	 *Cracks in a building caused by settlement (source: INERIS)*

	Dangerous phenomena	Description	
Mining-induced ground movements	**Slope movements**	These phenomena are observed on the sides of mining deposits or on the slopes of open-pit mines built on loose surface ground. There are two types: • **superficial movements** (involving volumes of around several tens of cubic meters). • **deep movements** (large land mass sliding along a surface, often circular).	 *Residue heap from polymetallic mine (source: INERIS)*
	Rock falls	A rock fall is a sudden movement of a slope during which rock masses of varying volume detach from a usually very steep wall and fall to the foot of the rock face. This type of phenomenon mainly occurs on the faces of open-pit mines excavated out of hard rock with very steep slope angles. Depending on the volume of falling rock, they can be called stone falls, block falls, rock falls or major rock falls.	 *Rock falls on the face of a bauxite mine in Villeveyrac (34) (source: INERIS)*

Dangerous phenomena	Description
Hydrological/hydro geological disturbances, mining-induced floods	Flooding risks linked to natural phenomena (runoff rainwater, watercourse swelling) do not fall under mining risk and thus will not be studied here. They have been the subject of studies in the field of natural risks. Former mining operations and the evacuation of *mine waste water* (during the exploitation phase) as well as *flooding* phenomena (post-exploitation) may disrupt underground and surface water circulation in the following ways: • increase or reduction in the flow of springs or watercourses; • rising water table levels and the appearance of sodden and marshy areas; • flooding in low-lying areas with mine water; • sudden flooding; etc. Flooding due to rising water table level may be due to both the stopping of mine water drainage and a decrease in local water consumption. These phenomena may be taken into account as part of a PPRN (Flooding Natural Risk Prevention Plan). Mine-induced floods can also result from the failure of a settling pond for mine water overflow, the modification of a water outlet after a collapse or due to poor maintenance of an overflow gallery, or the failure of the plug of a mine reservoir.  *Sodden area, iron mine, Pays-Haut Lorrain (54) (source: GEODERIS)*

<table>
<tr><th>Dangerous phenomena</th><th>Description</th></tr>
<tr><td>Mining-induced environmental pollution</td><td>Multiple pollution sources may be present in mining sectors; they are the result of old extraction and exploitation operations.
These sources, which may contain metals (e.g., lead, nickel, mercury) and metalloids (e.g., arsenic, antimony), can potentially cause risks to human health and to the environment.
Natural surroundings can be contaminated by drainage water from inundated mines, runoff water from ore deposits, tailings or washing wastewater, or by seepage water in old mines.
The impact of former mining sites may be felt even in distant territories.

Arsenic pollution in a watercourse, mining region of Cévennes (30). (source: Cerema)

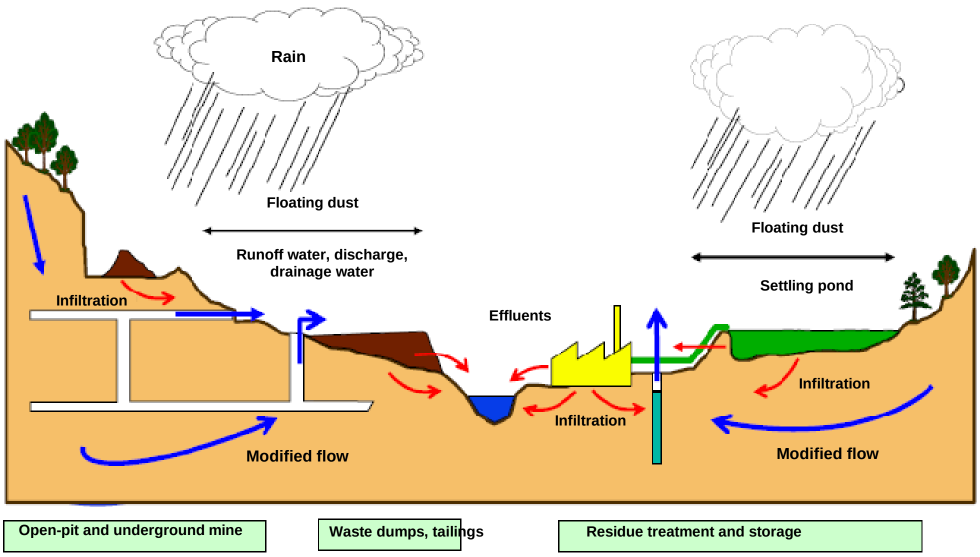
Pollution ↔ [Source + Transfer + Target]


Diagram showing different pollution sources and transfer paths of pollutants in a mining context (source: INERIS)</td></tr>
</table>

Dangerous phenomena	Description
Gas emissions linked to mining	When mines are shut down, non-inundated underground voids can form a more or less confined reservoir in which gases (which are diluted or evacuated by ventilation during exploitation) may accumulate at high concentrations and, when they rise to the surface through underground galleries or through natural faults or fractures in the rock, become potentially dangerous, causing intoxication, asphyxia, inflammation or explosion. Mine gas is generally a mixture of gases of varying origin and content. Some gases are present in the deposit before mining starts (methane (CH_4), carbon dioxide (CO_2), etc.); others are produced by a chemical transformation of the deposit or certain elements of the mine, during or after mining (carbon monoxide (CO), hydrogen sulfide (H_2S)).[9] Mining can also create connections between the surface and geological layers that are likely to emit gas.  *Illustration of mine gas releasing into the air (source: INERIS)*
Ionizing radiation emissions	Former uranium mining sites can cause specific exposures to ionizing radiation due to the uranium content of the materials and waste found there, as well as the presence of radionuclides from uranium. These substances were already present in the ore and rocks before they were extracted from the subsoil, and no new radioactive products were added by mining activity. Rather, the mining modified the distribution and physical state of the uranium and radioactive substances originally present in the subsoil, at the same time leading to an increased risk of dissemination into the environment and thus of human exposure, even after mining has stopped.[10]

[9]The most well-known gas is probably “firedamp,” which is primarily composed of methane released in coal mines and may cause an explosion in ambient air (traditionally called a “firedamp explosion”).

[10] “Les sources d’exposition aux rayonnements ionisants due aux anciens sites miniers d’uranium,” IRSN Sheet, February 12, 2009 (http://www.irsn.fr/FR/connaissances/Environnement/expertises-locales/sites-miniers-uranium/Documents/irsn_mines-uranium_sources-exposition.pdf)

<table>
<tr><th>Dangerous phenomena</th><th colspan="2">Description</th></tr>
<tr><td>Combustion and overheating of mine waste</td><td>Some mining deposits contain combustible materials and other oxidizable substances such as iron sulfides (pyrite). Some deposits may actually combust (with contact from an external heat source or after modifications of the deposit initiating self-heating phenomena).
Combustion in a waste heap can spread slowly from the surface to the very bottom. In this case, the combustion can continue for several decades.
The principal risks associated with this phenomenon are burns, falls into cavities created by combustion, and fire, linked to toxic or flammable gases.[11]</td><td>
Waste heap combustion – Rochebelle site,
Mining region of Cévennes, Alès (30).
(source: GEODERIS)</td></tr>
</table>

Furthermore, the presence of shafts or roadways that are open on the surface, insufficiently plugged, or have uneven borders or hidden infrastructures may present dangers and generate physical risks due to their accessibility (e.g., falls/drowning in a shaft, rockfall in a gallery, intoxication/asphyxiation).

[11] "Guide du détenteur de terrils et autres dépôts miniers issus de l'activité charbonnière (verse, bassins de décantation, dépôts de cendres)." Paquette Y., Laversanne J., 2003. Les fascicules de l'Industrie Minérale, 37 p.

4. MANAGING MINING RISKS

The potentially dangerous phenomena described above are managed with the help of the various tools presented in this chapter. The vast majority of these phenomena are subject to “hazard studies.”

Hazards are evaluated and mapped for the following phenomena: ground movements, gas emissions linked to mining, combustion/overheating of mine waste, hydrological/hydrogeological disturbances and mining-induced floods.

But for the hazard of mining-induced pollution, the task of mapping proves to be highly complex, if not impossible. Evaluating the environmental impact of possible pollution requires:

- a satisfactory characterization of pollution sources, and particularly a description of local geochemical backgrounds;
- accounting for pollution transfer vectors, including meteorological conditions that are likely to lead to a dispersion of pollution over time and space, thus affecting territories located at a far distance from the pollution sources;
- accounting for targets and their exposure, which depends greatly on how the surrounding land is used.

Because of these characteristics, the approach of evaluating hazard and induced risk has been deemed inappropriate for the pollution phenomenon. Thus, the risks related to these phenomena cannot be managed by means of a map of “pollution” hazards, but rather through an environmental study.

4.1 HAZARD STUDIES

“Hazard” is a very commonly used term in risk prevention. It means the probability that a phenomenon—in this case, one caused by mining—will occur on a site, during the course of a reference period, reaching a qualifiable or quantifiable intensity. Thus, hazard characterization is traditionally based on the intersection of **the predicted intensity of the phenomenon** and its **probability of occurrence**. In this context, the concept of **probability of occurrence** refers to how sensitive a site is to being affected by a phenomenon. Regardless of what type of event is anticipated, the complexity of mechanisms, the heterogeneous nature of the natural surroundings, the gaps in the available information and the fact that numerous disturbances, aftereffects or nuisances are not repetitive all demonstrate that it is generally impossible to reason in terms of a probabilistic approach. Therefore, we will prioritize a qualitative classification that characterizes a site’s **predisposition** to be affected by a given phenomenon.

Our knowledge of mining-related hazards was largely developed over the last few years in mainland France.

Understanding the hazards in areas affected by former mining sites requires research that should result in:

- an informative map that shows the site’s positioning in its environment and the details needed to evaluate the mining hazard;

- a hazard map, drawn based on the informative map, that locates and ranks the areas exposed to potential phenomena on the surface. Hazards are classified according to several levels, taking into account the type of phenomena, their likelihood of occurrence and their intensity.

  It does not include how the surface land is used. It objectively records the long-term potential for dangers or nuisances that are likely to be caused by the former mining site within the sector of study.

4.2 ENVIRONMENTAL STUDIES

Regarding the evaluation of the environmental impact of potential mining-induced pollution, an inventory of mining deposits was conducted between 2009 and 2012, covering mainland France, in application of Article 20 of EU Directive 2006/21/CE.

After the inventory was completed, the recorded deposits were grouped into sectors, which themselves were ranked into 6 classes: A, B, C-, C+, D and E. Class E is for sectors that are likely to present a risk highly significant to human health and the environment, while Class A designates sectors that present no risks to human health and/or the environment.

A methodological approach, drawing from one developed for managing polluted sites and soils,[12] determines what type of study should be conducted according to the classification of the sectors in question.

Class D and E sectors are subject to environmental studies following the approach of Interpreting Environmental Conditions, which is used to evaluate in detail the impact of mining on the quality of exposed environments (soil, water, air and foodstuffs) and to determine whether observed, established usages are compatible with environmental conditions. The intermediate classes, C+/C-, are subject to "orientation" studies intended to assess the potential level of risk in the sector in question.

4.3 TOOLS FOR MANAGING EXISTING RISKS

Risk is the intersection of a hazard and its stakes. Risk is evaluated for existing constructions, based on the hazard and its classification, as well as the condition of the land (geological and mechanical characteristics of the land). Government organizations determine the most appropriate measures to implement, namely:

- **monitoring**;
- **treatment of the area** (for example, backfilling cavities, pollution cleanup, etc.). The choice of treatment method depends primarily on:
  - technical aspects;
  - economic aspects;

[12] The methodology for managing polluted sites and soils is applied to the specific case of former mining sites on the basis of the French regulatory text Note of April 19, 2017, on polluted sites and soils.

- environmental aspects, particularly in cases where a site is being closed up.

However, since the existing methods are not universal, the choice also depends on:

- the objectives to be achieved in terms of managing risk and the planned use of the site;
- the fields of application, meaning the sites configurations and the characteristics of the environment in which the treatment is planned;
- the acceptable level of safety based on the stakes on the surface;

- **expropriation** (Art. L. 174-6 of the Mining Code): the decision of expropriation is only made in cases of serious threat to people when the means of safeguarding and protecting populations proves more costly than expropriation.

4.4 TOOLS FOR MANAGING FUTURE RISKS

After knowledge has been acquired through a hazard study, for example, or as part of an environmental study, a certain number of actions must be taken. In addition to informing the public on residual mining hazards and issuing public notifications (PACs), this information, as well as the conditions that will help ensure the prevention of mining risks, must then be taken into account in territorial development, particularly:

- **when processing applications for authorization for land development** (prior declarations, construction permits, development permits);
- **in urban planning documents**, in application of Article L. 101-2 of the Urban Planning Code (Territorial Directives on Development and Sustainable Development, Territorial Coherence Plans, Local (Intermunicipal) Urbanization Plans, municipal maps);
- ***via* documents modifying or influencing urban planning documents** (Public Interest Projects)
- **in specific regulatory documents** (Mining Risk Prevention Plans, for hazards that have been subject to a study and based on territorial stakes; Soil Information Sectors).

These tools are complementary and enable action to be taken at different levels (development guidelines, urban planning requirements and/or construction requirements). They should be used based on the stakes in the territory.

4.4.1 Soil Information Sectors (SIS)

Article L.125-6 of the Environmental Code, amended by Article 173 of the ALUR Law of March 26, 2014, stipulates that the government must create Soil Information Sectors (SIS) based on the information at its disposal. The SIS must cover land where, because of known soil pollution (especially when the land is being put to a new use), soil studies and pollution management measures are required to preserve the safety, health or hygiene of the public and the environment. Decree No. 2015-1353 of October 26, 2015, on the Soil Information Sectors provided for by Article L. 125-6 of the Environmental Code, setting out miscellaneous provisions on soil pollution and mining risks, defines the terms and conditions of application.

Two methodological handbooks have been written to assist actors in the SIS process:

- a handbook created by BRGM for DREALs and other relevant actors[13];
- a handbook created by the DGPR for local authorities for the purpose of responding to questions raised by local authorities or users[14].

4.4.2 Informing the public on residual mining risks

There are two types of information vectors:

- **Under the Environmental Code (Art. L. 125-5 and L. 125-7):**
  - The purchasers or lessees of real-estate properties in the zones covered by a plan for the prevention of foreseeable natural risks (PPRN)*, either prescribed or approved, are informed by the vendor or the lessor of the existence of the risks indicated by this plan. (*Mining Risk Prevention Plans (PPRM) carry the same effects as PPRNs (cf. Article L. 174-5 of the Mining Code); thus, the information of purchasers/lessee applies in the same conditions);
  - when land located in a Soil Information Sector [...] is subject to a sale or lease contract, the vendor or lessor of the land is required to inform the purchaser or lessee of this in writing;
- **Under the Mining Code (Art. L. 154-2):** the vendor of land in which a mine has been exploited in the subsoil is required to inform the purchaser of this in writing. The vendor shall also inform the purchaser, insofar as they are known, of serious dangers or disadvantages resulting from the exploitation. In the absence of this information, the purchaser may choose either to pursue cancellation of the sale or to obtain restitution of a portion of the price. The purchaser may also request, at the expense of the vendor, the elimination of dangers or disadvantages that compromise normal use of the land when the cost of said elimination does not appear disproportional to the sale price.

---

[13] "Élaboration des secteurs d'information sur les sols (SIS) dans le cadre de la loi ALUR. Guide méthodologique à l'attention des DREAL et acteurs concernés." BRGM Report/RP-64025-FR, November 2015.

[14] "Guide méthodologique à l'attention des collectivités relatif aux secteurs d'information sur les sols (SIS) et à la carte des anciens sites industriels et activités de service (CASIAS)," June 2017.

This obligation to inform also applies to any form of property transfer other than sale (lease, loan, etc.).

Regarding hazards related to ionizing radiation emissions, in 2003 the Ministry of Sustainable Development launched a program called “MIMAUSA” (History and Impact of Uranium Mines: Summary and Archives), the purpose of which was to make an inventory of sites on which uranium exploration, extraction or processing took place in mainland France.

4.4.3 Public notifications (PACs) from the State to local authorities

There are two types of public notifications:

- **Under the Urban Planning Code**, in application of Articles L. 132-1 to L. 132-3 of the Urban Planning Code:
    - the administrative authority (generally the prefect) must notify the city halls, or the Public Establishments for Intermunicipal Cooperation (EPCIs) that are competent in urban planning, of the technical studies it has at its disposal;
    - the municipalities or EPCIs must take these reference documents into account when drawing up or revising their urban planning documents (Art. L. 101-2 of the Urban Planning Code) and in applying land law.
- **Under the right to information on major risks**, in application of Article L. 125-2 of the Environmental Code:
    - State organizations must transmit to the mayors of affected municipalities the information necessary to inform the public on preventive measures in their territories, and particularly to establish their DICRIM (Municipal Information Document on Major Risks);
    - a new system was introduced by the circular of March 2, 2011: TIM (Transmission of Information to Mayors):
        - format unique to the territory and on a territorial scale;
        - information necessary to understanding risks, drawing up urban planning documents, and providing preventive information to the public.

4.4.4 Article R. 111-2 of the Urban Planning Code

Article R. 111-2 of the Urban Planning Code provides that a “*project may be refused or be accepted only under the condition that special prescriptions are complied with if it is liable to cause harm to the public health or safety because of its situation, characteristics, scale or proximity to other installations.”* This article allows authorities that are competent in urban planning, whether or not there is a PPRM, to react on an urban development project located in an area that is subject to a residual mining risk, either by prohibiting the project or by prescribing appropriate urban planning measures. For a project located in a low-level residual mining risk area, this article may be invoked, in special cases, to authorize construction if regulatory requirements (e.g., dimensions of façade openings, positioning of building on the parcel, etc.) ensure a sufficient level of safety.

4.4.5 Public Interest Projects (PIPs) (Articles L. 102-1 to L. 102-3 of the Urban Planning Code)

When major residual mining risks and important stakes are present, the prefect can adopt a public interest project, of which the prefect must notify the municipalities or Public Establishments for Intermunicipal Cooperation in application of Article R. 102-1 of the Urban Planning Code. This PIP must be taken into account in an urban planning document, which should allow it to be carried out. The regulatory zoning plan and the provisions of the local or intermunicipal urbanization plan regulations (PLUs/PLUIs) must not prevent the PIP from being carried out, which in practice involves integrating the written and graphic provisions of the PIP.

4.4.6 Urban development and planning documents

Article L. 101-2 of the Urban Planning Code provides that "the actions of local urban planning authorities shall aim to achieve [as an] objective (...) [while complying with sustainable development objectives] (...) the prevention of foreseeable natural risks, mining risks, technological risks, pollution and nuisances of any kind." It is therefore the responsibility of municipalities or their urban planning bodies to take into account the information issued by government authorities as they consider development plans, and when they draw up or revise urban development and planning documents (SCoTs, PLUs, PLUIs, municipal maps). In the case of a PLU/PLUI, this information is factored into the sustainable development plan (PADD), the development and programming guidelines (OAP), the presentation report, the regulatory zoning plans and the regulations.

4.4.7 Mining Risk Prevention Plans (PPRMs)

Established by Article L. 174-5 of the Mining Code, Mining Risk Prevention Plans (PPRMs) use available knowledge of hazardous zones caused by former mining sites in a given territory, to define the conditions of construction, occupation and use of soils in that zone, as well as the measures relating to the organization, use or exploitation of existing property. PPRMs carry the same effects as Natural Risk Prevention Plans (PPRNs). Their primary objective is to ensure the safety of people and limit risks to property.

4.4.8 Summary

French government and local authorities have several tools available to help account for mining hazards and/or environmental risks in development and urban planning: factoring them into urban planning documents (SCoTs, PLUs, PLUIs, municipal maps), drawing up Mining Risk Prevention Plans and defining Soil Information Sectors, creating PIPs.

These tools vary in terms of the requirements that apply to new constructions. A PLU allows for the implementation of urban planning requirements (a building's location, dimensions, external characteristics) but does not allow for so-called "construction" provisions that pertain to the building's structure (e.g., foundations, size and location of load-bearing walls). A PPRM, on the other hand, can prescribe these types of provisions.

Article R. 126-1 of the Construction and Housing Code:

"The Natural Risk Prevention Plans provided for by Articles L.562-1 to L.562-6 of the Environmental code, or the Mining Risk Prevention Plans established in application of Article 94 of the Mining Code, may set special rules for construction, development and exploitation with regard to building types and characteristics, as well as their equipment and installations."*

** now Art. L. 174-5 of the Mining Code.*

The table below summarizes the tools available.

Table comparing the tools used to account for mining risks in urban planning and land development (source: Cerema)

List of the principal tools used to account for risks in land development		Scale of application	Creation and oversight	Content
Planning documents	**Territorial Directive on Development and Sustainable Development (DTADD)**	Regional or interregional	Created on the State's initiative and under its responsibility, in partnership with local authorities	**Territorial development guidelines** (Regional application of State policies in various domains or application of an individual policy)
	Territorial Coherence Plan (SCoT)	Supramunicipal (urban area, district/arrondissement)	Instructed by local authorities (ECPIs[15]), in partnership with State organizations	**Territorial development guidelines**
Urban planning documents	**Local Urbanization Plan/Local Intermunicipal Urbanization Plan (PLU/PLUI)**	Municipal (PLU), intermunicipal (PLUI)	Instructed by a local authority (municipality), in partnership with State organizations	**Urban planning requirements** Defines the rules for planning, development and use of the land in a given territory
	Municipal Map (Carte Communale, CC)	Municipal	Drawn up by State organizations on behalf of municipalities, or by the municipalities themselves	**Urban planning requirements** Application of the National Regulations on Urban Planning to the municipality
Documents modifying or influencing urban planning documents	**Public notification (PAC)**	Municipal	State	Must be implemented via urban planning documents and application of land use laws
	Public Interest Project (PIP)	Municipal or supramunicipal	State	**Urban planning requirements**

[15]EPCI: Public Establishments for Intermunicipal Cooperation

List of the principal tools used to account for risks in land development	Scale of application	Creation and oversight	Content
National Regulations on Urban Planning ***(Article R. 111-2 of the Urban Planning Code)***	Parcel / project	State / municipality	**Urban planning requirements**
Mining Risk Prevention Plan (PPRM)	Supramunicipal	State	**Urban planning requirements**[16] **Construction requirements**[17] Defines: • the conditions for construction, occupation and use of the land; • measures pertaining to the development, use or exploitation of existing property.
Soil Information Sectors (SIS)	Parcel / project	State	Identification, scope and characterization of SIS.

[16]Under the Urban Planning Code.

[17]Under Article R. 126-1 of the Construction and Housing Code.

5. WHICH MANAGEMENT TOOL TO USE FOR WHICH “POST-MINING” HAZARD

Risk prevention stakeholders (the State, local authorities) have a number of prevention tools at their disposal. Choosing the right tool will depend on the **type of risk** (linked to a hazard that may be characterized by a hazard study or linked to Soil Information Sectors for pollution risks) and the **characteristics of the affected territory.**

The decision to draw up a PPRM does not apply in every case and must be made by taking into account both the level of residual mining risk and the stakes associated with it. It results from an analysis of the hazard map, conducted at the request of the DREAL by the administration’s expert, and from a preliminary study of stakes conducted by the DDT/DDTM.

This preliminary study’s objective is not to result in a detailed map and analysis of stakes, as this can be done as part of the PPRM, but rather to evaluate the impact of hazards on the territory in question.

Thus, it consists of a succinct territorial analysis combined with hazard data and a hazard map. The territorial analysis is conducted based on the urban planning documents of the municipalities in question, which will help identify and locate the urbanized areas and areas to be urbanized, make an inventory of projects in the municipality and analyze the economic and demographic data contained in the presentation report for the PLU. By cross-referencing these data with the hazard map and hazard data, the user can evaluate the impact of mining hazards on the territory, identify the possibilities for development outside the hazard areas and compare them to the needs of the territory while accounting for demographic factors.

Table of mining risk management tools based on potentially dangerous phenomena.

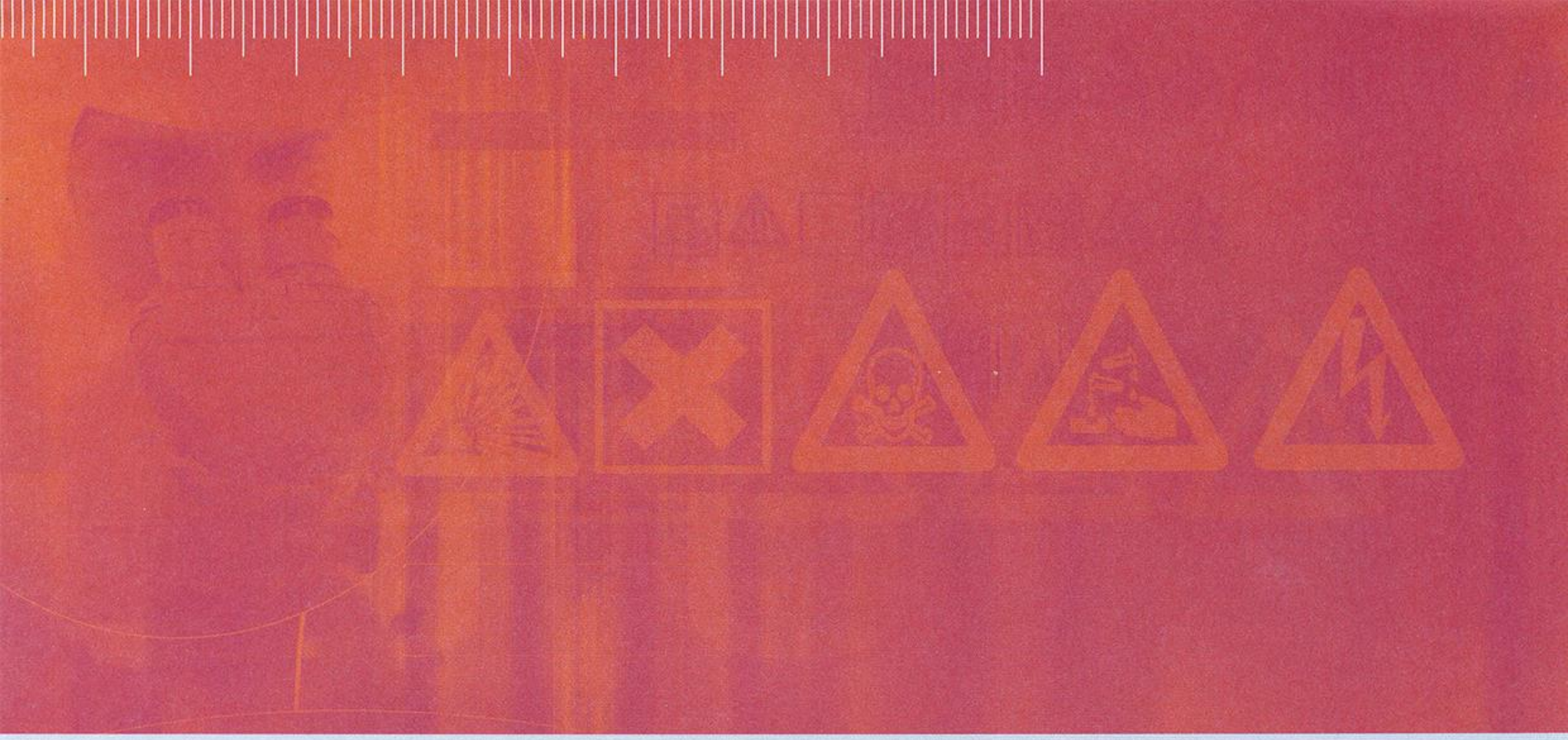
<table>
<tr><th colspan="2">Dangerous phenomena</th><th>Risk management tools available to State organizations</th><th>Urban planning management tools available to local authorities</th></tr>
<tr><td rowspan="8">Mining-induced ground movements</td><td>Localized collapses</td><td rowspan="11">Hazard studies</td><td rowspan="11">PAC
Inclusion in applications for urban planning authorizations

SCoT, PLU, PLUI, municipal map, PIP and sometimes a PPRM, if applicable in special cases</td></tr>
<tr><td>Continuous subsidence</td></tr>
<tr><td>Discontinuous subsidence</td></tr>
<tr><td>Generalized collapses</td></tr>
<tr><td>Crevices</td></tr>
<tr><td>Settlement</td></tr>
<tr><td>Slope movements</td></tr>
<tr><td>Rock falls</td></tr>
<tr><td colspan="2">Gas emissions linked to mining</td></tr>
<tr><td colspan="2">Combustion and overheating of mine waste</td></tr>
<tr><td colspan="2">Hydrological/hydrogeological disturbances, mining-induced floods</td></tr>
<tr><td colspan="2">Ionizing radiation emissions</td><td>Request to IRSN (Institute of Radiation Protection and Nuclear Security)</td><td>PAC
Inclusion in applications for urban planning authorizations

PIP, SUP and RUP (Restrictions of use between parties), if applicable; RUCPE (Contractual restriction of use for the benefit of the State), PPRM in certain special cases</td></tr>
<tr><td colspan="2">Mining-induced environmental pollution</td><td>Applying methodology for managing polluted sites and soils to mining sites

Soil Information Sectors (SIS)</td><td>PAC
Inclusion in applications for urban planning authorizations

SCoT, PLU, PLUI, municipal map</td></tr>
</table>



INERIS

controlling risks
for sustainable development

Institut national de l'environnement industriel et des risques

Parc Technologique Alata
BP 2 - 60550 Verneuil-en-Halatte

Tél. : +33 (0)3 44 55 66 77 - Fax : +33 (0)3 44 55 66 99

E-mail : ineris@ineris.fr - **Internet :** http://www.ineris.fr