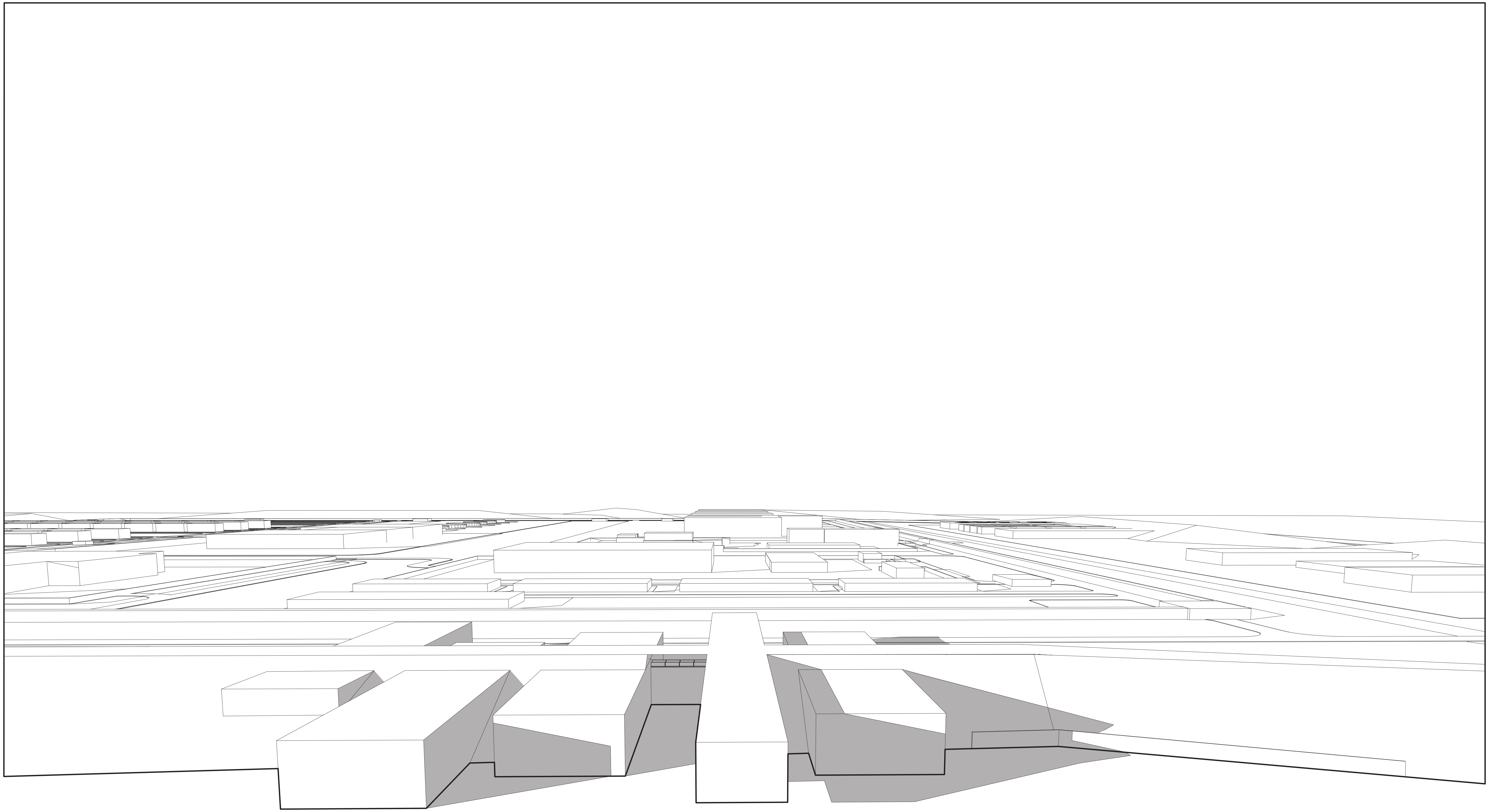

Atomic Clock

Italian National Repository of Nuclear Waste

Politecnico di Torino

Department of Architecture and Design
MSc Architecture Construction City
Politecnico di Torino
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ATOMIC CLOCK

Italian National Repository of Nuclear Waste

Tutor : Professor Giovanni Corbellini

Candidate : Alexandra Farcas

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Abstract

As nuclear processes and technologies evolved, radioactive waste began to generate and accumulate over time. This radioactive waste must be stored in a way that doesn't endanger the environment or the safety of present and future generations. The existence and management of radioactive waste is the most crucial issue for all nations that engage in nuclear activity (primarily nuclear energy), as well as for those that do not engage in such activity but still produce radioactive waste for use in research, medicine, and other fields.

All EU nations are required to develop and implement national programmes for the management of spent fuel and radioactive waste in accordance with the EU's Radioactive Waste and Spent Fuel Management Directive 2011/70/Euratom. The projects should encompass all categories of spent fuel and radioactive waste that fall under the purview of EU member states as well as all phases of management, from generation until their time of disposal. Since August 2015, EU nations have submitted national reports detailing their nuclear waste implementations every three years. Based on those, a report is produced that includes information on the inventory of radioactive waste and spent fuel found on the country's territory as well as the general implementation of the specified directives. In terms of radioactive waste, the industries, medicine, nuclear power stations (NPP), fuel cycle facilities, and research account for the majority of waste that is now present in Italy. Nearly all of the nuclear program's waste resulting from the energy plants is currently kept on the grounds of each installation where it was created while the waste that is generated by research activities, the medical field or industrial is currently stored in temporary deposits possessed by authorised national operators. Therefore, to resolve the problem of radioactive waste, the nuclear power-related obligations and assets were transfered to the SOGIN corporation which will handle the necessary actions associated with the development of the repository. A particular charge on the price of power was used for financing all these activities regarding the repository that will deal with the radioactive matters.

The repository is foreseen to operate for up to 50 years, a time in which the cells on the site will be filled with nuclear waste. After this time, a phase of surveillance begins which is presumed to last for at least 300 years.

This extended period of time is supported by the scope of eliminating the danger that represents the nuclear waste taking into account that after this period the waste will reach a radioactive level similar to the natural one. In this sense, the concept of time becomes a crucial architectural issue that influences the design outcomes of the project and its ability to shift through time. The site of the repository and its facilities have been therefore designed thinking how everything will advance after 350 years, how its performance will change and how the image and form will transform. With reference to time, the project will experience 3 different main periods that relate to the lifetime of the nuclear waste. The first period will be the operational phase in which the repository processes and stores the nuclear waste, the second one will be the dormancy phase, when the waste will be buried and supervised, followed by the last phase, the afterlife, when the repository can be given back to normal uses, its memory included.

One of the important resources of the repository is the Technological Park which will serve as a research centre open to global partnerships where projects in the sectors of energy, waste management, and sustainable development will be carried out. Thus, the Technological Park is created as a means of assisting the selected region by strengthening the local economy and acts as a catalyst between the nuclear field and the citizens of Alessandria to involve and attract them by giving it a more empathic look.

The archive that is situated within will represent a core component of the project through its involvement with the citizens and also through its main purpose of gathering all the important documents regarding the activities related to the nuclear waste that take place on site. The landscape of the archive will engage with its visitors through a series of level changes that will permit people to reach the top of the archive and overlook the whole repository. This path will be directed through walls which will provide information regarding the nuclear waste written in multiple languages to be accessible to all. The building will comprise 4 blocks buried into an artificial hill that will host the archives and will last until the afterlife phase, and by 1 building that will represent the offices and public spaces that will only last for 50 years, being removed after this time.

Introduction

"Our universe developed 13.8 x 10^9 years ago from a high-energy density singularity, the so-called Big Bang. It then expanded and was cooled by this expansion, the current 2.725-K background radiation being remnant radiation from the first seconds after the Big Bang. ... Long-lived radionuclides, which became part of the composition of the protoplanets, gradually decayed, although longer-lived radionuclides such as ^{238}U, ^{235}U, ^{232}Th, and ^{40}K did not decay completely. These are left as a reminder of the natural radioactivity evolution over the 4.6 billion-year lifetime of the Earth. "– Ojovan, M.I., Lee, W.E. and Kalmykov, S.N. (2019) An introduction to nuclear waste immobilisation. Amsterdam: Elsevier.

The study of radiation started with the invention of the X-ray tube by the physicist Wilhelm Conrad Roentgen in 1885 which discovered a new form of radiation rather than the ionising radiation that was the only one in existence since then. This discovery represented the starting point of utilising natural radioactivity for the medical and research purpose and in 1930, with the production of the first artificial radioactive materials by Marie and Pierre Curie, they're usage represented a growth in society's benefit in fields of science, agriculture, medicine and industry. Those new actions together with other various human activities that used natural and artificial radioactivities generated waste products, the majority of which have high radioactive concentrations. Human society is known for being careless with managing the waste that is produced and this new waste with significant levels of radionuclides requires a certain type of management not to harm the life surrounding it and to confer protection toward humans and other living beings. In comparison to other waste categories, radioactive waste management has been handled differently by society, by containing it and confine it rather than dispersing it into the environment.

This method of managing the radioactive waste is particular to it, because this waste has to be conditioned and/or immobilised in order to minimise as much as possible potential migration or dispersion of contaminants. " immobilisation... the conversion of a waste into a wasteform by solidification, embedding or encapsulation." -The International Atomic Energy Agency (IAEA). The difference between conditioning and immobilisation is that conditioning could contain immobilisation but not the other way around and it mainly represents a matter of scale. Conditioning refers to those procedures that make possible the production of a waste container capable of managing transportation, handling and storage. Is important that the radioactive waste is handled with care because safety must be ensured in all of the steps of the process and for a long period of time since, depending on the grade level of radioactivity, the waste has to be isolated for different periods of time that range between a hundred up to thousands of years.

This issue of time represents one of the core principles of this thesis because radioactive materials are continuously irradiating the medium in which they've been immobilised and sometimes even at noticeable levels which causes damage and structural changes. Regarding the short time periods, the changes can be observed, understood and even handled but this is not an actual solution for the long time periods which become an obstacle for the future generation. They need to be shielded from potential radiation exposure, economic consequences and taken into consideration the need for surveillance or maintenance.

The present generation needs to obviate the problems that could be caused in the future and to bring a better understanding regarding the radioactive field in order to ease the fear that comes with the term. Many people are scared of this branch of science since all that is known is referenced to war, bombs and weapons, as they are well known events that represent a part of history (Atomic bombings of Japan and the accidents at Chernobyl, Fukushima) but in reality this fear of radiation is causing more harm to the public health than the radiation itself. The thesis itself is based on researching and understanding the field of radioactive waste which stays at the base of the architectural design proposal for the Italian Nuclear Waste Repository through which present and future generations will have a place to observe, understand and remember the radioactive work carried in that place.

The proposal will generate a welcoming space for people that will visit the repository, creating a unique experience that guides them through the knowledge that will be discovered through the landscape of the site.

01

The Nuclear Matter

Radioactive Waste

01.1 General Informations

Radioactive waste is often seen as dangerous and feared when in fact the world is naturally radioactive. The Earth contains radionuclides and radiation, which are crucial in natural processes. Long-lived radionuclides, for instance, maintain elevated temperatures deep down and protect the Earth's thermal balance. There are existing stages of natural radioactivity that have been adapted to by living organisms, or even stimulated by them and even more, soft radiation of carbon (^{14}C) is thought to have created the ideal environment for the emergence of life.

On another note, waste represents a major part of human society and has been dealt with since pre-history and will be continuously dealt with also in the future. Its disposal has to be managed properly to safeguard the planet and the environment for next generations. Especially in the case of radioactive waste, this process needs to be handled with special attention because of its radioactive properties and in diverse manners depending on the level of radioactivity the waste has.

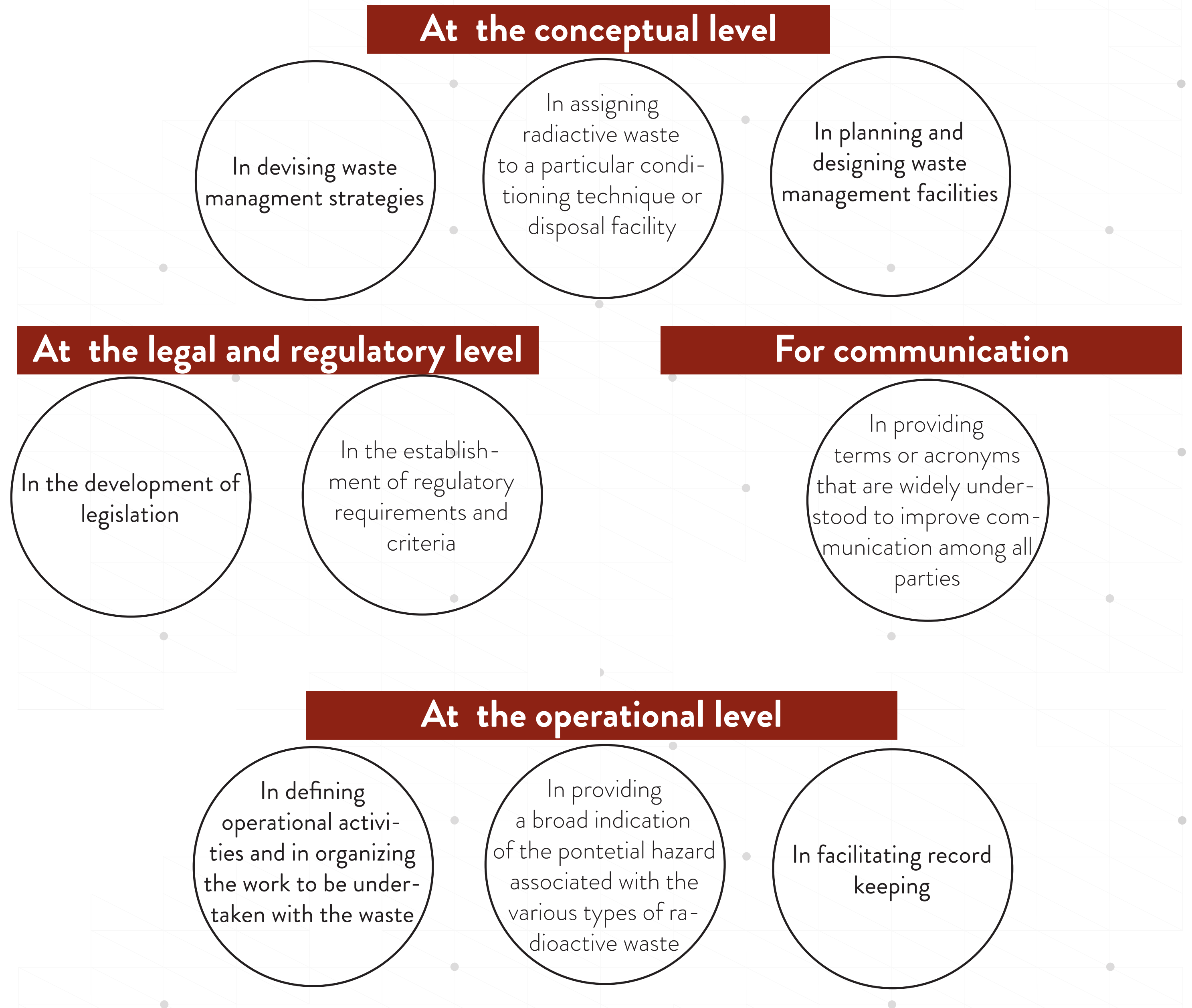
Radioactive waste is by definition "any material that contains or is contaminated by radionuclides at concentrations or radioactivity levels greater than the exempted quantities established by the competent authorities and for which no use is foreseen"(stated by the The International Atomic Energy Agency). Once it becomes waste it can no longer be recycled and therefore it has no specific use foreseen other than being eliminated. Depending on the concentration of radionuclides that exceeds the normal levels, the higher or lower can be the threat that the waste contains. Another factor that can influence this concentration is the nature of the radionuclides. Therefore, it can be said that radioactive waste is still normal waste but depending on the levels of ionising radiation it can become a risk. Over-irradiation or high doses of radionuclides can become fatal but the biological effects caused by radiation fluctuate depending on various reasons as: the amount of exposure, its rate, the area of body affected and even the type of radiation.

High doses of ionising radiation can deliver certain evident clinical symptoms if enough individual cells are damaged and can be classified as deterministic, meaning that the effects are greatly influenced by the dose exposed to. Those effects can of course be negligible if under a certain dose and do not affect the body. Low doses can only influence the body if the doses are received over a long period of time. There may be a limit below which radiation is not dangerous at all to the body, according to some data. Additionally, some researchers have provided proof that low-level radiation may have a positive effect (hormesis), presumably as a result of an adaptive biological response.

As it was already stated, radiation is something natural and is found everywhere. This is called background radiation and its levels are not constant as they vary worldwide and are continuously changing, depending on the exposure to it. The current generation already receives a certain level of radiation from natural and man made sources such as : cosmic rays from outer space, the surface of the Sun, the Earth's crust (terrestrial radionuclides), building materials and even from air, water and the food that humans eat. It can be said that a part of the exposure is constant and uniform for everyone, but of course there are other exposures that vary substantially on the location as cosmic rays tend to be more intense at higher altitudes for example. Moreover, people acquire radiation doses also from artificial sources, such as X-rays that are used in medical procedures, and can vary depending on the activities and practices carried out. All of these represent the background radiation exposure which is a normal exposure and even the radioactive discharges made by man are usually fixated on developing beneficial medical applications.

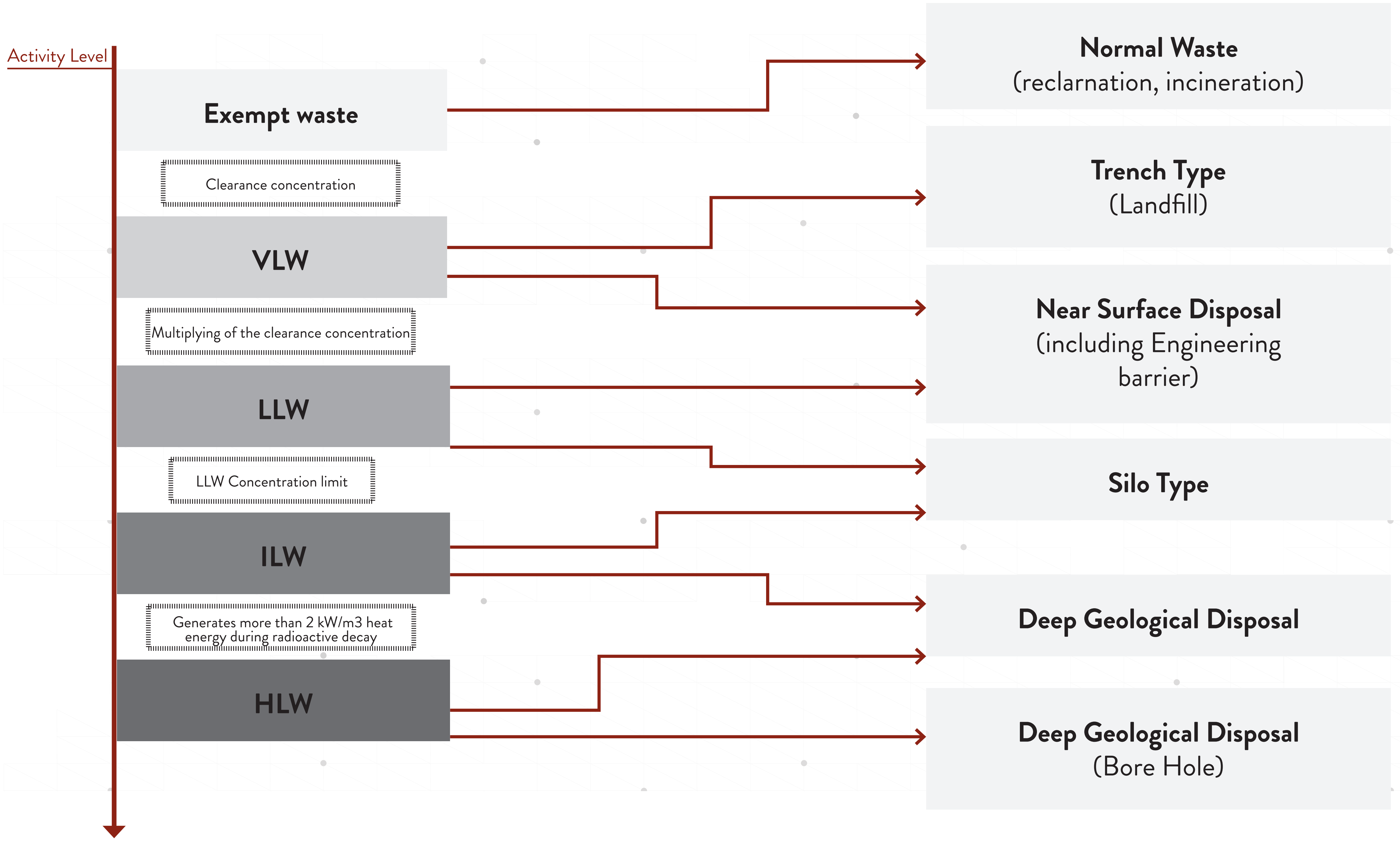
01.2 Types of Radiactive Waste

Therefore, in order to decide on the best methods of disposing the waste and offer long term safety for people, a waste classification according to the potential hazard of the radioactive waste is needed. This classification will aid in many stages of the process such as the conceptual stage, the operational level, the legal and regulatory level and for communication.

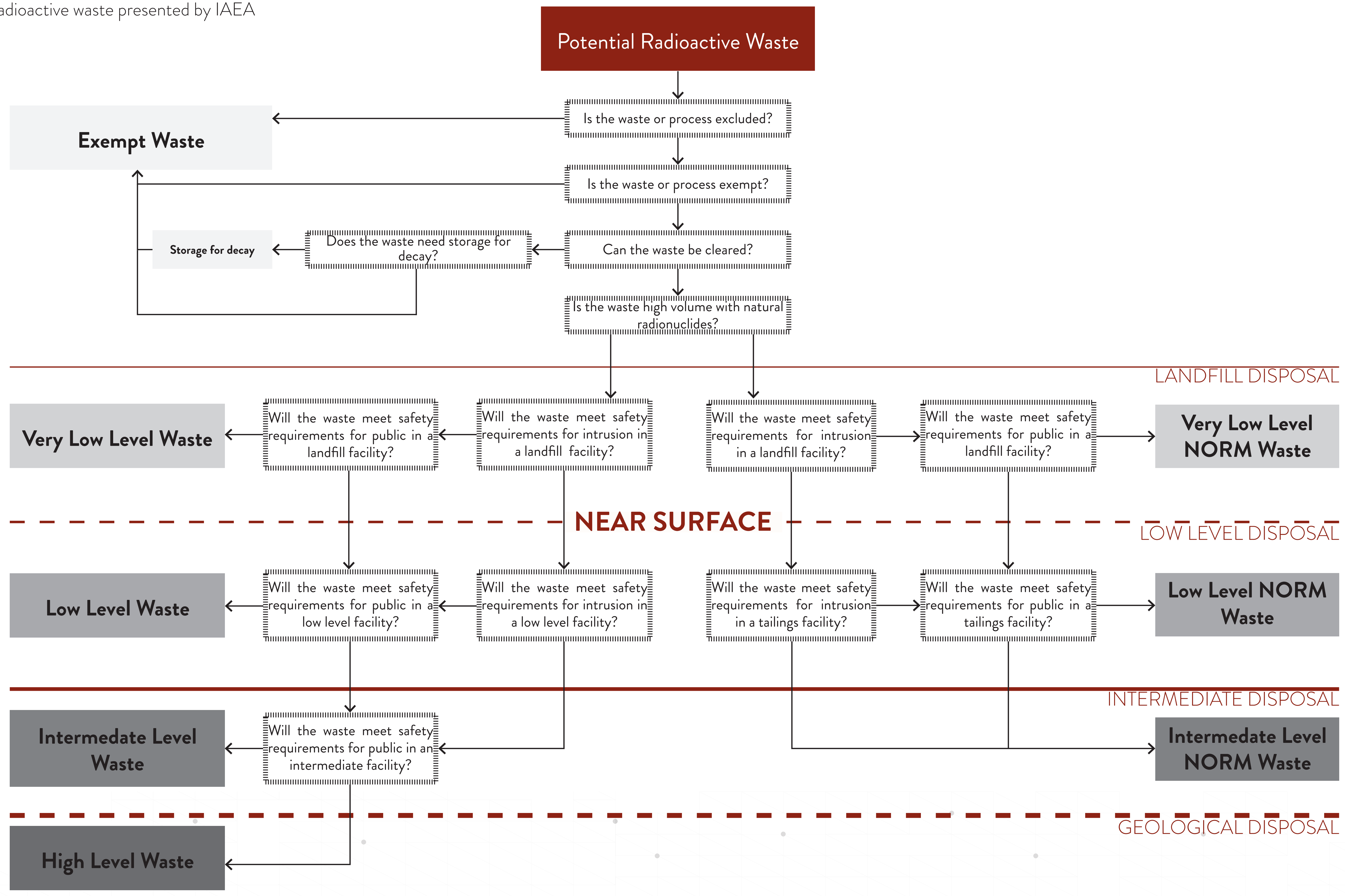


The first classification of the radioactive waste proposed by IAEA contained only 3 large groups : High level waste (HLW), intermediate level waste (ILW) and low level waste (LLW), but was subsequently changed when this system granted certain drawbacks. One of the reasons was that there isn't a very apparent connection between the categorization system and safety considerations for managing radioactive waste, particularly disposal. Additionally, several nations utilise diverse definitions of radioactive waste in accordance with their respective national policies or regulations. Therefore, to overcome those drawbacks, another classification got created, including :

- **Exempt waste (EW)** : contains insufficient radioactive material to be considered radioactive, thus fulfilling the requirements for clearance, exemption, or exclusion from governmental oversight for radiation protection. This type of waste can be safely disposed of, without explicitly taking into account the radioactive properties.
- **Very short lived waste (VSLW)** : it can be kept for a short time, up to a few years to allow it to decompose and then is released from regulatory oversight but only in accordance with plans approved by the regulating authority. This category of waste is made mostly of radionuclides with extremely short half-lives and are met in the field of research or medicine.
- **Very low level waste (VLLW)** : Despite the EW criteria, VLLW is very similar but the difference between the two is that the latter doesn't require a high level of containment and isolation making it eligible for disposal in sites resembling near-surface landfills with minimal regulatory oversight. It can also be intermixed with other hazardous trash such as soil and rubble, usually found in those landfills.
- **Low level waste (LLW)** : Suitable for near surface disposal and also containing a limited amount of long lived radionuclides , bringing it above clearance levels. It requires powerful regulation and confinement for a limited period of time which could lead to hundreds of years. This period is decided by each country but usually the regulatory control is set at a period of 300 years. Therefore, in order to contain it, near surface disposal facilities can have multiple design options that range from simple to more complex engineered facilities. The waste can also be disposed of at differing depths up to 30 metres, depending on safety assessments and on national practices which are managed by the regulatory authorities. LLW covers a very wide range of radioactive waste.
- **Intermediate level waste (ILW)** : it contains long lived radionuclides at a greater quantity and for this it requires a greater degree of containment and isolation as against LLW. For this type of waste, the near surface disposal won't suffice since it can harm the biosphere and it requires clearance at depth, between a few tens to several hundreds of metres. This is required because that depth provides a long period of isolation from the environment and also avoids human intrusion. As a result, institutional controls will not be necessary for the long-term safety of disposal sites at such intermediate depths.
- **High level waste (HLW)** : This waste is defined by the large concentration contents of both short and long lived radionuclides and therefore it requires a greater level of containment and isolation. This can be achieved through deep geological disposal along with engineered barriers. As opposed to the other categories, HLW generates significant amounts of heat during the radioactive decay process and the heat is generated even for several centuries after. Heat generation represents a crucial part in designing geological disposal facilities.



Scheme presenting the processs of classification regarding radioactive waste presented by IAEA

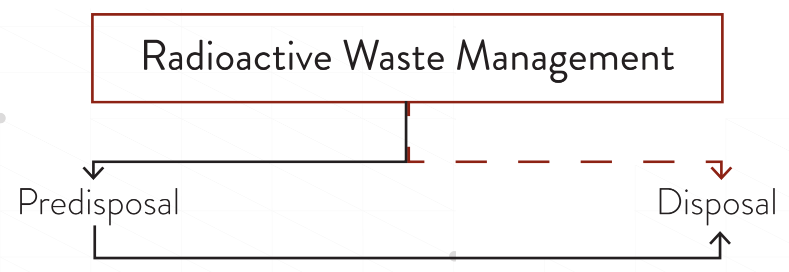


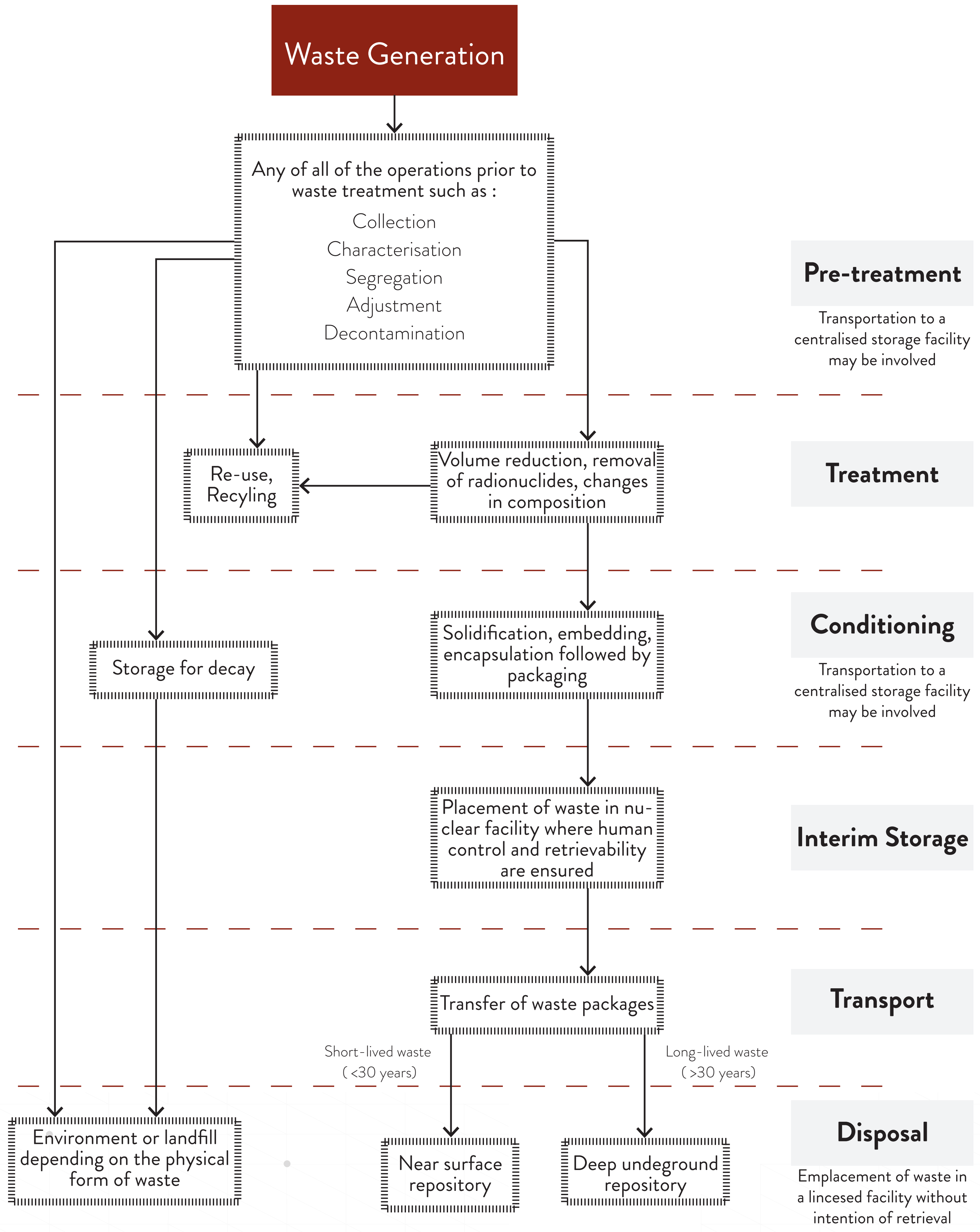
01.3 Managment

The main concern regarding the management of radioactive waste is its safe management. There are a lot of reasons for which the public acceptance is lacking but they all have at the base the fear of not being safe enough or not being able to achieve trust from people that safety can in fact be obtained. Thus, the nimby syndrome „"not in my backyard", has been developed among humans and represents almost an impediment in achieving the purpose of radioactive waste management. Its purpose is to get rid of the radioactive waste in a way that protects the environment and humans, as well in the present as in the future without causing irreparable damage to the upcoming generation. "We do not inherit the Earth from our ancestors; we borrow it from our children. "

Usually, the waste can derive from three main sources : the Nuclear Fuel Cycle (NFC) used in military practice and to generate power, the Non-NFC institutes that also includes non-nuclear industries, research and medical benefits, and from Accidents. The approaches towards radioactive waste management depend on those sources and on the country of origin. All the activities that consider the management of the radioactive waste are generally divided into predisposal and disposal stages. This management of the waste requires several steps before disposal, including decommissioning, pre-treatment, treatment, conditioning, immobilisation, storage, and transport. All those activities take place in the predisposal stage.

Predisposal represents a stage that entails a number of critical actions that facilitate the handling operations and prepare the waste for the final stage, disposal. For safe management, every process has to be handled with care because it interconnects with all the other processes throughout the planning, design, construction, operation, and decommissioning of a facility and certain decisions taken at one point could restrict or rule out alternatives at another one.



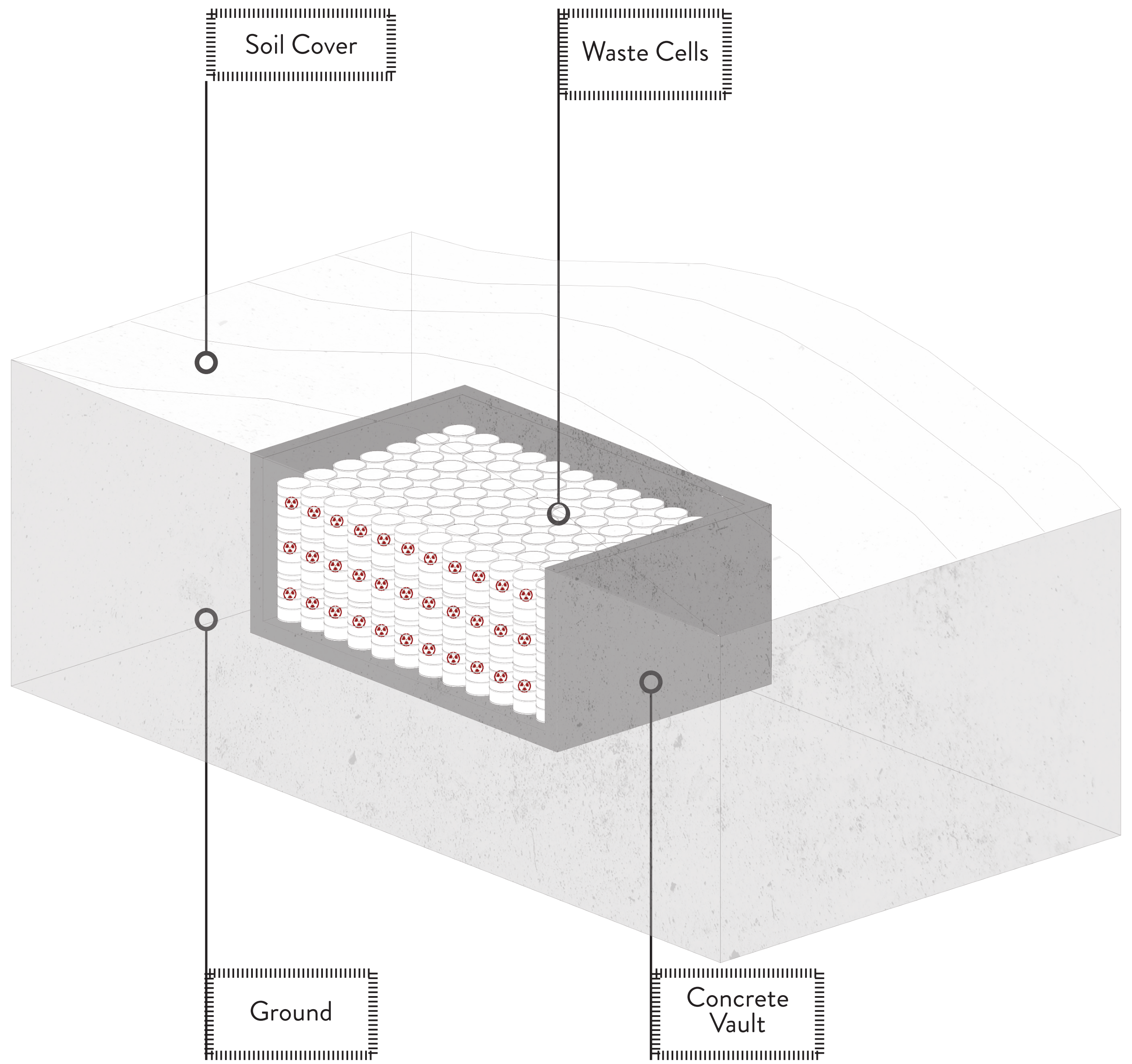


01.4 The Disposal Process

Disposal represents the final step for the radioactive waste management and consists in placing the waste in a certain location, or a repository. In this way, the waste will not be disturbed in any circumstances and its contents will remain captive for many years or hundreds of thousands years and even more. Although the phrase "repository" frequently causes misunderstandings, it is important to distinguish between "storage," where waste must by definition be retrievable, and "disposal," which is meant to be permanent. The word "repository" is frequently used in the context of nuclear waste to refer to a location for temporary storage that could one day become permanent. In this last phase of disposal, the radioactive waste shouldn't be under any governmental control as there is the probability that in the future human society will develop in such a way that the radiation knowledge will differ and its location will be forgotten. This represents one of the reasons why today's actions regarding radioactive waste management should be carried out thinking of the future generation, so as to not burden them.

Depending on the type of waste, different designs of disposal facilities emerged in order to accommodate the radioactive waste. These types of facilities are divided into two big categories of repositories that also contain sub-categories. The first one is represented by the **Near-surface repositories**, which is defined by radioactive waste that decay to harmless levels in an interval of time ranging between decades to centuries and is usually disposed in near-surface engineered structures that have the ability to remain safe over the whole period of time required for the waste to lose its radioactivity. The second type is the **Geological repository**, characterised by its method of burying the waste at great depth, below the ground level. This feature makes it ideal for the high level waste (HLW) which needs to be isolated for hundreds or thousands of years without disturbance. The main distinguishing characteristic is that the depth below the earth is typically sufficient to prevent potential infiltration by plants, animals, and people for periods of time longer than 300 years.

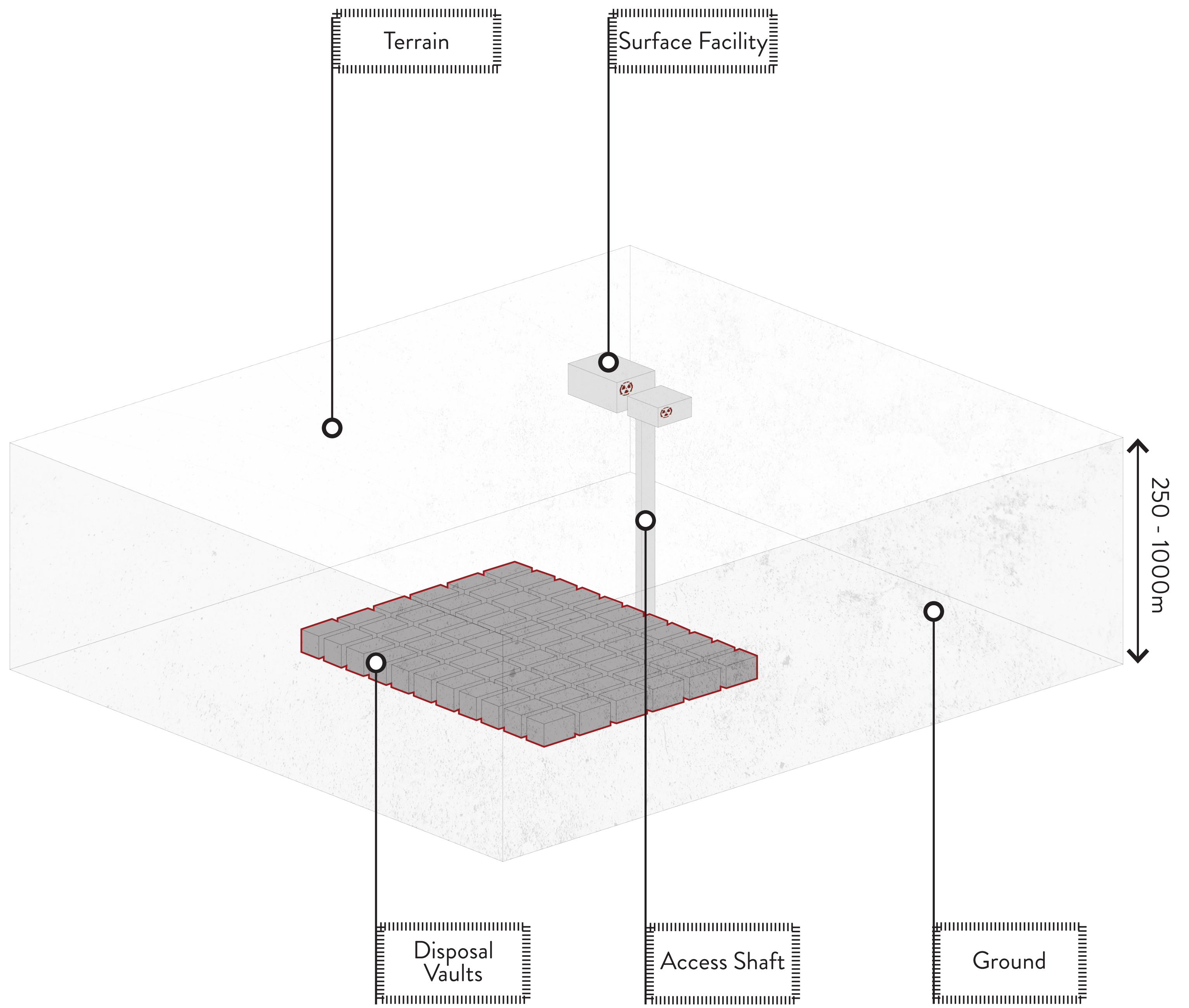
NEAR-SURFACE DISPOSAL

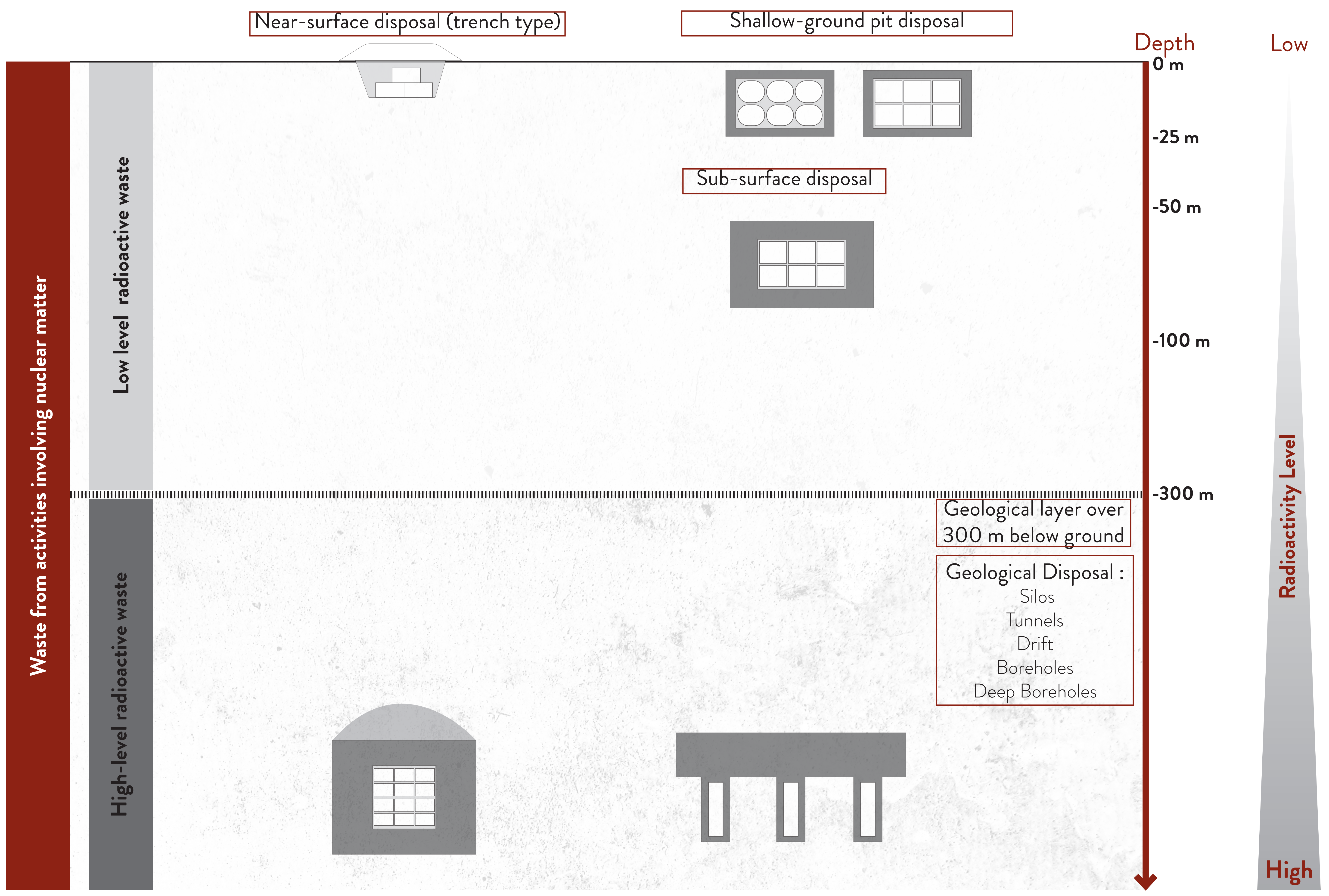


As stated above, besides the two main categories there are other sub categories defined by IAEA in one of its Safety Guides :

- **Specific landfill disposal:** it is similar to a conventional landfill facility for industrial refuse with the possibility of covering the waste. Could be attributed to VLLW.
- **Near surface disposal:** it is a facility that contains engineered trenches or vaults that are constructed on the ground or tens of metres below the ground level. Could be attributed to LLW.
- **Disposal of intermediate level waste (ILW):** The ILW could be actually disposed of in more than one way. It could be placed in a facility made in vaults or silos buried in a few tens of metres or hundreds of metres below ground level,or it could be placed in purpose built facilities and facilities developed in existing mines or in facilities resulted by drift mining into the mountain side where the overlying cover surpasses 100 metres deep.
- **Geological disposal:** it is a facility built in tunnels, vaults or silos in certain geological formations (e.g. in terms of its long term stability and its hydrogeological properties) situated at least a few hundred metres below ground. Could be attributed to HLW.
- **Borehole disposal:** it is a facility that contains an array of boreholes or a singular one, ranging in depth from a few tens to several hundreds of metres. Such a borehole disposal facility is made to exclusively dispose of limited amounts of waste, particularly abandoned sealed radioactive sources. For the disposal of solid high level waste and spent fuel, a design option for very deep boreholes that reach depths of several kilometres has been considered, however no State has chosen to use this design in a disposal site.
- **Disposal of mining and mineral processing waste:** in this case, the disposal is often on or near the ground surface, but this particular radioactive waste stands out from other radioactive waste due to its huge volume, physicochemical form, and inclusion of long-lived radionuclides of natural origin. Typically, the waste is stabilised in place and covered with a number of layers of rock and soil.

DEEP GEOLOGICAL DISPOSAL

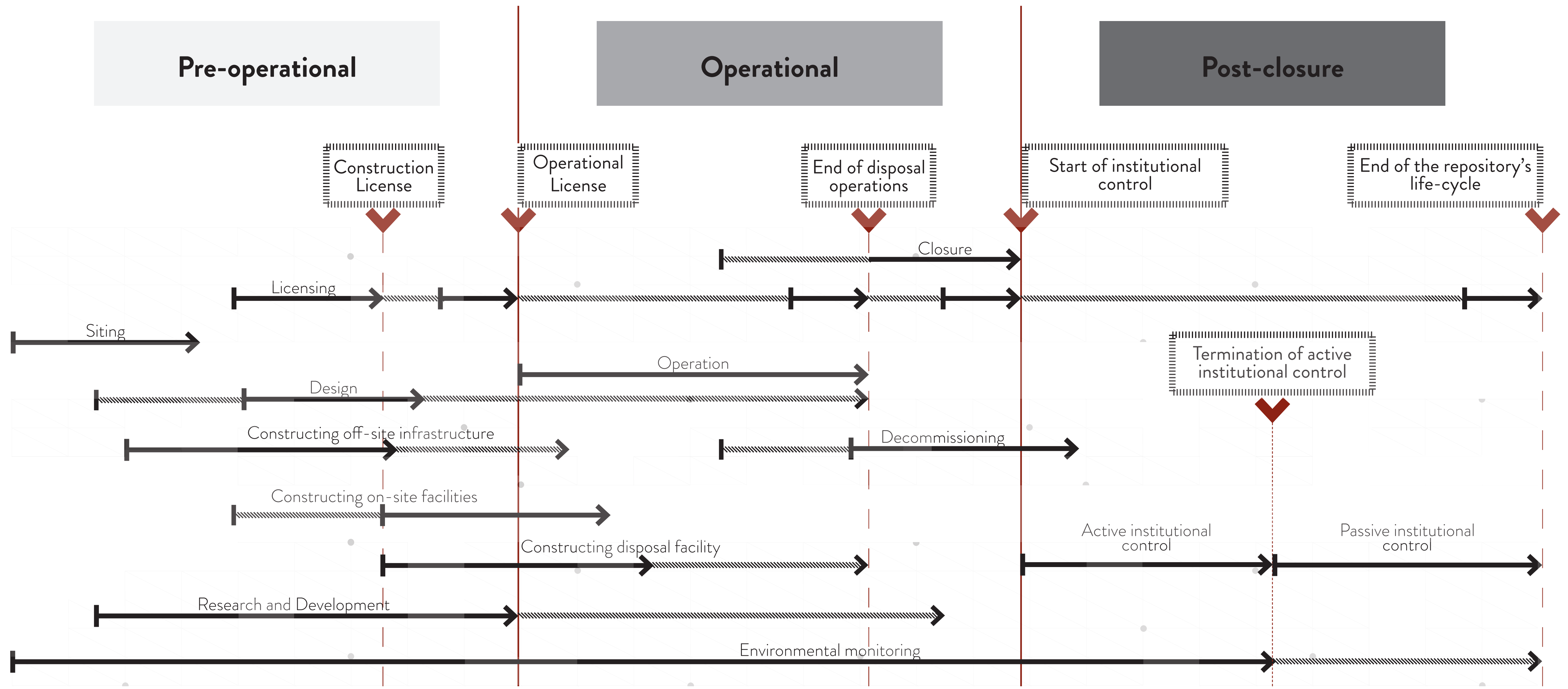




01.5 Life Cycle of Disposal Facilities

Disposal facilities are typically anticipated to advance over several years or even decades, during which a complete programme of research, design, and assessment work is carried out. The IAEA describes this lifespan as consisting three phases :

- **The pre-operational period** : it includes site evaluation such as its selection, verification and confirmation, safety assessment, design studies and it also ensures safety in the time of operation and after.
- **The operational period** : this phase begins when waste arrives first at the facility, when radiation exposures could occur. Programmes for monitoring, surveillance, and testing are still to guide operational management choices and serve as the foundation for decisions involving the shutdown of the plant or portions of it.
- **The post-closure period** : When all of the facility's engineered containment and isolation features have been installed, all operating buildings and supporting services have been shut down, and the facility is in its final configuration, this phase starts. After it has been closed, the disposal facility's security is guaranteed by passive features derived from the features of the location, the facility, and the waste packages, as well as by specific institutional controls, especially for near-surface facilities. In order to assure public health, monitoring is also attributed and after the period of active institutional control, the licence will be terminated whenever all the essential technical, legal, and financial conditions have been met.



01.6 Signals for The Future

The topics discussed above all relate to the need of safeguarding the spaces where the repositories are located, especially for the future generations that will come. For the present generation it is easy to find and exploit the information regarding radioactive waste and any complications that could appear at the sites can be swiftly dealt with but what will happen with the future generation that could lack information or understanding about it. Nonetheless, there are several ongoing researches among experts on methods of post-closure measures with the purpose of preserving the information regarding the repository, of ensuring safety and of preventing the wrongful usage of the contents of the repository.

Repositories of radioactive wastes are built with the aim to maintain a certain isolation from the human environment for a long period of time by using man-made and natural barriers to prevent the escape of radionuclides. Experts believe that a repository that is appropriately built, situated, and equipped with these passive safety mechanisms will provide adequate protection after it is eventually closed. For enhancing the sense of security, there are arguments in favour of activities related to the post-closure phase of the repository designated to prevent or lessen the possibility of intrusion into the repository and give further assurance to the general public. One of the main reasons for continuing those activities of the repository even after its closing is to ensure that future generations don't lose knowledge about the repository's existence and the foundational knowledge it has amassed over its history. This preservation is necessary as it helps in reducing the probability that any inadvertent intrusion takes places that could lead to the endangerment of the environment or humans in the future. The active measures of the repository can ensure a high level of safety guaranteeing that no intrusion will happen, but this can only be stated for the first century or so after the closure of the facility. After those measures start to decline, passive measurements could take their place, like markers, or even archives, for retaining the information, which can help in reducing the probabilities of issues for a long term period.

The preservation of knowledge through different means not only provides a database for future generations but also gives them freedom of action.

Therefore, the information permits to communicate to potential intruders the dangers that are buried and that they should be careful. Nordic and NEA Working Groups have investigated information preservation techniques for this purpose.(Issues in radioactive waste disposal Second report of the Working Group on Principles and Criteria for Radioactive Waste Disposal – te_909_web) On-site markers or monuments supported by national or international archives, as well as a range of other documents and rules, are generally considered to be the most effective way to communicate information regarding the existence of an underground repository. Nordic and NEA Working Groups has stated that the information conserved should comprise :

As primary information :

- The geographical location of the repository.
- The design of the repository, its physical shape and barriers.
- The radionuclide inventory.

Secondary information :

- Laws and criteria governing waste disposal.
- Licensing documentation submitted for the repository, including the final safety assessment.
- Records from the operational phase of the repository, such as databases on locations of waste packages and design modifications.
- General information about the society disposing of the waste.
- Potential risks associated with the wastes.

Although all that information could be preserved for thousands of years, it was proven through human history that the best that could be expected is several hundred years.

Another method of safely informing intruders could be the on-site markers that could take the form of monuments and could last for long periods of time. However a question arises "what kind of markers could live through time and keep their meaning?". A great deal of proposals have been made concerning those marks but none has been conclusive as language could not enhance their meaning for a vast period of time as it has a half life, like radioactive materials.

Symbols could also be an option as they are more universal but can change meaning in time and reverse their meaning. Jon Lomberg tried to succeed over language and symbol by proposing the usage of a visual storytelling that could show a sequence of events but again this collapsed since it could be read from bottom to the top and give it a whole other meaning.[Fig 1]

Another panellist and landscape artist named Mike Brill tried to envision a "landscape of thorns" that could cause people fear and make them avoid the place, although this has also failed as it was seen as a cause of interest and could make people want to explore it. [Fig 2]

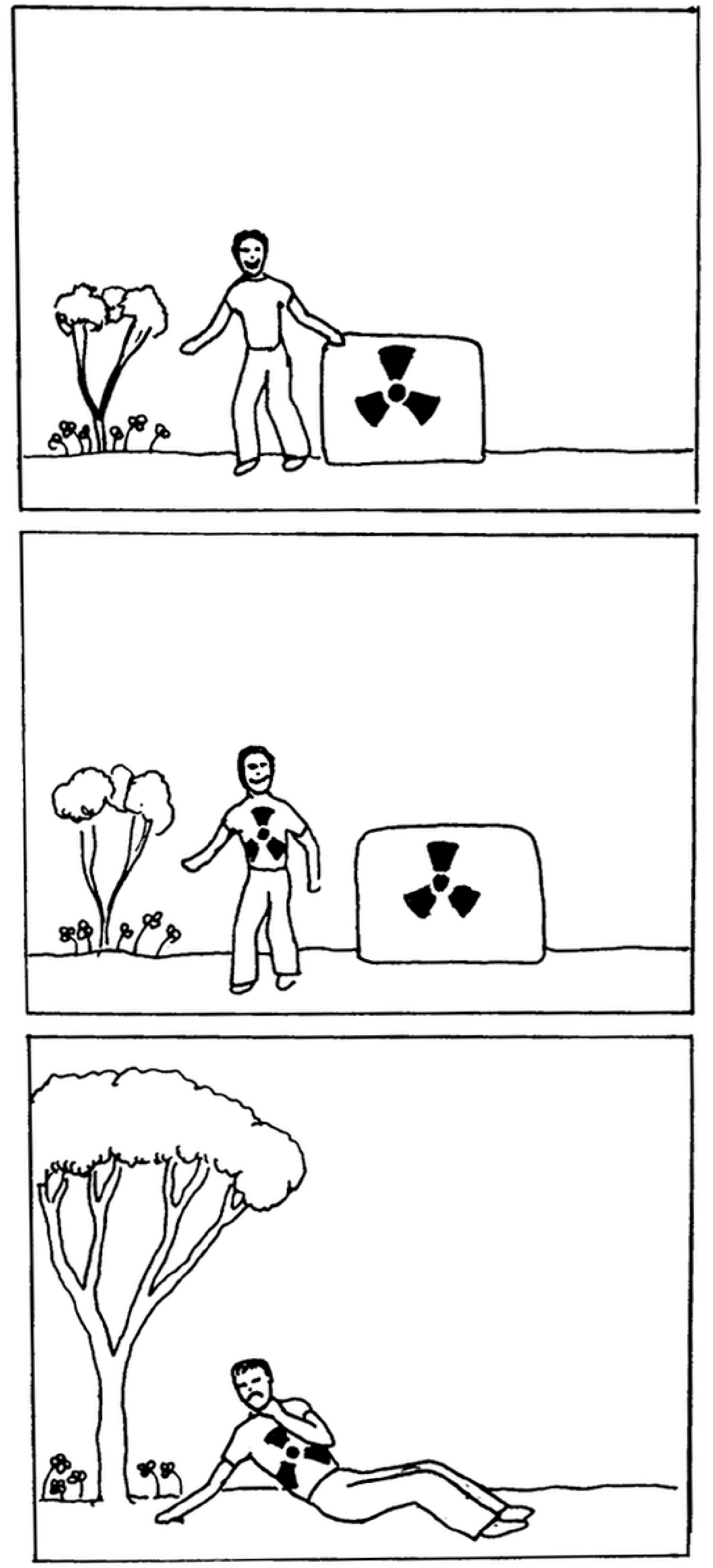


Figure 1 - Source : Jon Lomberg - 'Radioactive trefoil symbol' // https://99percentinvisible.org/app/uploads/2014/05/lomberg-comic.png

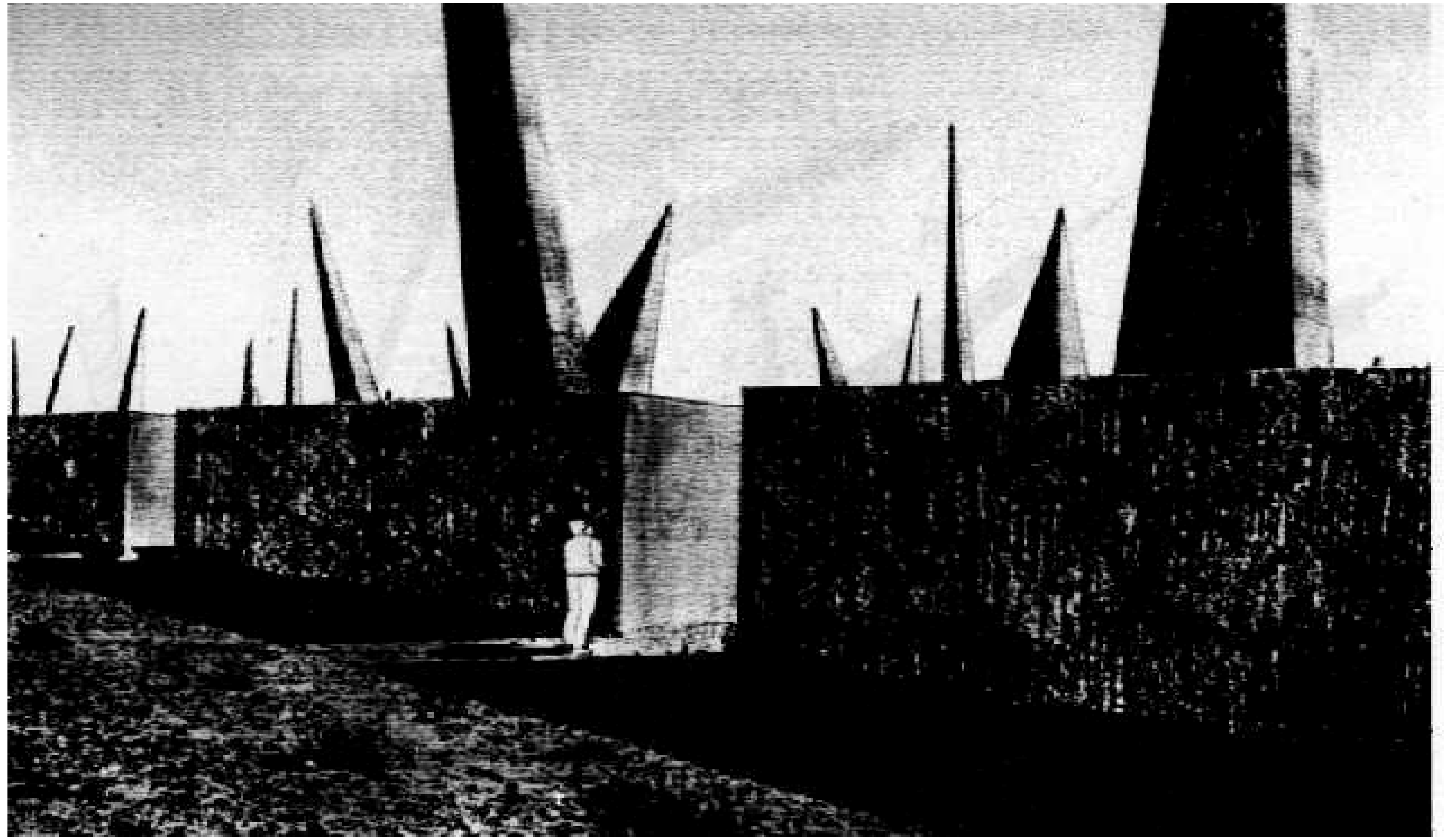


Figure 2 - Source : Michael Brill and Safdar Abidi - 'Spike Field', view 2 // https://archinect.imgix.net/uploads/br/brzydik72gzy0xde.JPG?auto=compress%2Cfor-mat

The most interesting approach came from the Human Interference Task Force that concluded that the most durable concept that was able to live through time was culture, such as religion and folklore. Even if they transform through time, the main idea is always conserved. Therefore, it was suggested that a genetically altered cat species, released into the wild to act as living Geiger counters, could change colour in the presence of radiation. With this new breed of cat, it might be conceivable to write songs or tell tales about the "ray cats" and convey the message that if one sees a cat that abruptly changes colour, he should avoid that area.

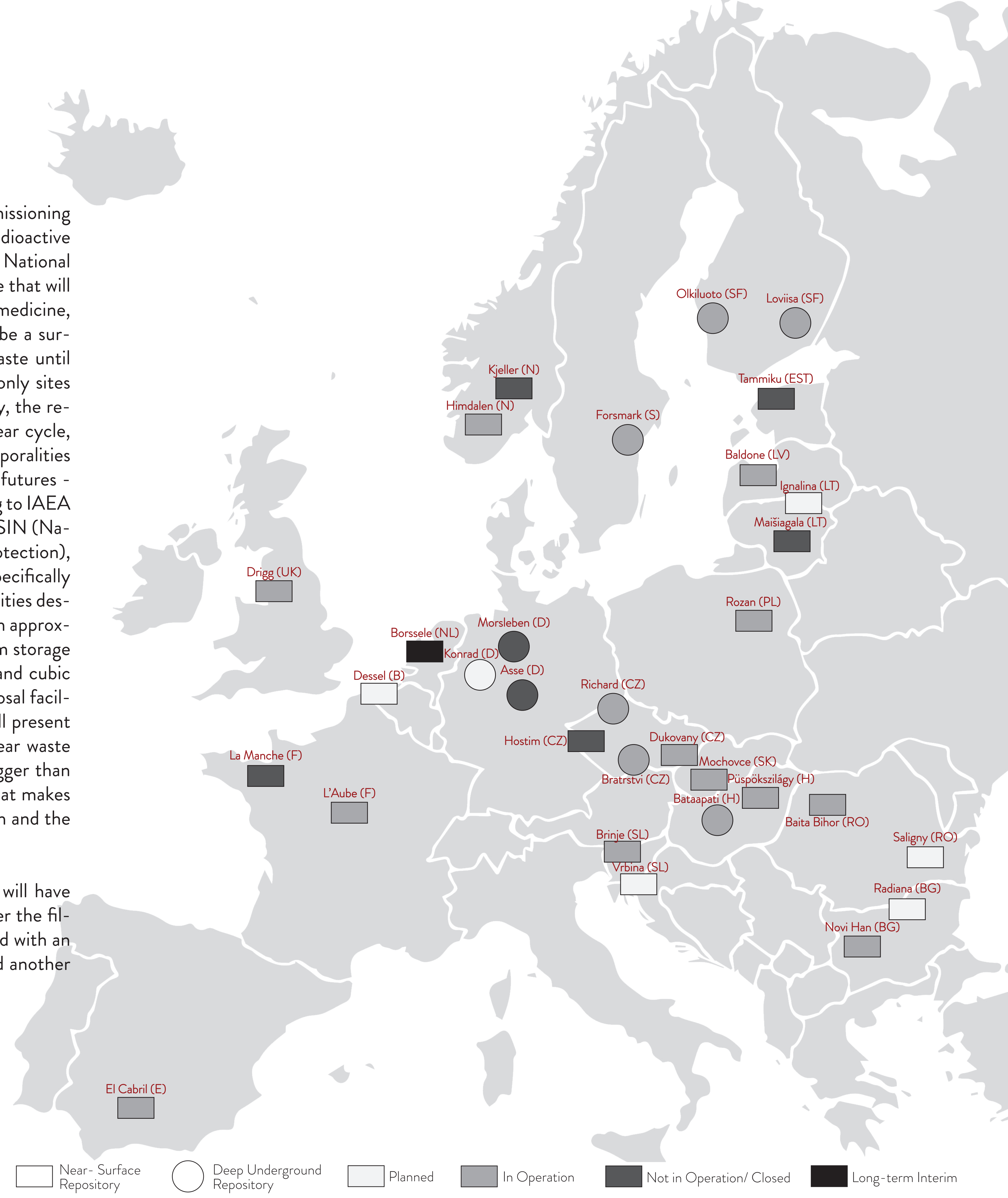
Figure 3 - Source : mnn.com - 'May the ray cats keep us safe' // https://99percentinvisible.org/app/uploads/2014/05/cats_0.jpg

The Italian Resolution

02.1 The National Repository

Sogin is a company that deals with the decommissioning of Italian nuclear plants and with the management of radioactive waste. It was proposed by them the establishment of a National repository assigned to host all the Italian radioactive waste that will result from decommissions (60%) and from the field of medicine, industry and even from research activities(40%). It will be a surface environmental infrastructure which will host the waste until the end of its lifetime rather than temporary since the only sites designated for this task in Italy are provisional. In this way, the repository will represent a step further in closing the nuclear cycle, deemed to be “an industry in decline”.(The Multiple Temporalities of infrastructure: Atomic Cities and the memory of lost futures - Leila Dawney 2021). The Repository will be built according to IAEA (International Atomic Energy Agency) standards and to ISIN (National Authority for Nuclear Safety and Radiological Protection), which propose natural and engineered barriers that will specifically contain the radioactivity at minimum risks. It will host facilities designated for the disposal of VLLW and LLW which will reach approximately 78 thousand cubic metres and will offer long-term storage for the ILW and HLW with a close quantity of 17 thousand cubic metres that will later be shipped towards a geological disposal facility better suited for their final disposal. Those barriers will present characteristics meant to guarantee the isolation of nuclear waste from the environment for a very long period of time, bigger than 300 years, at which point it will reach a level of decay that makes its radioactive properties inconsequential to human health and the environment.

On top of those safety measures, the repository will have low impact on the landscape of the territory because after the filing procedure is completed, the waste cells will be covered with an artificial hill made from waterproof materials that will add another layer of protection and will also avoid water infiltration.



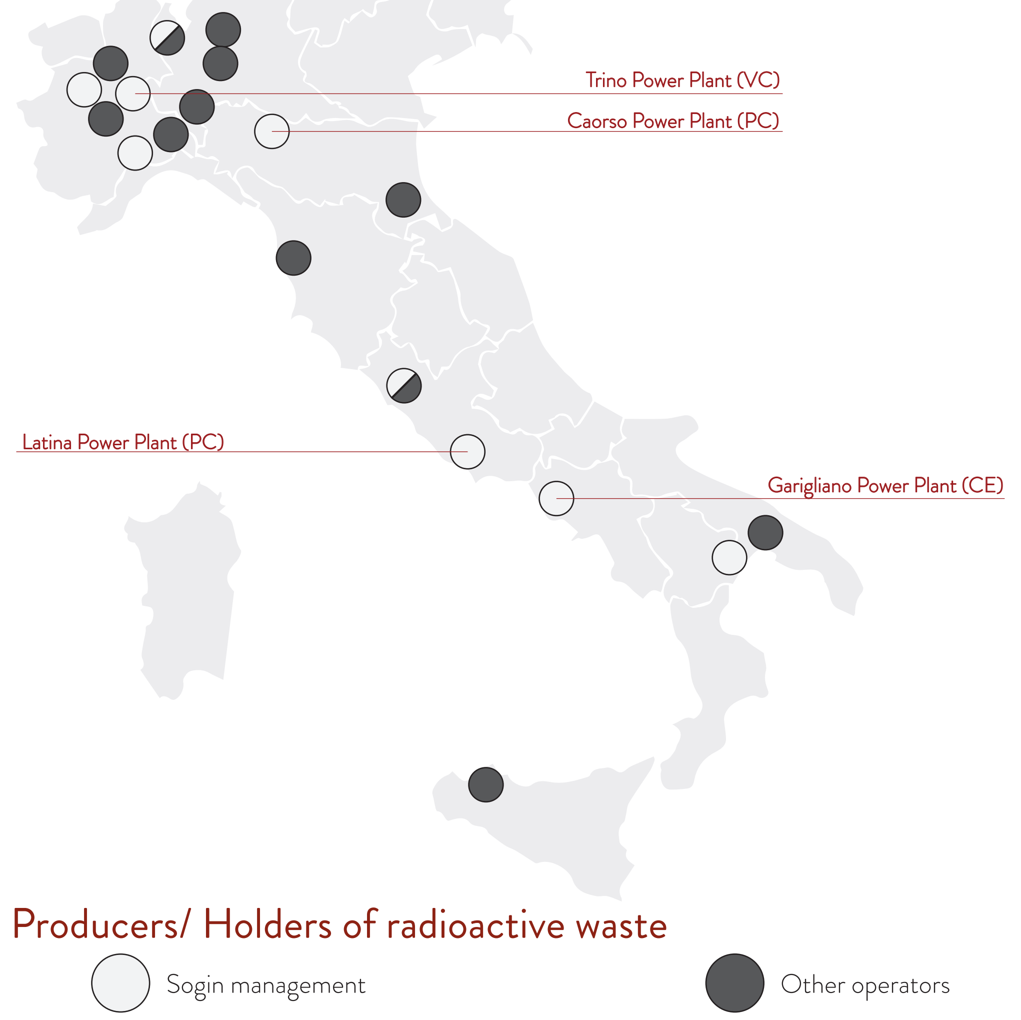
02.2 Technological park

Along with the National Repository there will be integrated also a Technological Park, that will act as a research centre available for international collaborations in which will take place activities related to energy, waste management and sustainable development fields. The Park will present two types of structures, some functional ones dedicated for the National repository and other independent ones strongly related to innovation and environmental protection. Those buildings will ensure that the Repository is built in a way that will be beneficial for the economy of the territory and will provide employment opportunities for peoples. Therefore, the Technological Park can be seen as a way of supporting the chosen territory by implementing structures necessary for the site that will boost the local economic field and will make the construction of a National Repository more agreeable to the public.

Disregarding the research that will be developed in the laboratories, the Park will include :

- **General services that support the National Repository and the Technological Park :** Those services will represent administrative and management activities such as reception, guardianship, maintenance workshops;
- **Paths for vehicles and pedestrians, parking lots :** The areas of the Repository and of the Park, although adjacent to each other they must be separated by a special fence and supplied with independent internal paths. The access to the Repository will have controlled access from the internal to external roads;
- **Green areas :** The roadways, a microclimate management system, and integration into the landscape will all be characterised by those areas;
- **An Archive :** It will serve as a way to deposit all the necessary information regarding the Repository and as a way to further deliver the information into the future for the upcoming generations;
- **An Environmental Laboratory :** This laboratory will have the purpose of analysing environmental samples from air, water, from the interior and exterior premises of the site to confirm the absence of contamination. The analysis will be periodically posted for the local communities;
- **Training structures :** Those structures will provide training courses on topics such as radiation protection, management of radioactive waste, safety and environmental protection, all in accordance with the respective legislation. Specific post-diploma and post-graduate courses will be organised in the area to aid in the assimilation of young citizens in the region that will house the National Repository.

In this manner, The Technological Park will serve as a hub for industrial innovation in science and technology as well as an employer for skilled workers.



02.3 Storage solution for VLLW and LLW

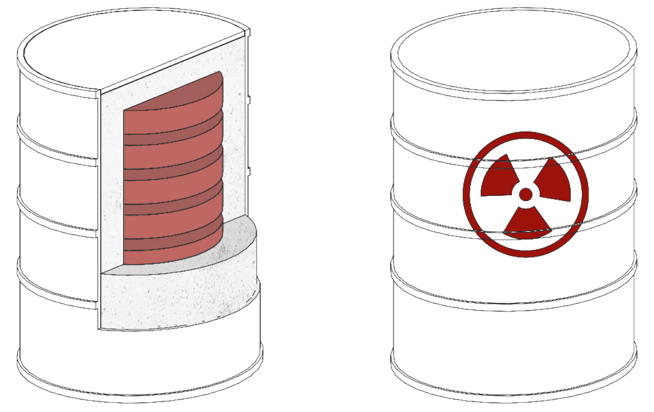
The very low level radioactive waste and the low level waste must be isolated, through engineered and natural barriers, from the environment until their radioactivity decays. Those barriers are multiple and arranged in a series that guarantees the effectiveness of the containment even if there will be a cause of degradation or weakening of one of the barriers. This will allow for the Repository to be in full control even in severe scenarios and throughout the entire operational life of the site.

There are 4 stages that the VLLW and LLW encounters :

- **Operational Phase :** In this phase the waste is received, checked and sorted. This phase lasts 40 years through which the first 15-20 years will represent collecting waste mainly from the dismantling of Sogin nuclear installations. After, the waste will be collected from medical, industrial and research activities;
- **Closing Phase of the Repository :** In this phase the deposit is filled and thus it can be closed and protected by the multi-layer water proof cover. This cover requires low maintenance and can serve for a long term. For the duration of the isolation period, the cover and other barriers prevent precipitation from coming into touch with garbage;
- **Surveillance Phase :** This phase will last for approximately 300 years and will allow the radioactivity from the waste to be reduced to less than 1/1000 from its original radioactivity. In this period the Repository is controlled and monitored to confirm the efficiency and the isolation capabilities conferred by the barriers and also to prevent human intrusion on the site. In this phase the only activities done on site will be periodic checks and maintenance;
- **Unconditional Release Phase :** In this phase the radioactivity of the site has reached negligible level and does not present dangers for humans and environment, therefore the Repository can be released.

The storage solution used by Sogin represents a multi-barrier system that starts by conditioning the waste in a cement matrix which immobilises the radionuclides. This is later placed in a metal container that allows the waste to be handled and transported with care and safety. This process represents the first barrier of the waste, called the artifact. Afterwards, those containers will be placed in a structure and immobilised inside it with grout (qualified cement mortar), thus forming the second barrier. All of the operations happening to form the second barrier take place into the Module Packaging Plant (ICM) unit. From there, the waste is transferred to the Cell Production Plant (IPC) that will generate the third barrier. This next barrier is called the cell and means burying the modules in a reinforced concrete cell that will be placed partially underground inside which it can incorporate 240 modules arranged on 5 levels. The last barrier is represented by an artificial hill that will cover 90 lined cells and will present different characteristics and functions. The hill will harmonise the infrastructure with the site environment.

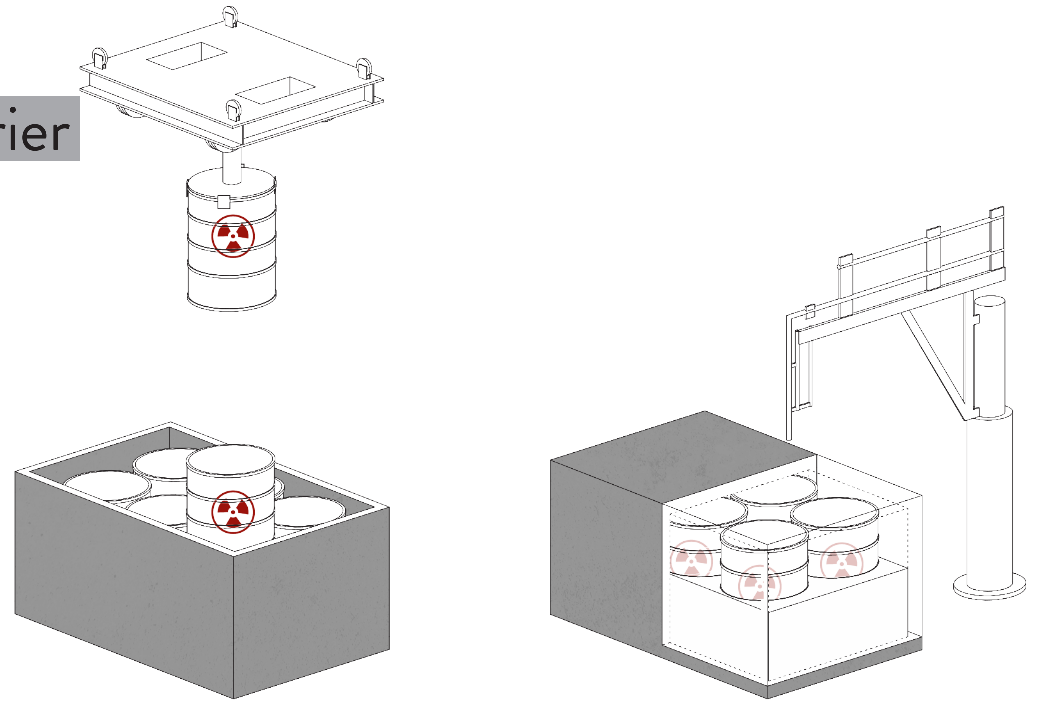
1st Barrier



The Artifact

The artifact represents a method of storage for the radioactive waste that could have a cylindrical or parallelepiped form made from metal containers. The waste is conditioned inside in a cement matrix making it ready to be transported further in a safe way. Every artifact has an identity document, a barcode, which provides information about the type of waste located inside.

2nd Barrier

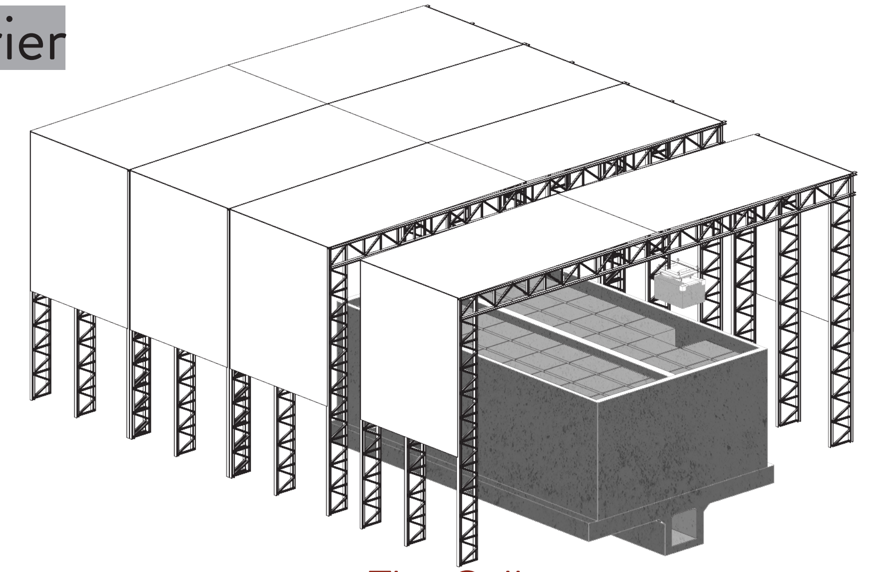


The Mdule

(3m x 2m x 1.7m)

Further into the process, the artifacts are placed inside the module, which is a structure made in special, reinforced or fiber-reinforced concrete designed to last up to 350 years.

3rd Barrier

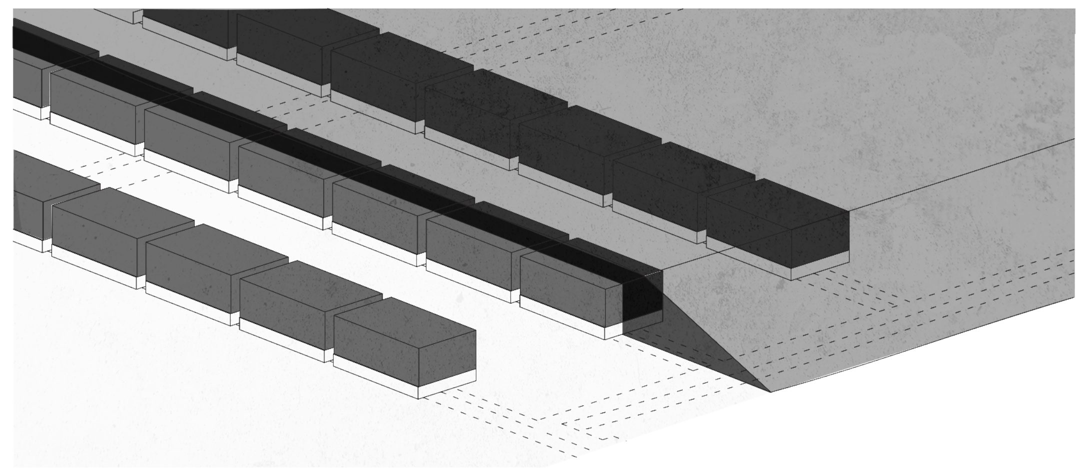


The Cell

(27m x 15.5m x 10m)

The cell is a structure made from special reinforced concrete designed to hold 240 modules and to last for upt to 350 years.

4th Barrier



The Multi-Layer Coverage

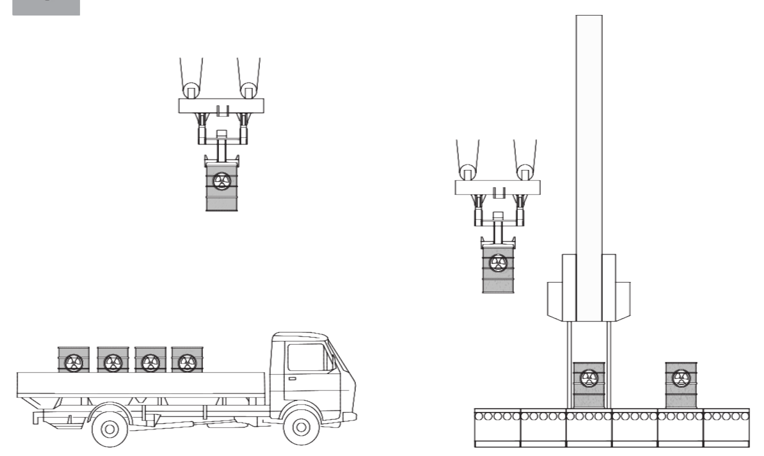
After the cells have been filled, they will be covered with several different layers of materials to protect the waste from water infiltration and the external environment. The coverage will host 90 cells over a spawn of 350 years.

Waste Treatment Plant (ITR)

The Waste Treatment Plant has the function of treating the solid radioactive waste that is produced by internal operation during its operation but it doesn't manage the waste produced outside of it. The radioactive that could be produced by such buildings could be clothing or gloves contaminated during the maintenance activities. The radioactive waste arrived here is not yet conditioned and therefore it needs to be subjected to physical and radiological checks before being sent for treatment or/and conditioning. If the waste arrives at the treatment line, it is super-compacted and conditioned. Another part of the ITR is represented by the cutting workshops that reduced the volume of large but weak contaminated components produced during maintenance activities.

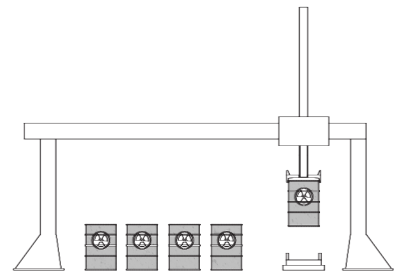
From this building, the items produced are further sent to the Modules Packaging Plant (ICM) to be secured into the second barrier, the concrete modules.

1



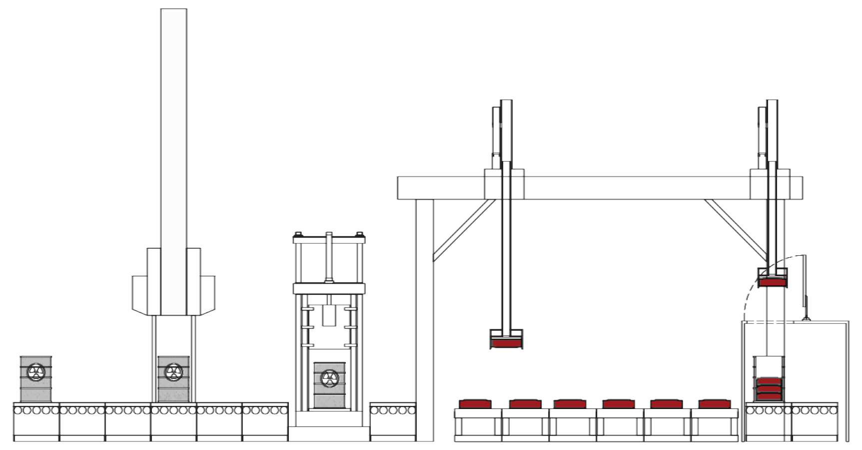
The artifacts arrive at the ITR where they undergo administrative control, following to be unloaded from the truck and sent to the temporary storage area.

2



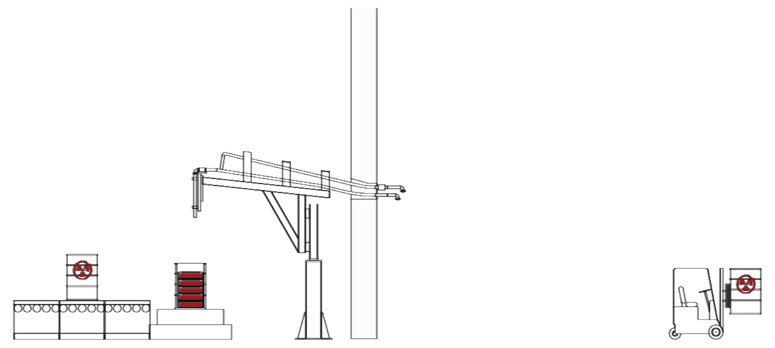
In the temporary storage area the compactable waste is selected and sent further to be compressed.

3



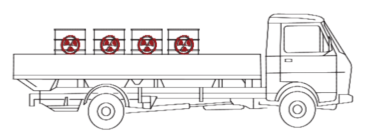
The waste is compacted and selected to be cemented in empty containers.

4



The containers filled with waste are being incorporated with the compacted compressed material by cementation.

5



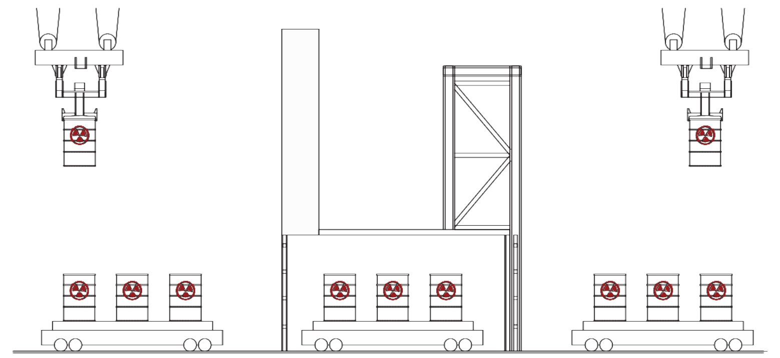
The waste is further loaded into the trucks and sent to the Modules Packaging Plant.

Modules Packaging Plant (ICM)

The Modules Packaging Plant is the place where the second barrier is created, the module. The structure manages to create 8 modules each day and the waste that arrives is already conditioned and therefore there is no need for waste treatment operations. The activities anticipated for the ICM refer only to the handling of the already packaged waste, their disposal into the modules and their immobilisation with cement mortar (the grout). Some checks are also realised and can be of 3 types : administrative checks, visual checks and direct measurements. After the checks, the artefacts have to be temporarily stored into a buffer area.

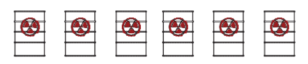
The checked artifacts are then placed into the module in order to be grouted and leather sealed with cement mortar. Every module is carefully monitored to the very last detail, knowing its content and position in the cell. From the ICM the modules are transferred towards the Module Disposal Unit (USM).

1



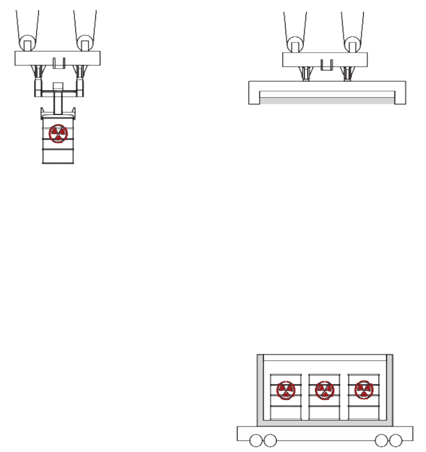
The artifacts enter the facility and are sent into the storage area.

2



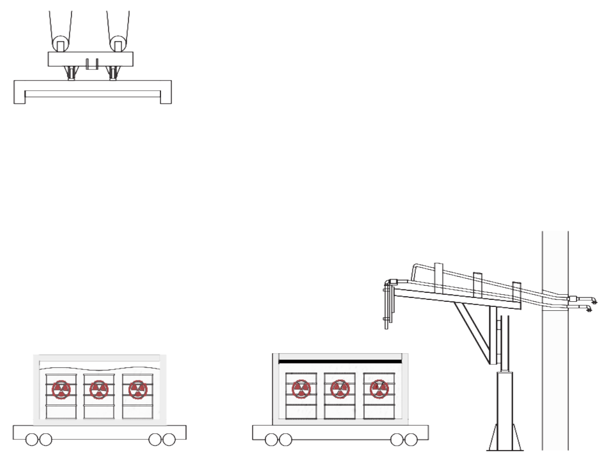
Firstly the artifacts will have to be placed into a buffer area.

3



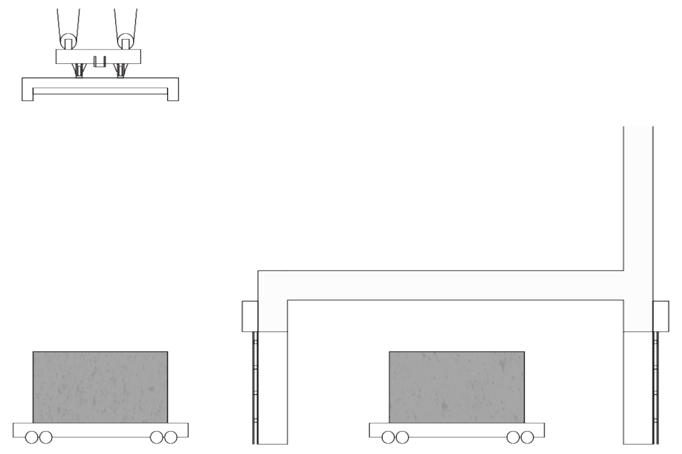
After waiting into the buffer zone the artifacts are placed into the module. The module receives an anti floating device and its cover.

4



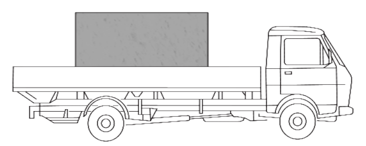
The module arrives at the grouting area where is immobilised with cement mortar. After grouting the module has to be sealed.

5



By being sealed they are ready to exit the ICM and therefore are ready for transportation.

6



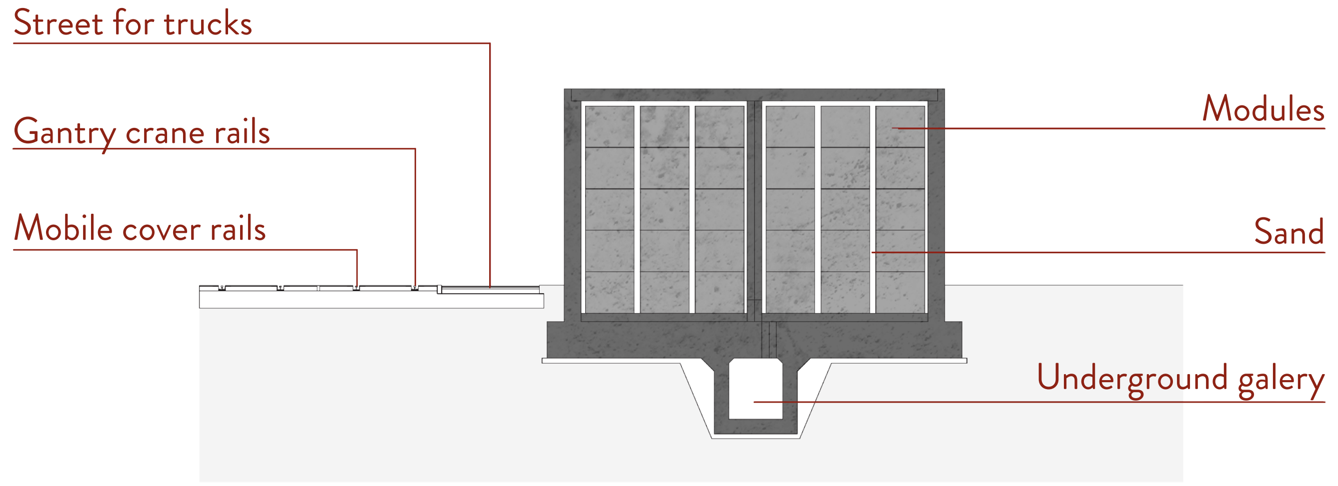
The module is loaded into the trucks and sent to the Module Disposal Unit.

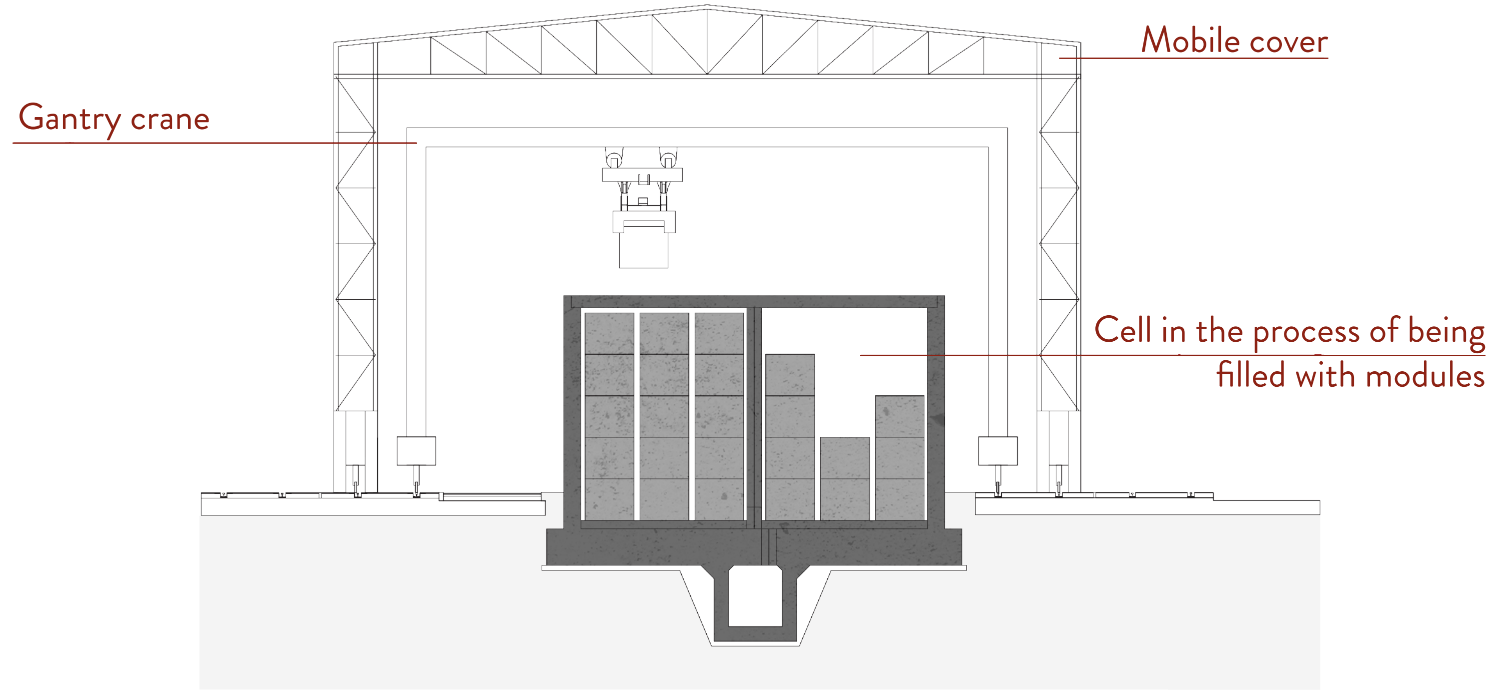
Modules Disposal Unit (USM)

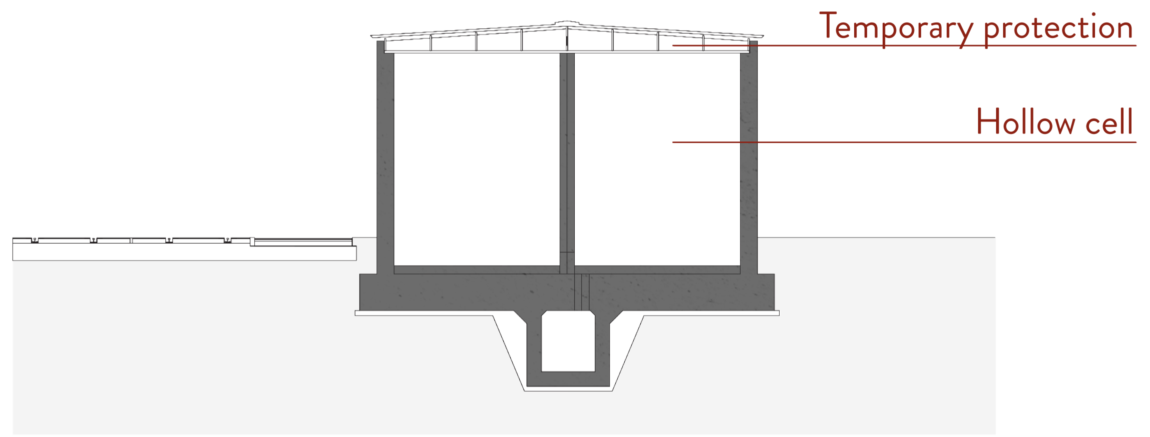
The Modules Disposal Unit represents the last step of the VLLW and LLW where they will be isolated from the environment for approximately 300 years until their radioactive decay. The structure is composed of 90 cells arranged in 9 rows of 10 cells and occupies an area of 10 hectares, and because the design of the cells is modular and adaptable, it is possible to increase the volumetric capacity and change the way the cells are arranged if the inventory estimates and/or the morphological qualities of the selected site call for it. After the cells are placed into the row, they are sealed and waterproofed. They will be later covered with several layers of inert material with certain properties in order to achieve the collection or drainage of rainwater. This will grant to the system the necessary resistance to any erosion phenomena. The multilayer roof will also serve the purpose of preventing concrete structures that make up the cell from deteriorating to phenomena like freeze/thaw cycles and dry/wet cycles. Topsoil will make up the last layer in order to improve visual integration with the surrounding.

Each cell has a temporary barrier installed between the building and filling phases in order to keep rainwater out and shields the interior from inclement weather. On the other side, the temporary protection is taken apart during the filling phase, and the cell is covered by a mobile covering/gantry crane system that can be moved along tracks. This prevents the entry of rainwater and allows for the filling of the cell.

Each row is served by a technical service tunnel that allows the employee to inspect the cells but it also has the function to house the water collectors that collect the water which infiltrates and also contains rainwater collectors for the empty cells during the pre-operational phase. A rear tunnel that houses the pipes for transporting the water to the collection tanks, where it is eventually released, connects the tunnels to one another. To allow air exchange prior to an inspection intervention, the tunnels are ventilated.







02.4 Temporary storage solution for ILW and HLW

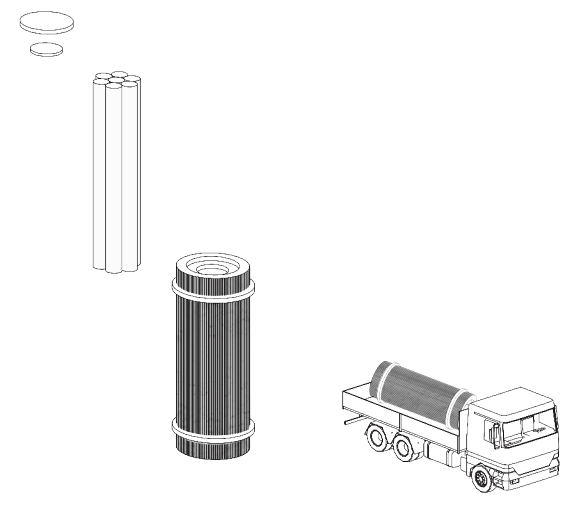
The Repository is defined by 2 main types of waste that needs to be dealt with in different ways. The VLLW and LLW has been dealt, as previously explained, through a multi-barrier system, but a different strategy needs to be applied to the ILW and HLW waste that requires a 'provisional long-term' storage. Because of their particular feature of lasting hundreds of thousands of years until their radioactivity decayes, they need to be isolated into deep geological formations , meaning several hundreds of metres underground.

In order to provide safety conditions for the duration of storage in the CSA and for subsequent transfer to the future geological deposit, the container and the waste conditioning matrix will be combined to create a product with a usable life that is sufficient. Only waste that has already undergone conditioning by its producers will be delivered to the facility. In the Repository facilities, high activity waste is not treated or conditioned. Different types of containers will be used to arrange and condition the nuclear plant decommissioning waste. Therefore, the HLW that will be received will be only unloaded and transferred in the storage.

The following categories of high activity waste can be identified as being created by nuclear sites and structures that are currently located on the national territory during decommissioning and diverse operations.

- Homogeneous waste from the process activities of the nuclear power plants of the cycle plants and other national producers;
- Activated and/or contaminated dry solid heterogeneous waste, coming from the decommissioning activities of the nuclear power plants and fuel cycle plants, and other national producers;
- Residues resulting from the reprocessing of irradiated fuel elements;
- Irradiated fuel from research centres.

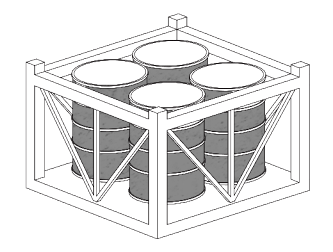
1st Barrier



The Cask

Canisters, which are 180 litre cylindrical stainless steel containers, are inserted and placed inside the cask and used to condition the vitrified and compacted waste. It ensures that both during storage and during transit, rigorous safety criteria are met. Extreme mechanical and thermal strains can be absorbed by it.

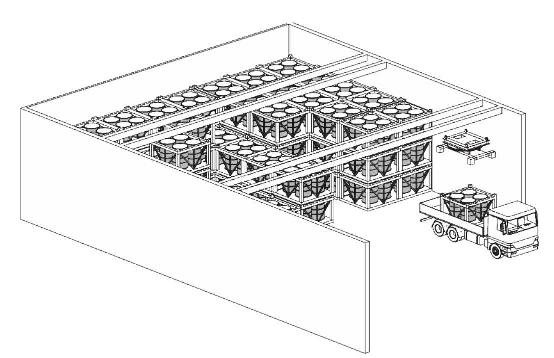
2nd Barrier



Stackable Metal Racks

At the CSA, customised stacking racks that can hold all different kinds of containers are used to store the non-shielding containers. They are kept in the naves, which may hold up to five stacking levels. The rack's design ensures the stack's stability against tipping over.

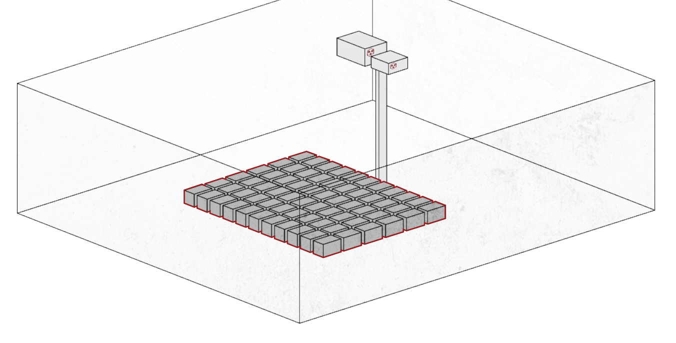
3rd Barrier



The Temporary Storage

After inspections, the containers or casks are moved to the locations designated for short-term storage. The CSA is a building intended for ILW/HLW storage over a 50-year span. Following that, it will be sent to a deep geological deposit for long-term disposal.

4th Barrier



Deep Geological Disposal

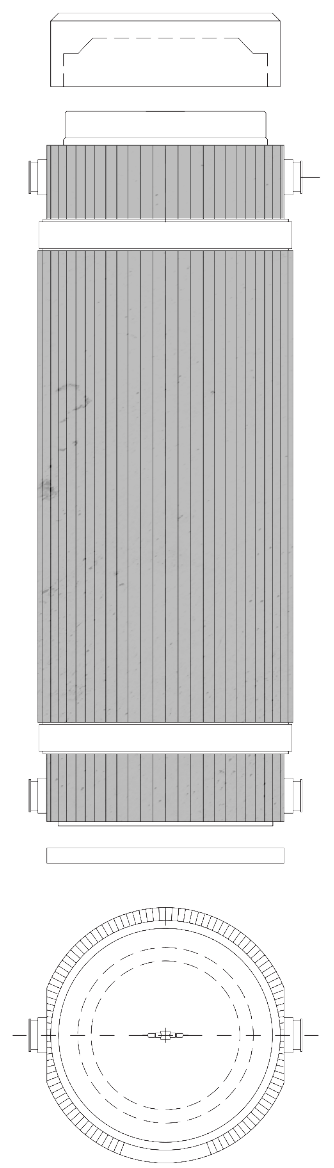
Final disposal is planned for deep geological formations, passive safety containment techniques, or barrier systems utilising geotechnical, geological, and technological components.

High activity waste storage complex (CSA)

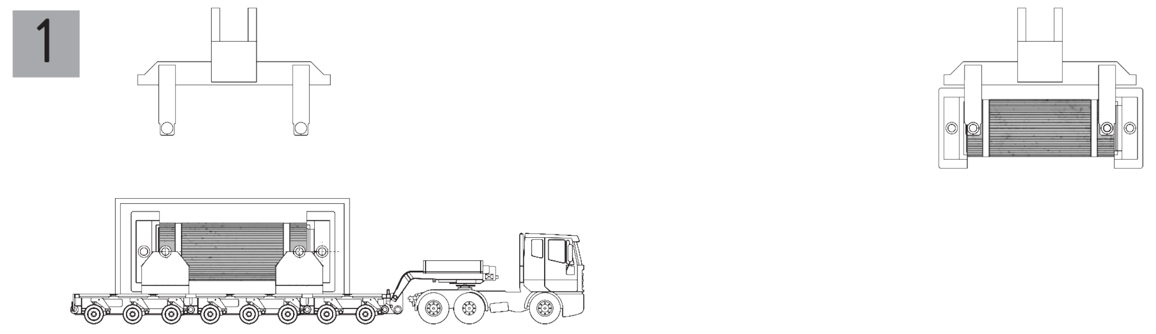
The High activity waste storage complex will accommodate the entire quantity of ILW and HLW from the Italian territory. The CSA's structures, systems, and parts are built to endure a variety of calamities, both natural and man-made, including earthquakes, extremely harsh weather, air impact, fires, and explosions. Its preliminary design accounts for the technical and operational needs relating to the various waste types that must be stored as well as associated artefacts and temporary storage cask management.

The storage structures are equipped with high-activity waste management technology and meet the strictest standards in order to be able to keep the waste for up to 50 years before transferring it into the geological repository.

Each of the CSA's buildings are presented with storage aisles accessible through sections with controlled access for the waste. The products can be packaged into a cask or a stackable metal rack, depending on the features of the waste. For the temporary storage of highly active waste, each building consists of three identical and modular naves. In addition to the three normal naves previously described, only one of the four structures features a fourth nave specifically intended for the temporary storage of radioactive fuel and cask reprocessing waste.

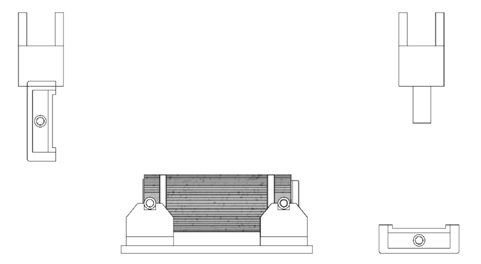


1



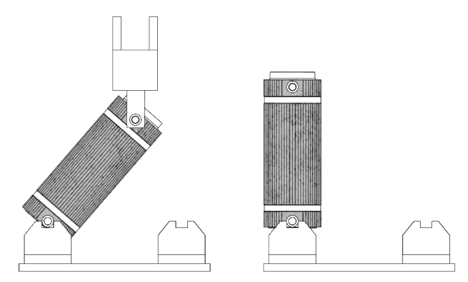
After the cask arrives it undergoes administrative checks. The cask is further unloaded and positioned on a support saddle.

2



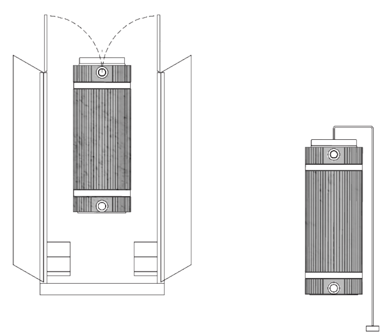
The shock absorbers get removed from the cask's helmet.

3



The cask is placed into a vertical position.

4



The cask is transferred to the control area where is checked visually and by using instruments. Later the cask is placed in the storage area.

Site Localization

03.1 Siting criteria

The process of localization, known also as sitting, aims at finding a suitable place for the repository through different phases of investigations and multiple evaluations. The first phase represents the selection of diverse areas that meet certain criterias related to the physical, chemical, naturalistic and anthropic characteristics of the territory to ensure the safety construction of a radioactive waste repository.

As an outcome, the first phase provides a set of potentially suitable areas :

- Class A1 - Highly competent area
- Class A2 - Competent area
- Class B - Insular area
- Class C - Area in seismic zone 2

67 Potentially suitable areas identified

Class A1 Class A2 Class B Class C

The criteria that the first phase basis its research have been elaborated by ISPRA in the Guida Tecnica n.29 following the recommendations given by the IAEA. Those can be of 2 types, exclusion criteria (CE), which excludes areas whose characteristics do not meet the safety requirements fully or partially, and investigation criteria (CA) which help in evaluating the areas that already meet the requirements of the exclusion criteria.

Exclusion Criteria

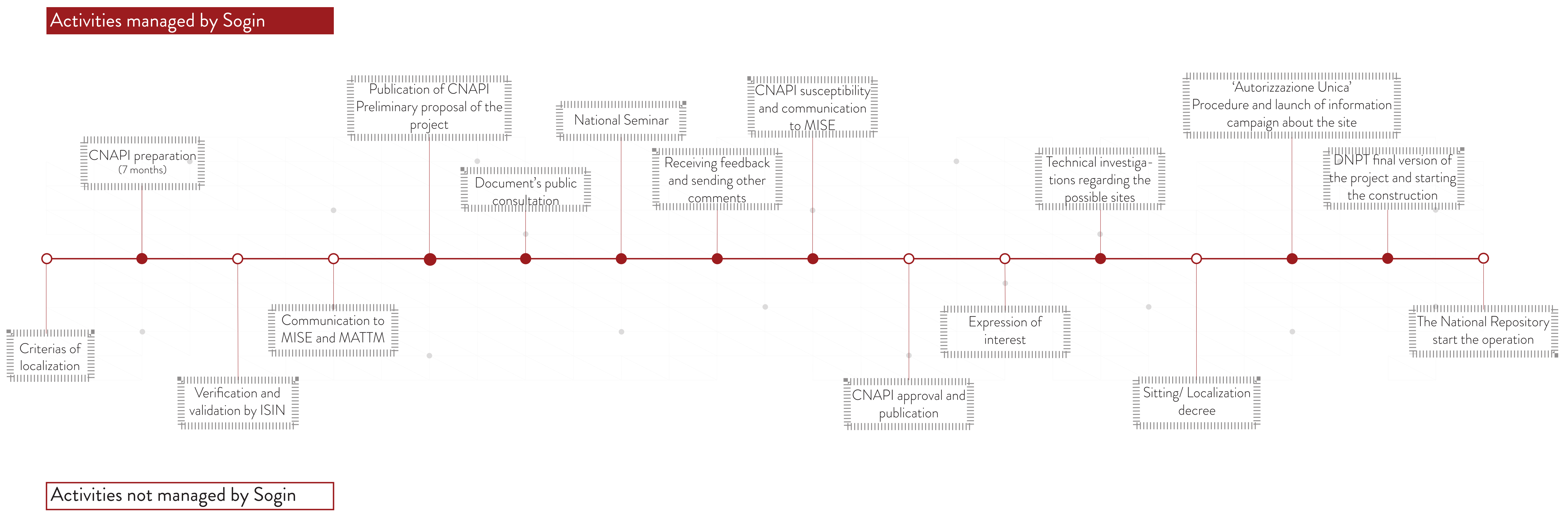
- **CE1** Area of active or quiescent volcanoes
- **CE2** Area of high seismic activity
- **CE3** Area of interest by superficial faulting
- **CE4** Area, characterized by geomorphological and/or hydraulic risk and/ or hazard of any grade as well as river belts
- **CE5** Area of holocene alluvial deposits
- **CE6** Area, located above 700 m a.s.l.
- **CE7** Area, characterized by an average slope greater than 10%
- **CE8** Area within 5 km from the current coast line or, if more distant, located under 20 m a.s.l.
- **CE9** Area, interested by morphogenetic karst processes or with the presence of sinkholes
- **CE10** Area, near surface piezometric levels or with piezometric levels which could anyhow interfere with the foundation of the disposal facility
- **CE11** Area naturalistic, protected under the legislation in force
- **CE12** Area at an unsuitable distance from residential zones
- **CE13** Area within a distance of 1 km from highways, all principal suburban roads, and the main and complementary railway lines
- **CE14** Area with known presence of underground resources
- **CE15** Area with industrial activities involving major accident hazards, dams and artificial hydraulic barriers, airports or operating military shooting ranges

Investigation Criteria

- **CA1** Area of active or quiescent volcanoes presence of secondary volcanic activities
- **CA2** Presence of significant vertical movements as a result of subsidence area of high seismic activity and uplift phenomena (tectonic and/or isostatic)
- **CA3** Geological-morphostructural setting and presence of lithotypes with vertical and lateral variation
- **CA4** Presence of endorheic type river basins
- **CA5** Presence of accelerated erosion phenomena
- **CA6** Weather and climatic conditions
- **CA7** Physical and mechanical parameters of the soil
- **CA8** Hydrogeological parameters
- **CA9** Chemical parameters of soil and groundwater
- **CA10** Habitats, animal and plant species of conservation importance, as well as geosites
- **CA11** Agricultural production of outstanding quality and places of archaeological and historical interest
- **CA12** Availability of primary transport infrastructures
- **CA13** Presence of relevant or strategic critical infrastructures

The second phase of localization has the purpose of identifying, inside of the potentially suitable areas, the sites that are subjected to a more detailed investigation. Those sites are chosen according to evaluations done at a regional scale. The third phase and last one, constitutes the detailed technical characterization of the sites, focusing on the long-term behaviour.

Steps of Localization



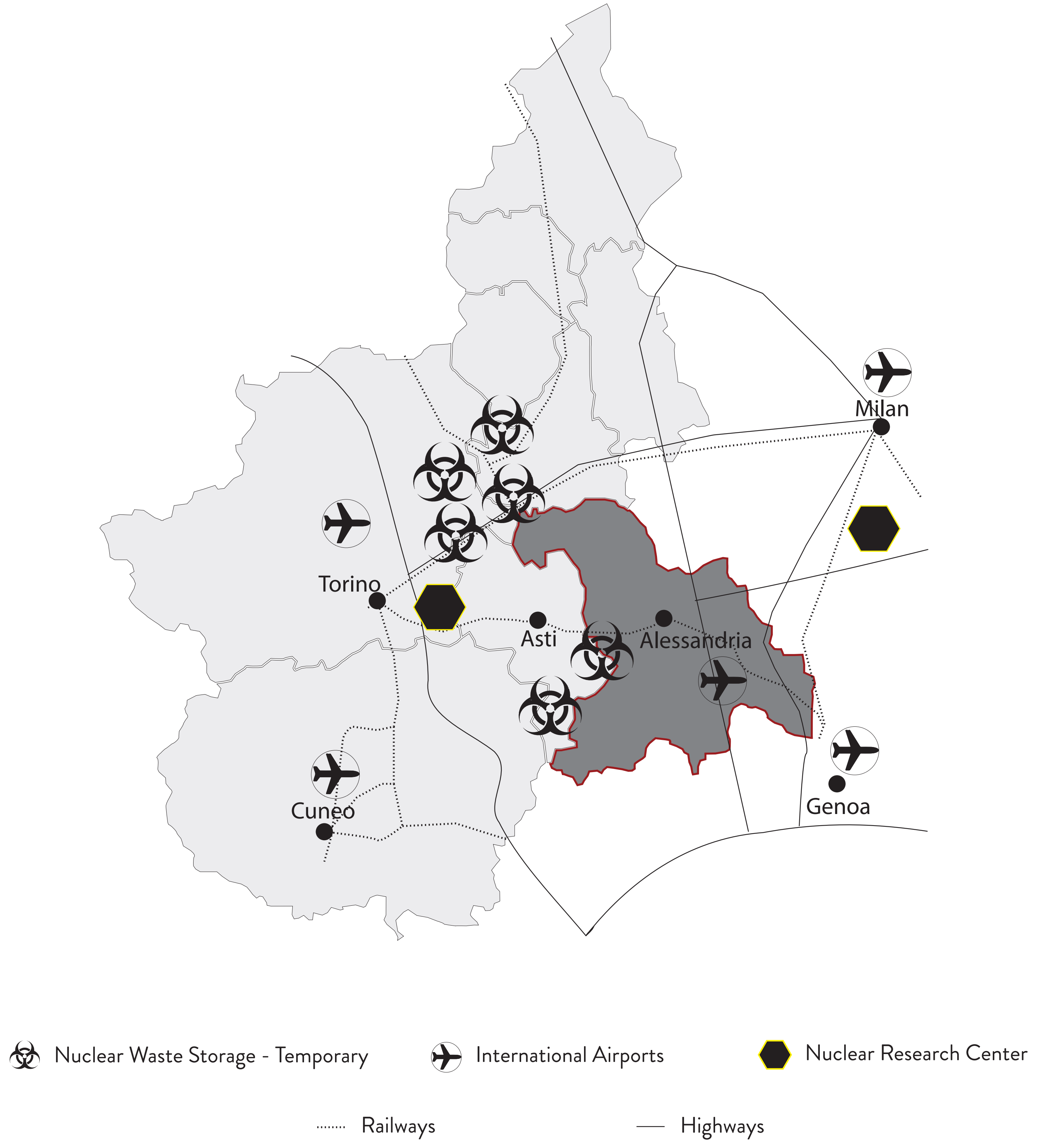
AL_8 Area

04.1 Project Area

The area of the project, called the AL-8 area, is located within the Alessandrina Plain and it is characterised by the presence of terraced surfaces that tend to converge as they advance towards the central sector of the Alessandria Basin. The area, mostly flat, has a slight slope towards the South and South-East of less than 1% and altitudes that reach between 142 and 100m above the sea level.

At an hydrographic level, the existent network found in the area is inconsequential and mainly regards some made up canals and irrigation ditches which attach to the Rio della Maddalena , the Rio Balocco and two other minor water courses that have their spring starting from N-NW and drain towards the Tanaro river. After multiple examinations performed in the area it was discovered that there are no indications of geomorphological instability or potentially floodable areas and thus the area doesn't present elements of landslide or flood hazards. The AL_8 area is also characterised by the cultivation of different types of grains and has a typically agricultural landscape that alternates between cultivation fields and farm houses although it also has a small area of wood arboriculture in the NE, more precisely a plantation of cherry trees. The settlements of the area are represented by systems of residential areas mainly linked to agricultural activities although the agri-food chains in the area (Quargnento, Alessandria and Castelletto Monferrato) don't represent a main aspect for the economy.

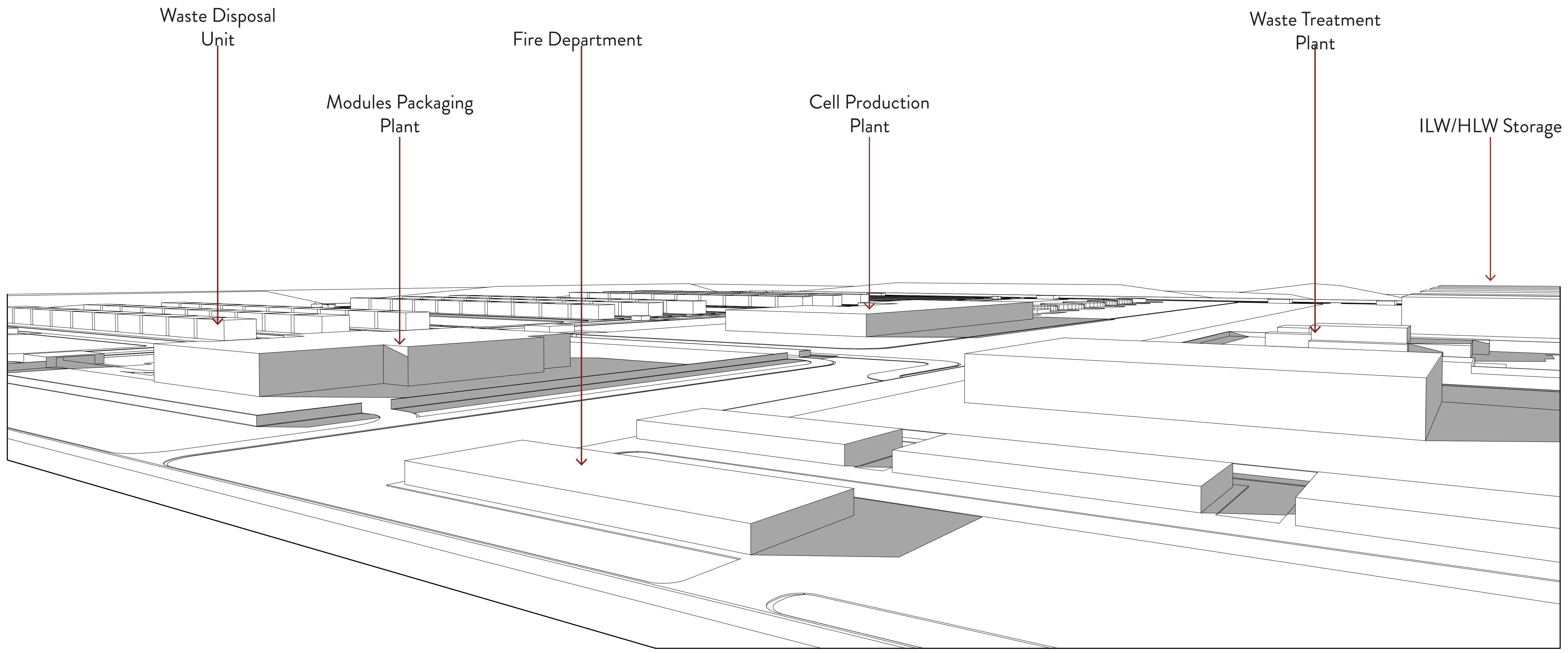
The Infrastructure of the area is crossed in the centre by the SP75 "della Fraschetta" road towards the NE-SW direction and in the other parts is characterised by minor local roads, mostly unpaved.



Site Characteristics

02

Defining The Strategy



Perspective overlooking the repository

The Masterplan

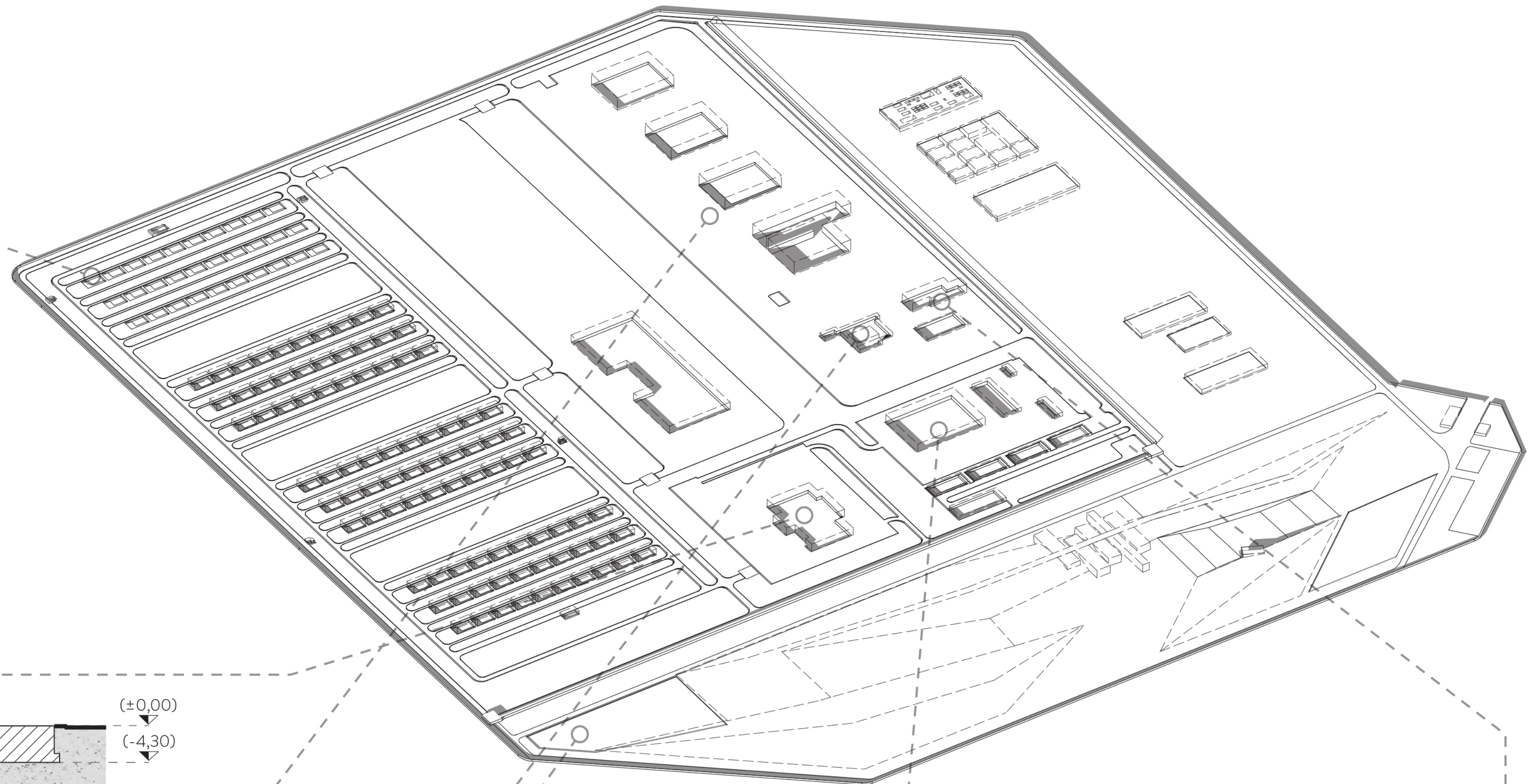
Legend

1. Waste Disposal Unit
2. Cell Production Plant
3. Modules Packaging Plant
4. Fire Department
5. Service Constructions
6. Offices
7. Modules Production Plant
8.Health Department
9. Waste Treatment Plant
10. LAB
11. Quality Control Plant
12.Office
13. ILW/HLW Storage
14. Study and Experimentation Center
15. Training School
16. Environmental Laboratory
17. Main Entrance
18. Public Entrance
19. Archive
20. Extension of Waste Disposal
21. Water Reservoir
22. Model of the Repository's cell, scale 1:1
23. Old Farm
24. Artificial Hills
25. Information Walls

N

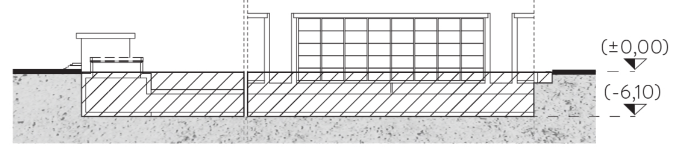
Earth Management

Year 2023 - 2027

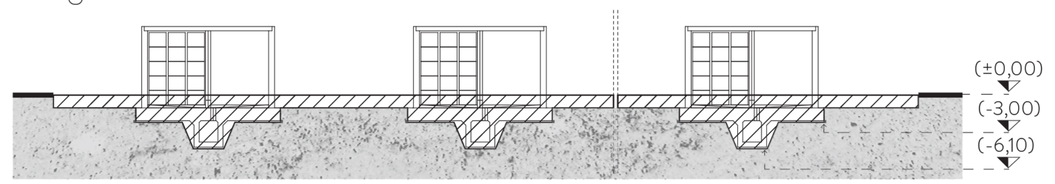


Earth obtained from each section :

Module Units :



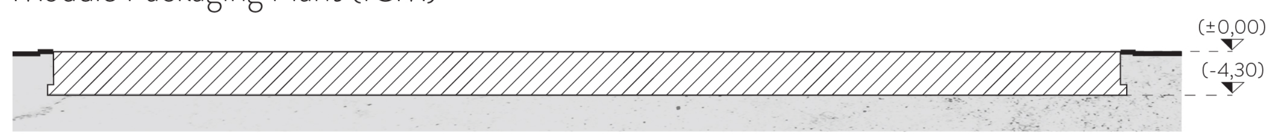
Longitudinal section



Cross section

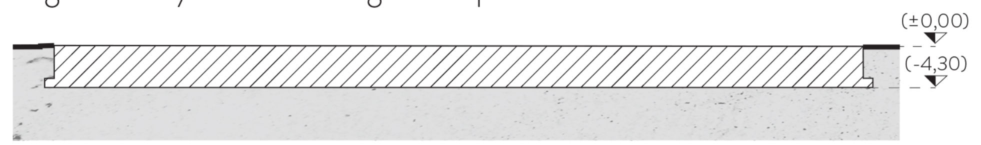
Total : ~400000 m³

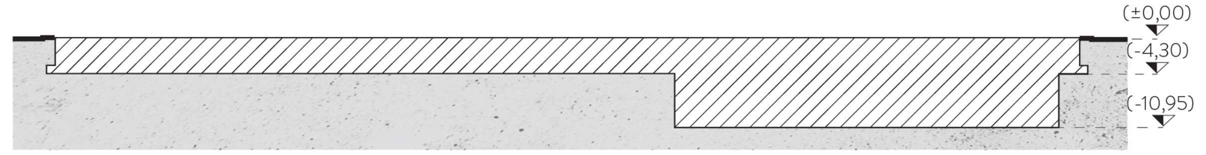
Module Packaging Plant (ICM)



Total : ~30000 m³

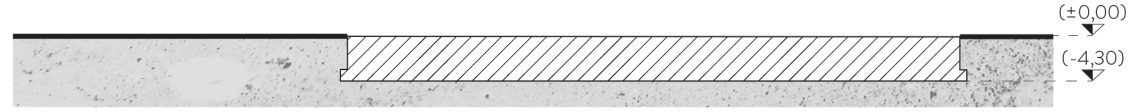
High Activity Waste Storage Complex (CSA)





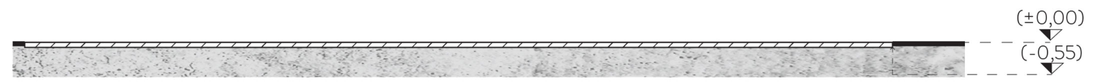
Total : ~250000 m³

Waste Treatment Plant (ITR)



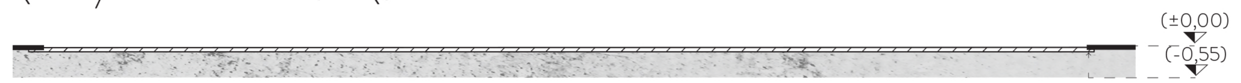
Total : ~20000 m³

Module Production Plant (IPM)



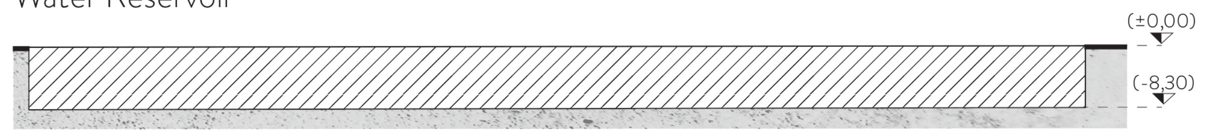
Total : ~4000 m³

Quality Control Plant (ICQ)



Total : ~1000 m³

Water Reservoir



Total : ~100000 m³

Other

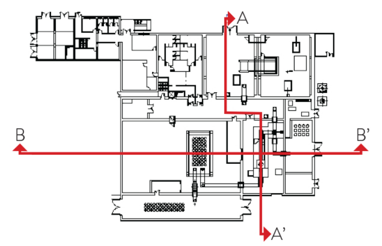
Total : ~300000 m³

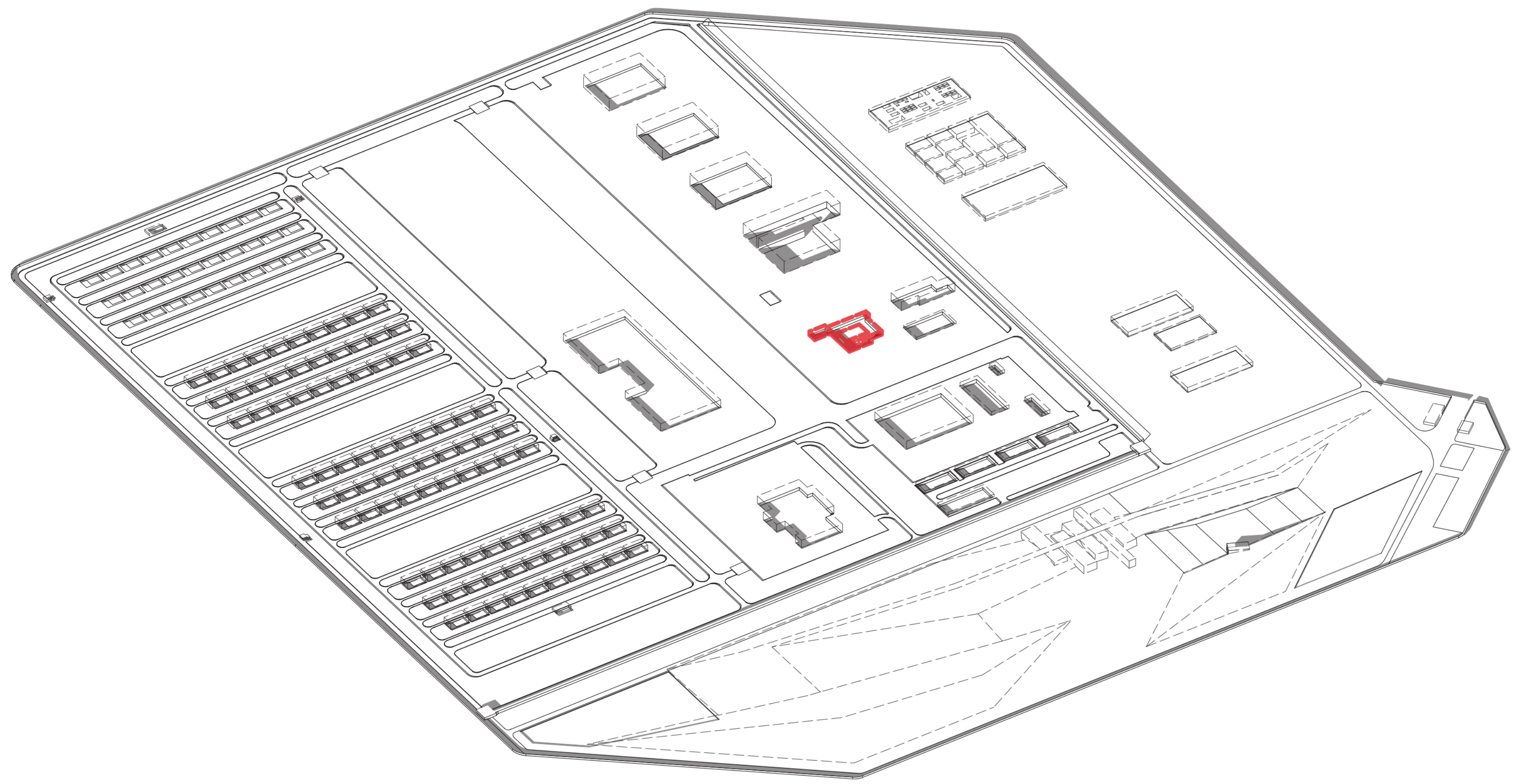
Needed :	Obtained :	Required :
~2.700.000	~1.200.000	~1.500.000

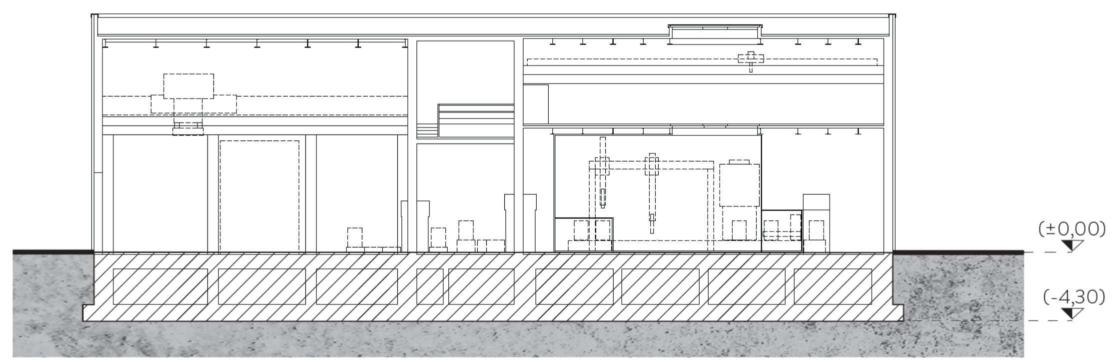
0 — 4

Buildings Section

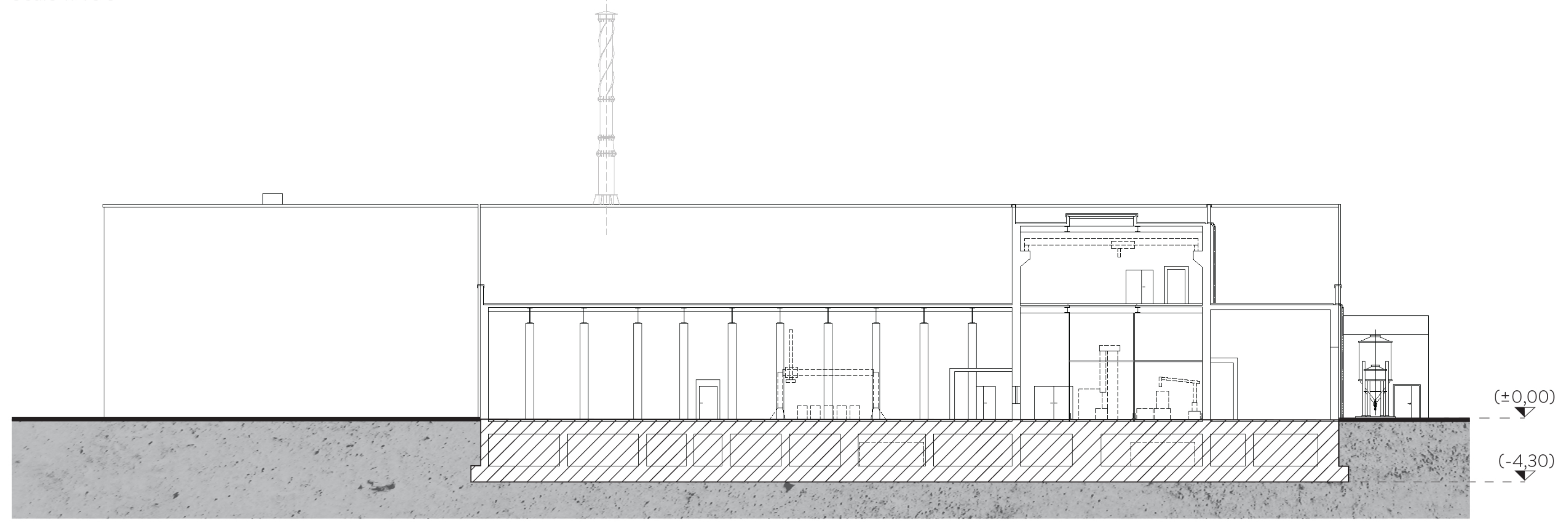
Waste Treatment Plant (ITR)







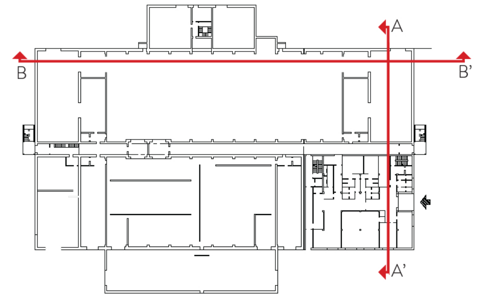
Section A-A'
Scale 1:400

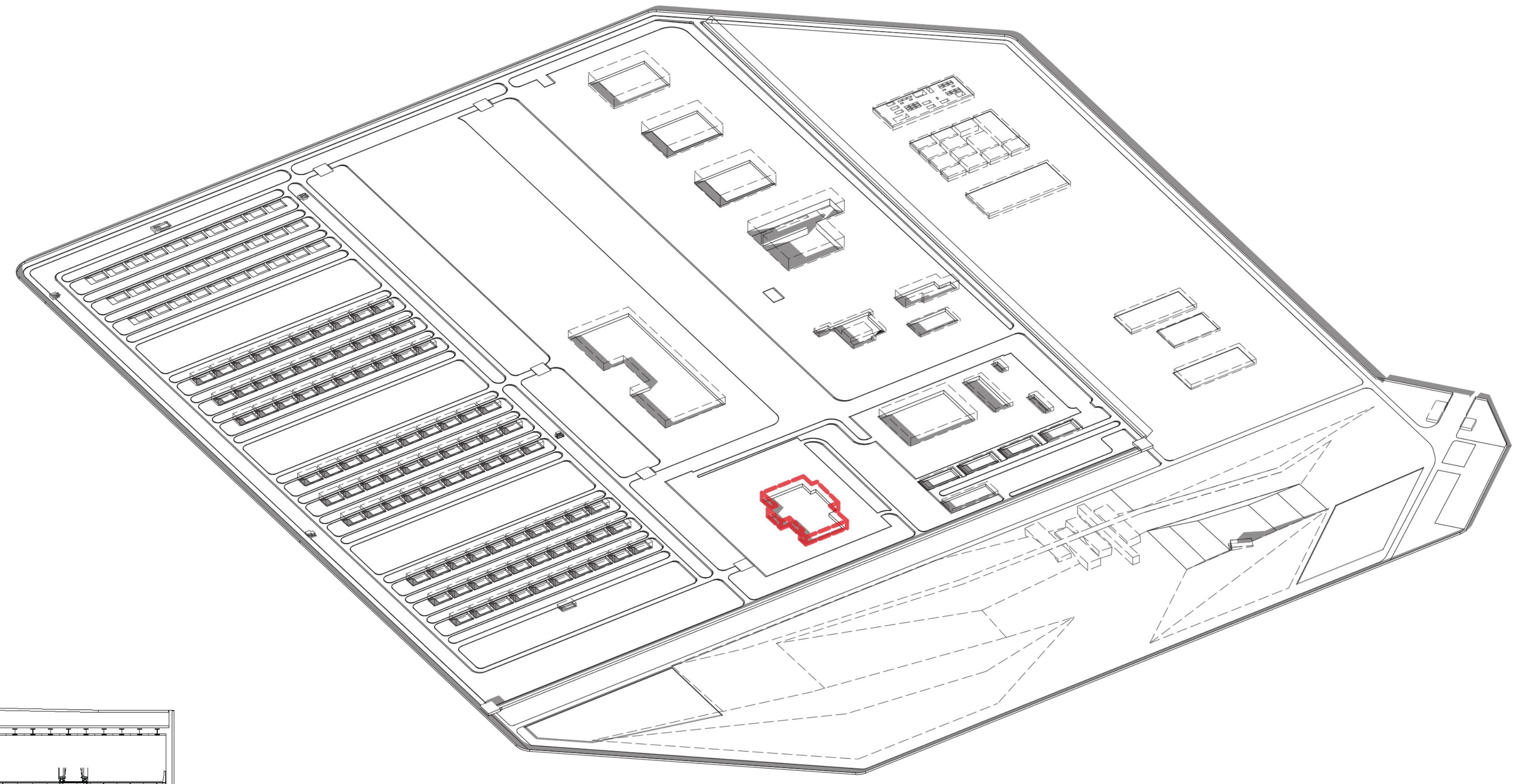


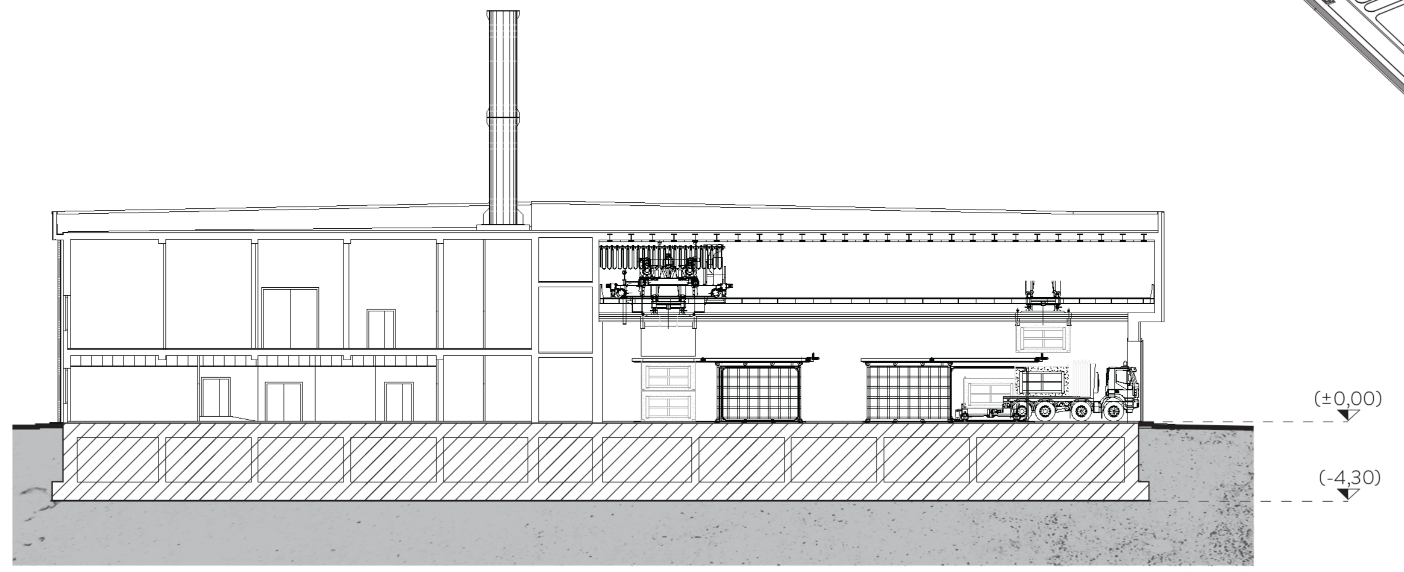
Section B-B'
Scale 1:400

Buildings Section

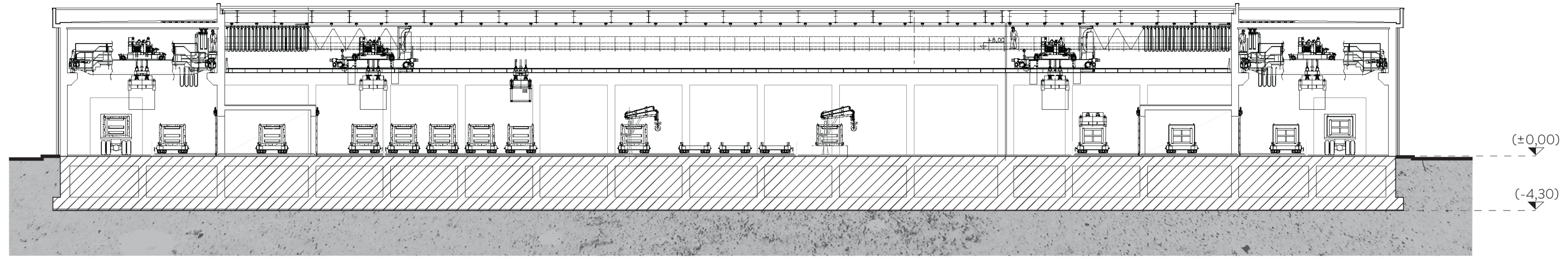
Module Packaging Plant (ICM)







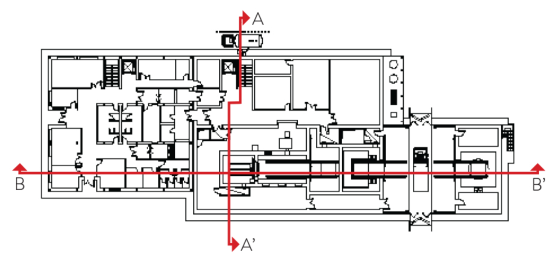
Section A-A'
Scale 1:400

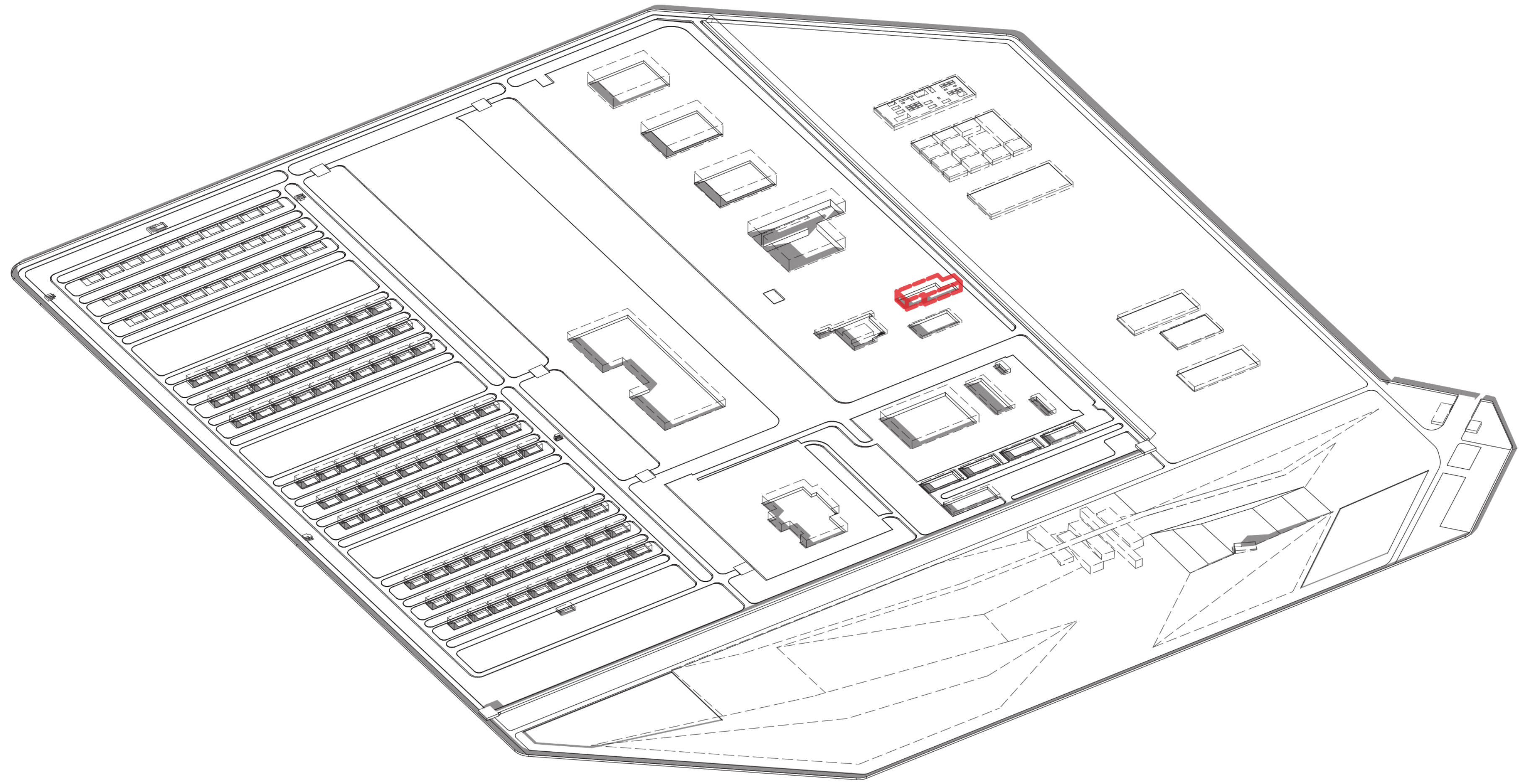


Section B-B'
Scale 1:400

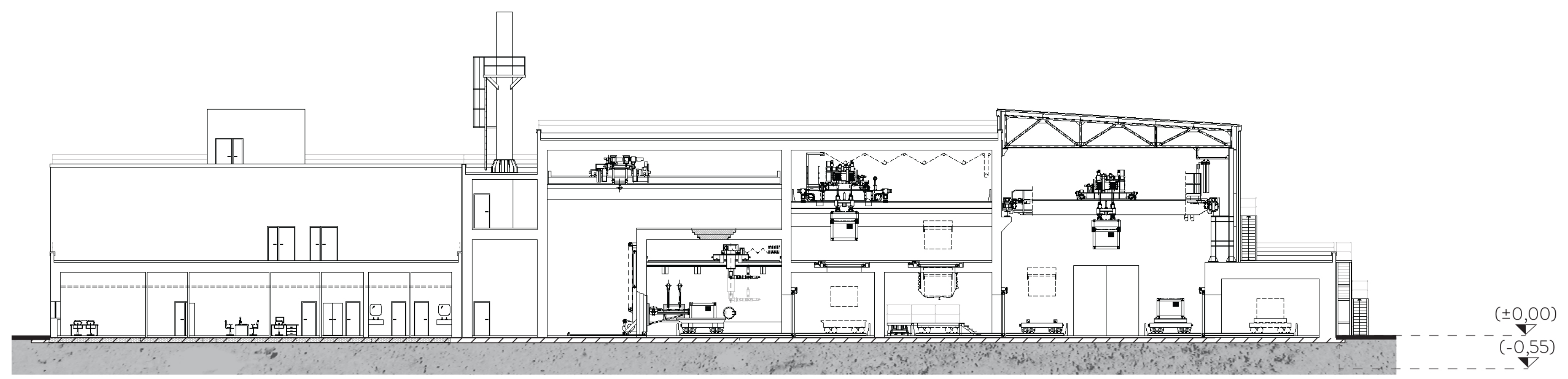
Buildings Section

Quality Control Plant (ICQ)





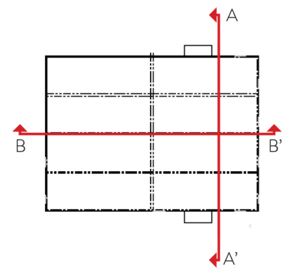
Section A-A'
Scale 1:400

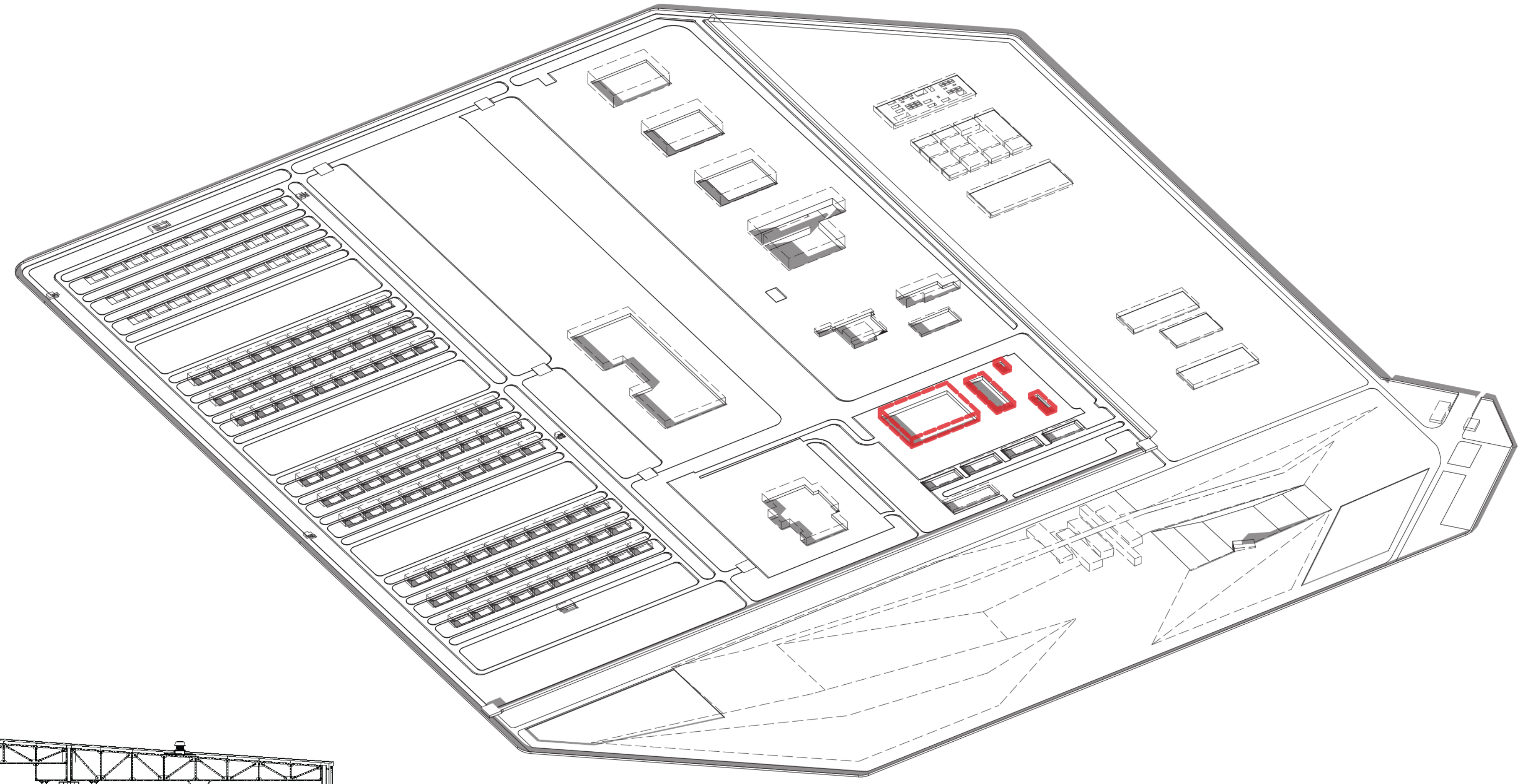


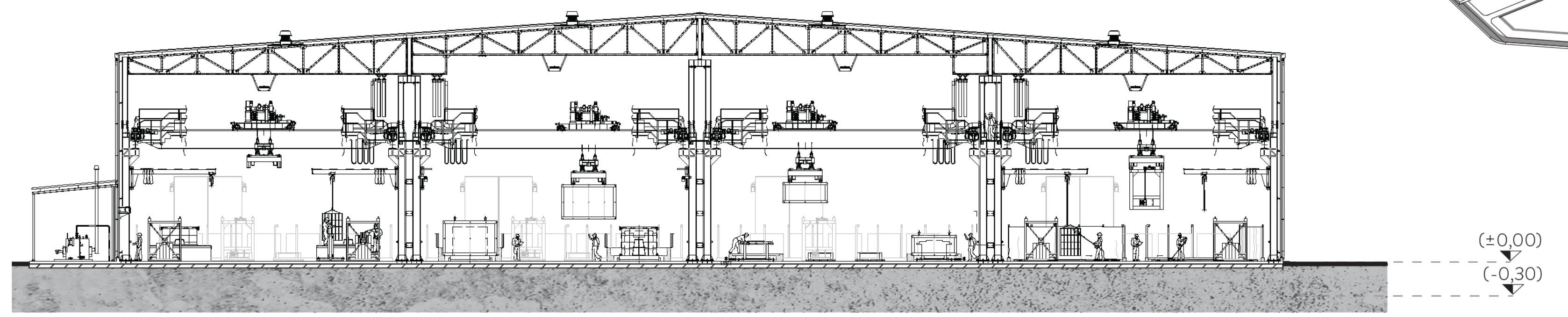
Section B-B'
Scale 1:400

Buildings Section

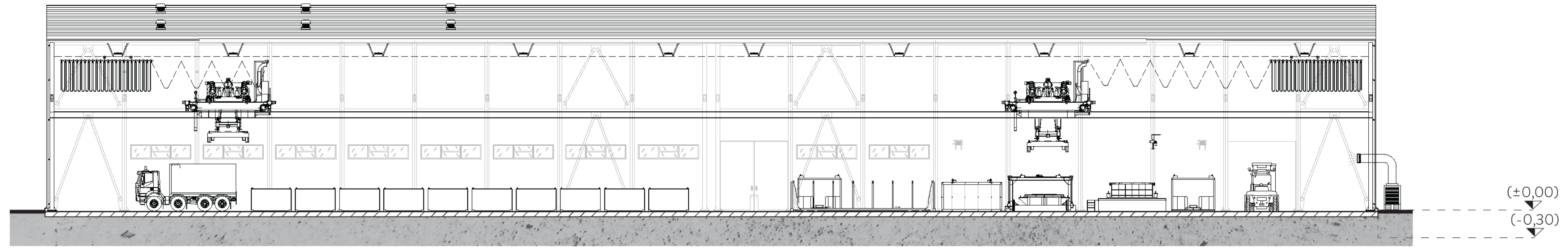
Module Production Plant (IPM)







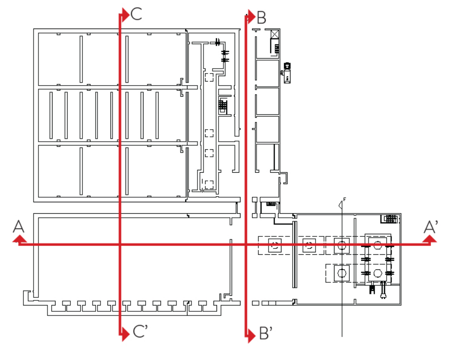
Section A-A'
Scale 1:400

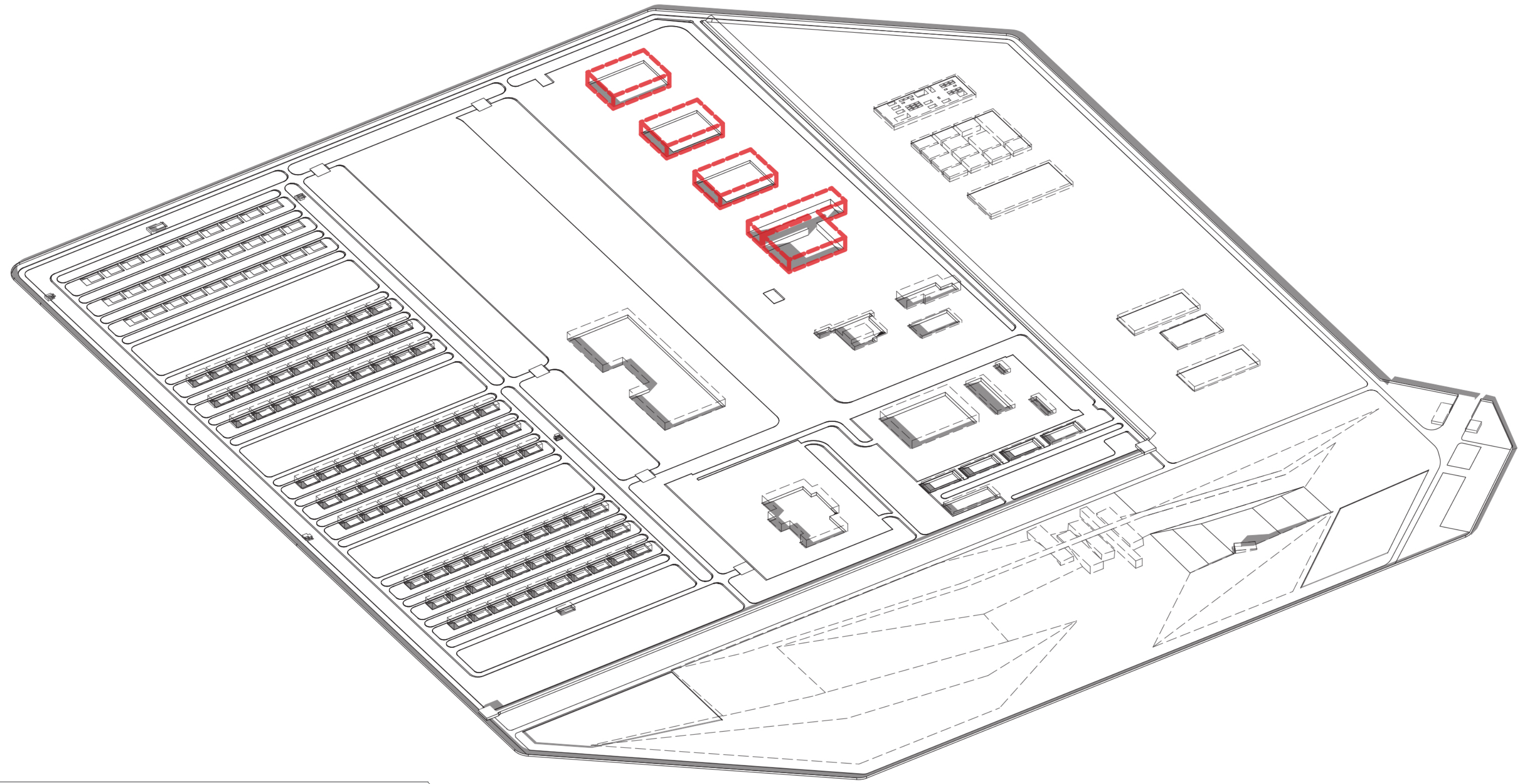


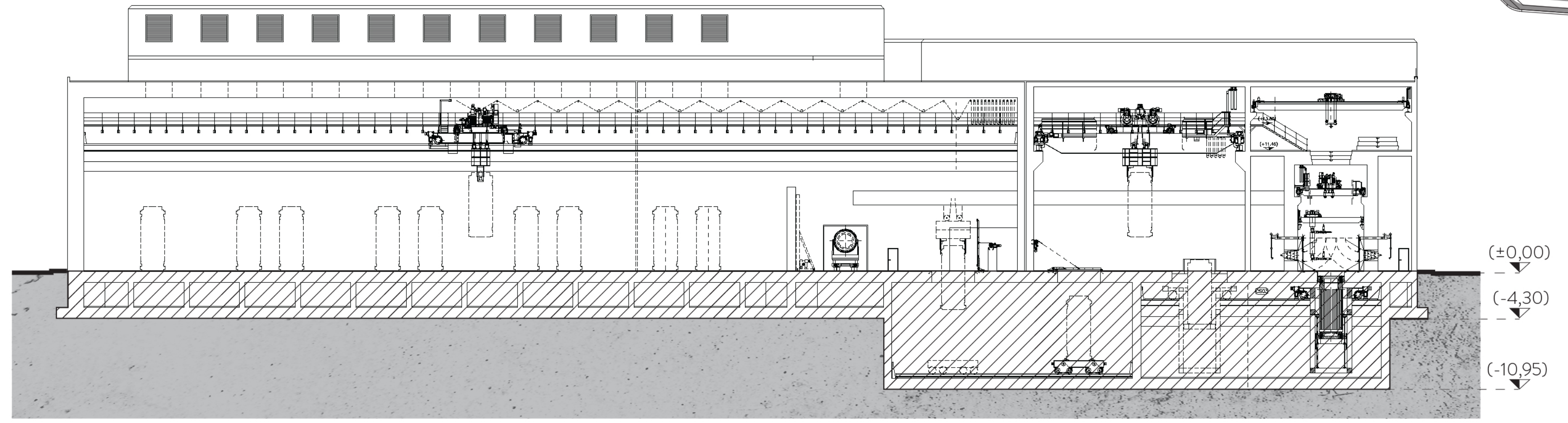
Section B-B'
Scale 1:400

Buildings Section

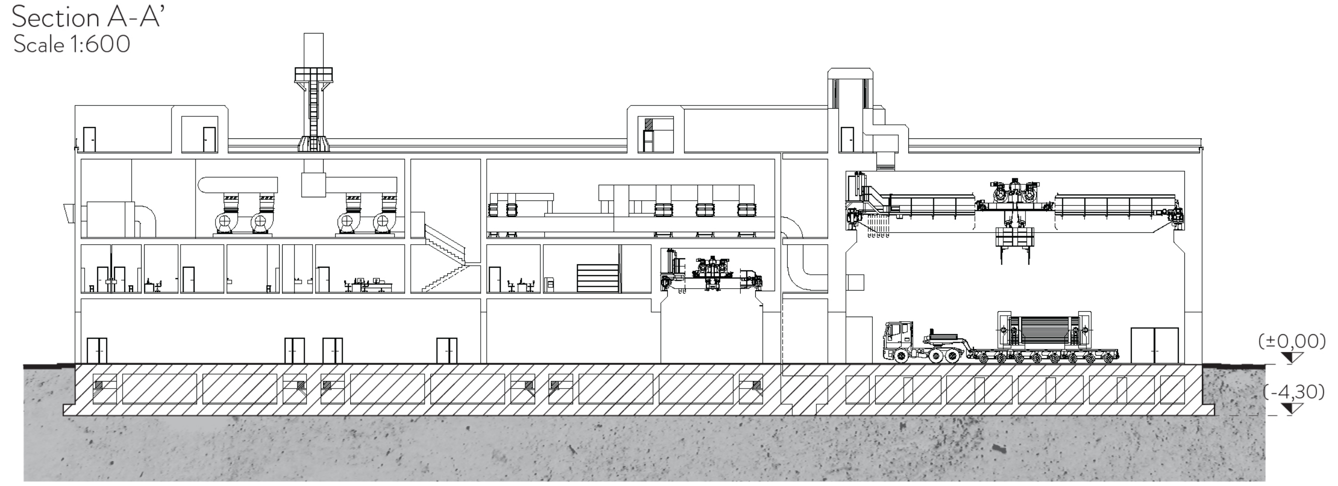
High Activity Waste Storage Complex (CSA)



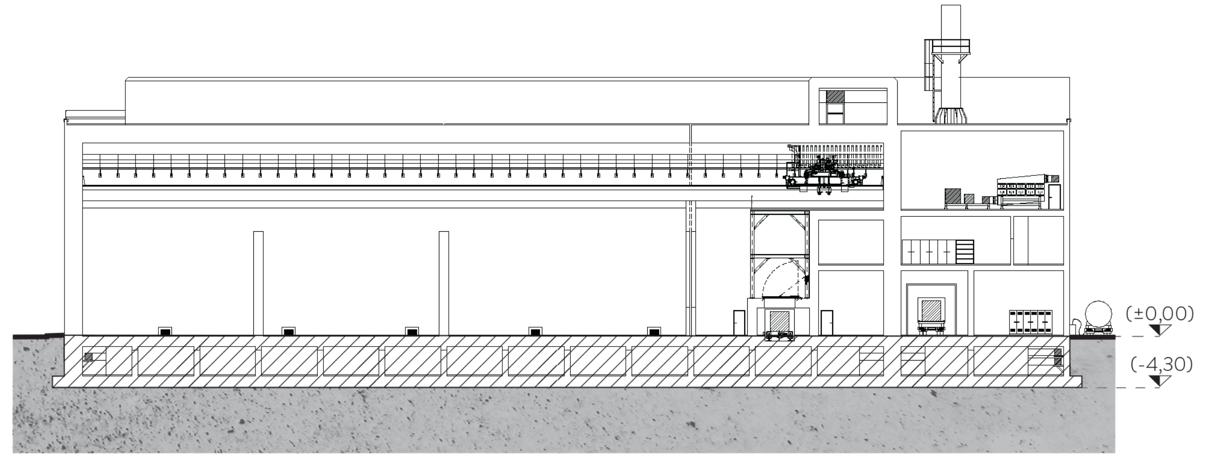




Section A-A'
Scale 1:600



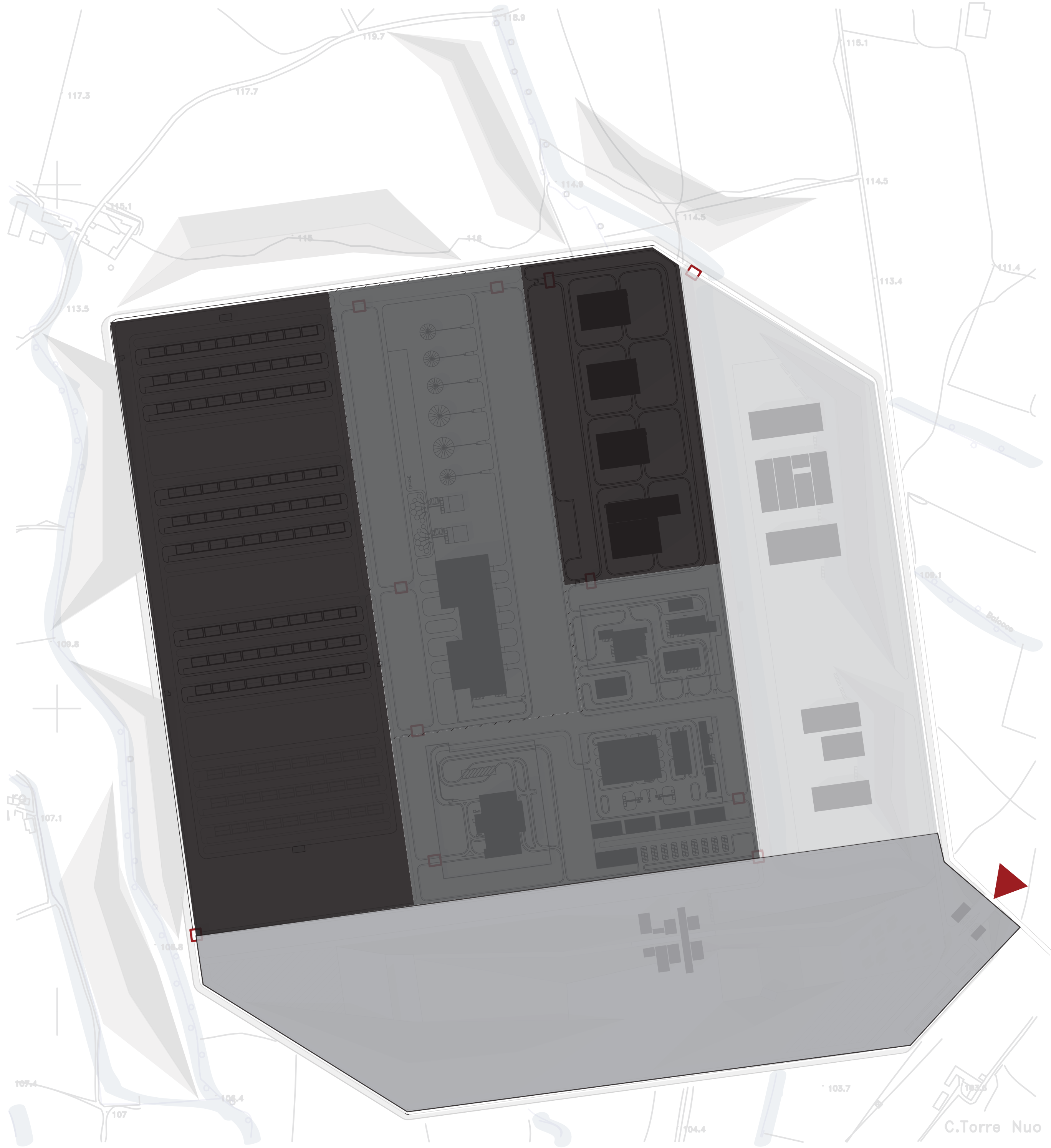
Section B-B'
Scale 1:600



Section C-C'
Scale 1:600

Security Dynamic

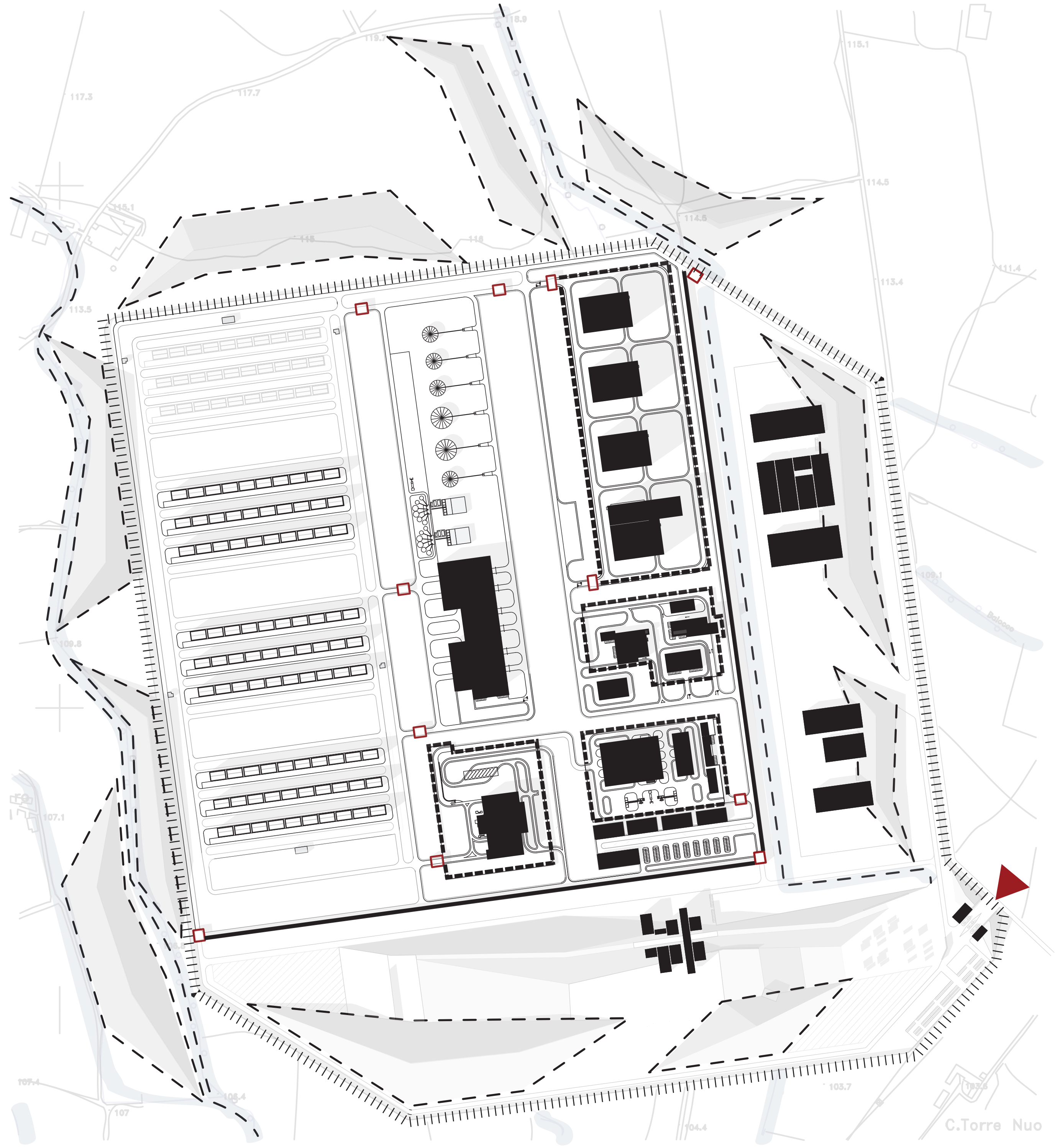
Site Division



Areas
Radioactive Level
- Vital
- Protected
- Restricted
- Supervised

Site Elements
- Entrance
- Buildings
- Control Points

Barriers

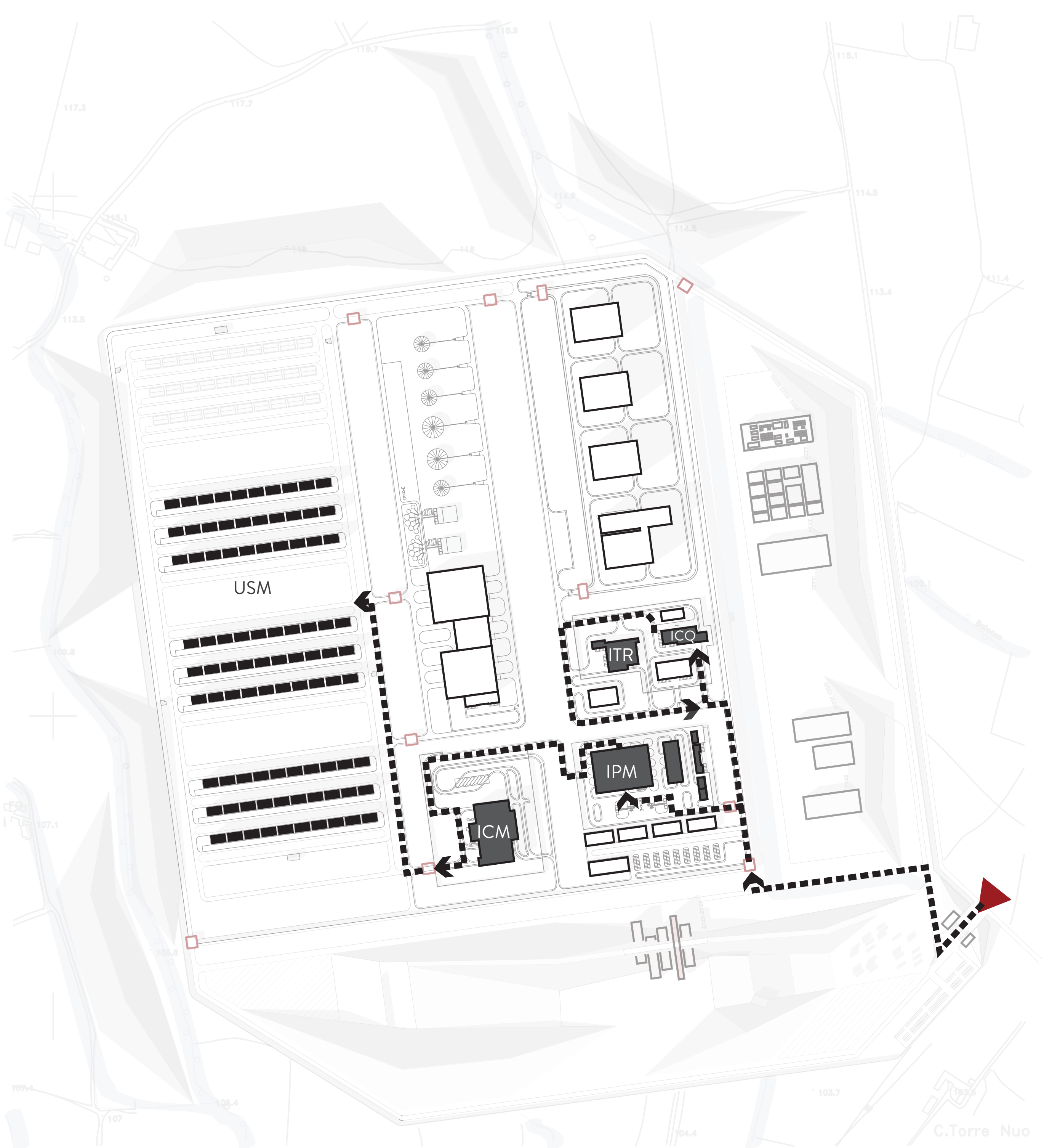


Barriers
- Internal Fences
- External Fences
- Protective Wall
- Natural Barriers

Site Elements
- Entrance
- Buildings
- Control Points

Waste Distribution

VLLW/LLW Waste

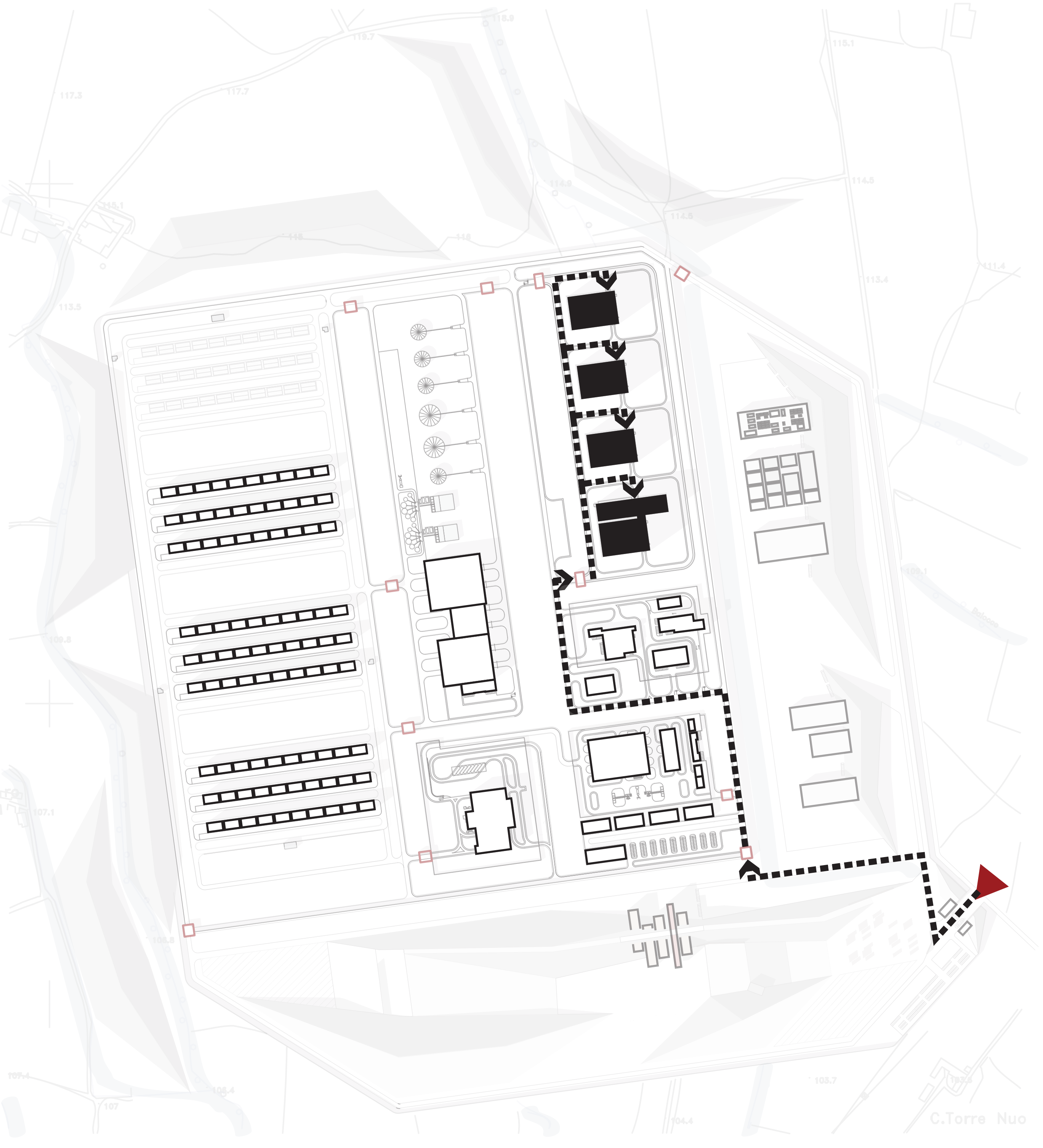


Legend
- VLLW/LLW
- Path

Site Elements
- Entrance
- Buildings
- Control Points

Path Order
External 1. ICQ 2. ICM 3. USM
Internal 1. ITR 2. ICM 3. USM

Temporary ILW/HLW waste

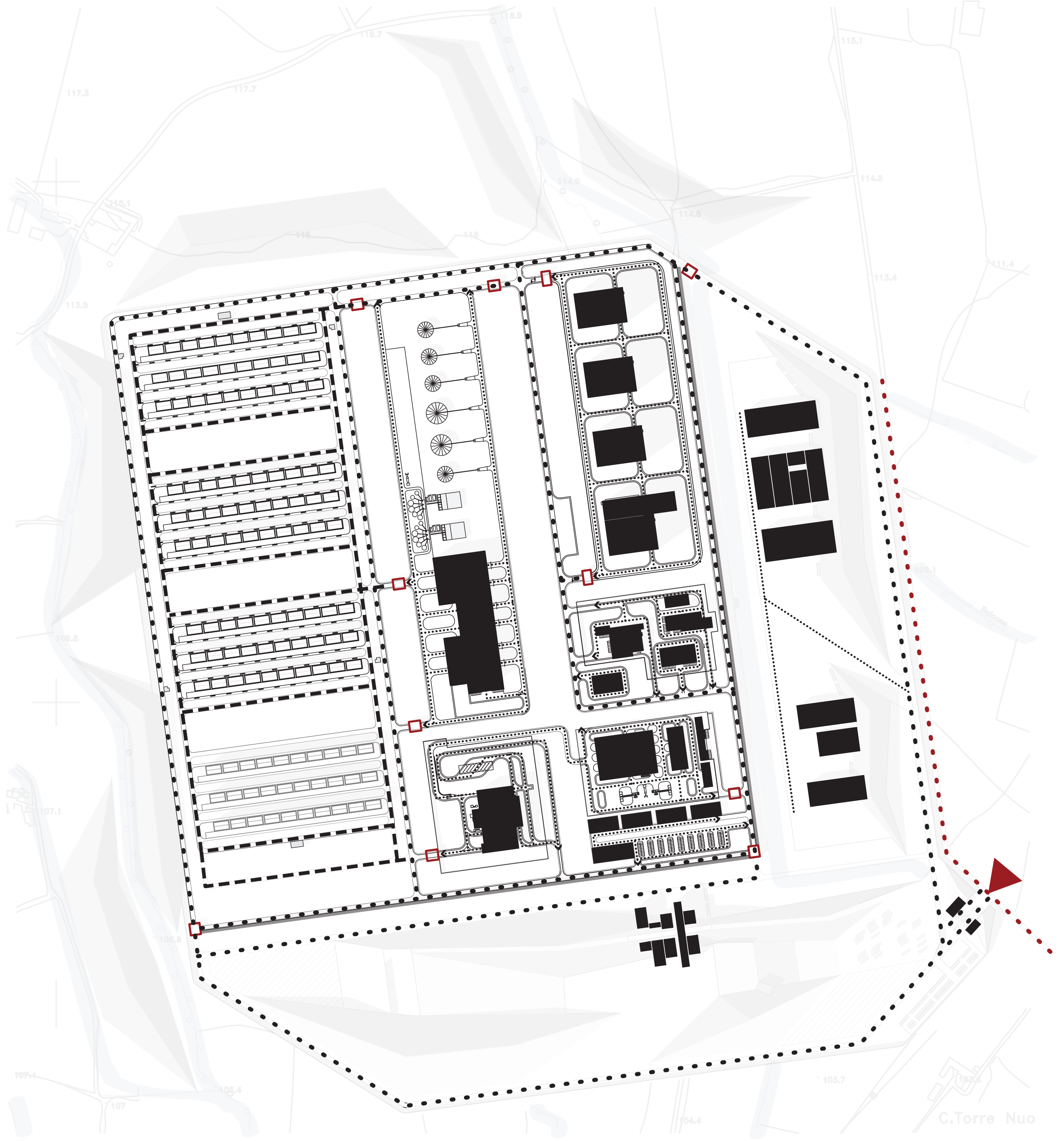


Legend
- ILW/HLW
- Path

Site Elements
- Entrance
- Buildings
- Control Points

Mobility

Transportation



Site Roads
- - - External Road
- - - Main Road
········ Secondary Road

Repository Roads
— — Main Road
- - Secondary Road

Site Elements
▶ Entrance
■ Buildings
☐ Control Points

Walkable Paths

Paths
- - - Archive
''''' Technological Park
········ Repository's Buildings
— — Repository

Site Elements
▶ Entrance
■ Buildings
☐ Control Points

Accesibility

Staff

Paths
- - - Technological Park
-'-'- Archive
— — Industrial
······ Repository

Site Elements
▶ Entrance
■ Buildings
☐ Control Points

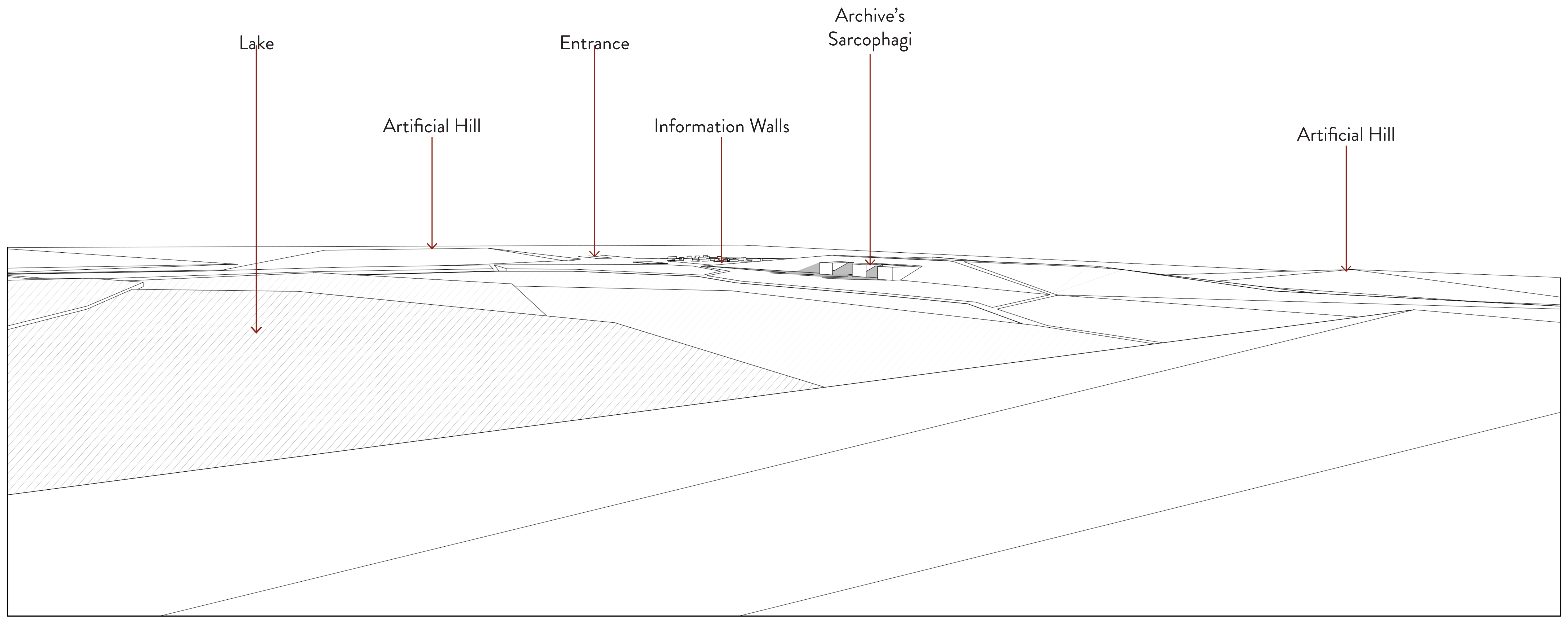
Visitors

Paths
■■■ Ordinary Visitors
········ Specialized Visitors
(Researchers, Artists etc.)

Site Elements
▶ Entrance
■ Buildings
☐ Control Points

03

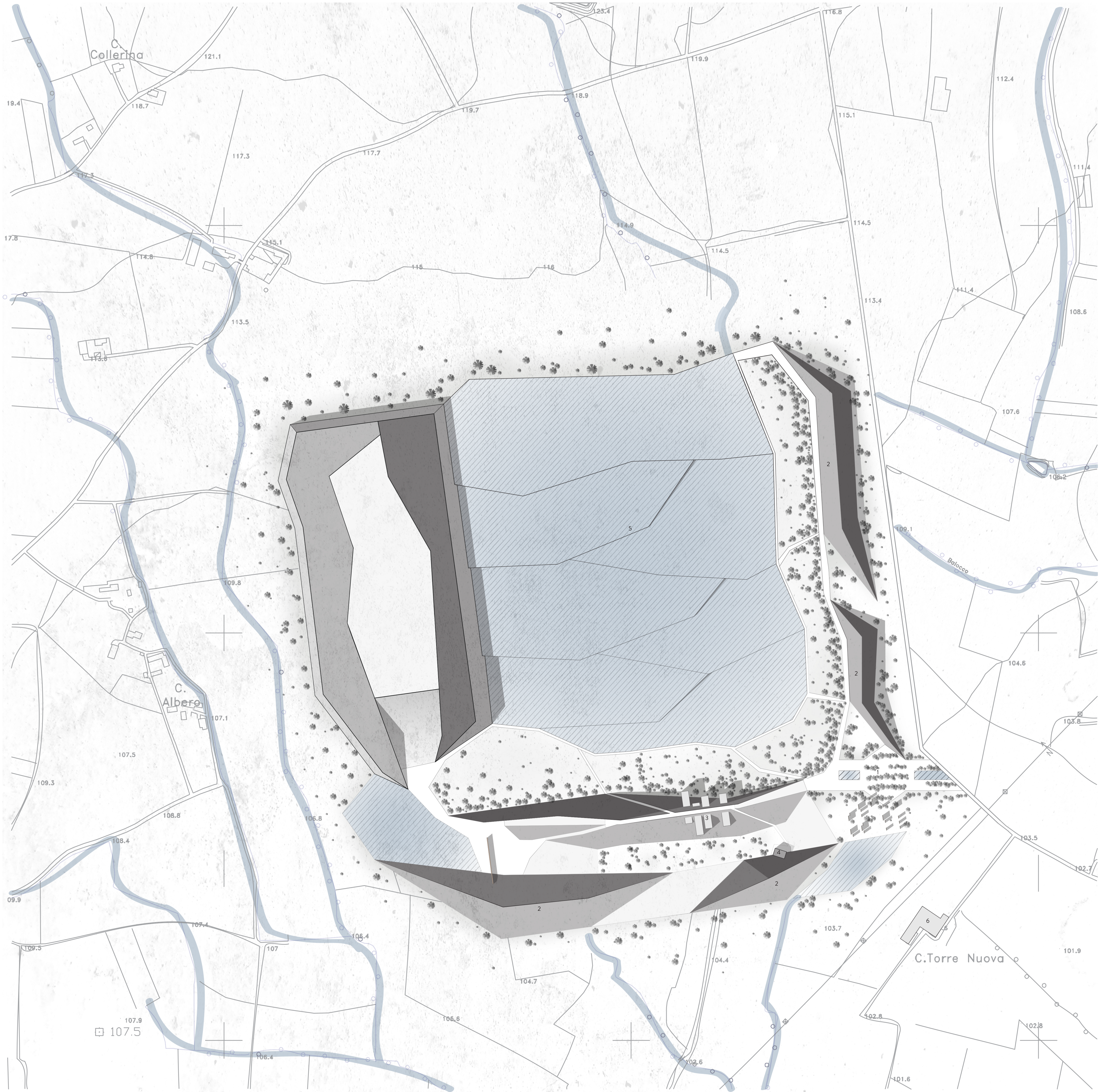
The Effects of Design



Perspective overlooking the repository (after 350 years)

The Masterplan

-After 350 years-



Legend

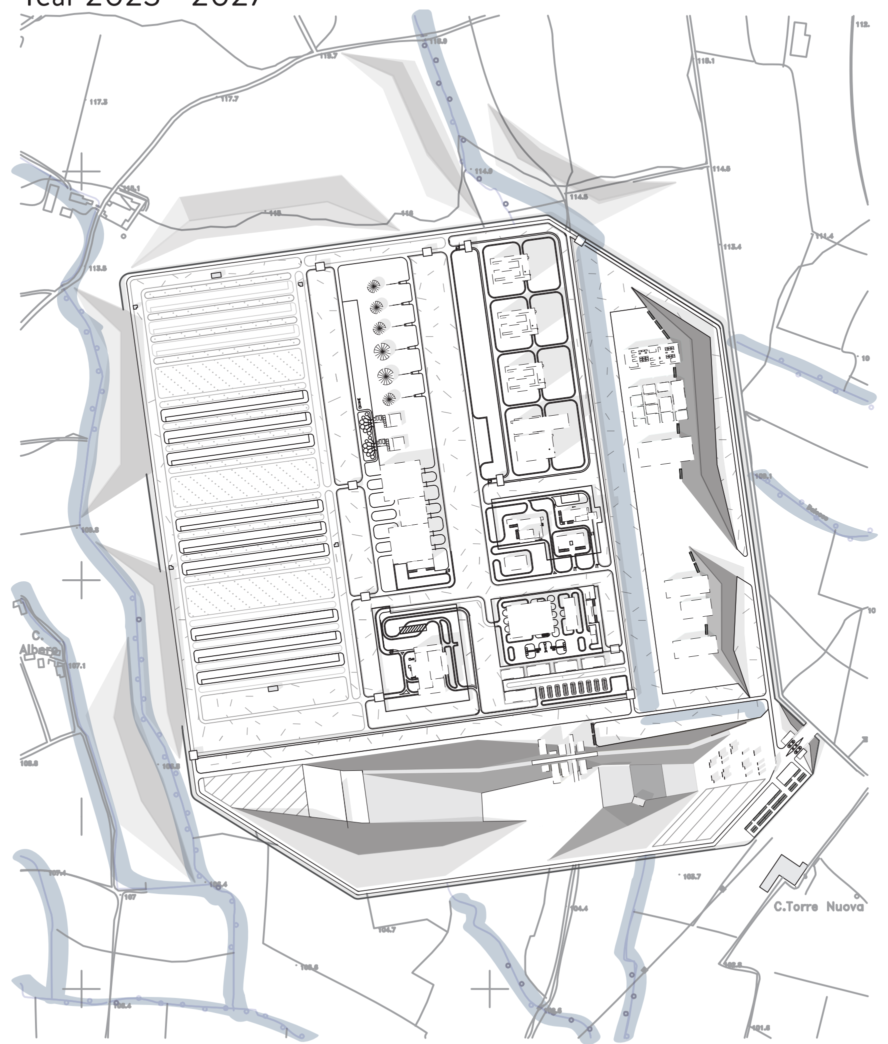
1. Information Walls
2. Artificial Hills
3. Archive
4. Model of the Repository's cell, scale 1:1
5. Lake
6. Old Farm

N

Time Management

01 Pre-Operational Phase

Year 2023 - 2027



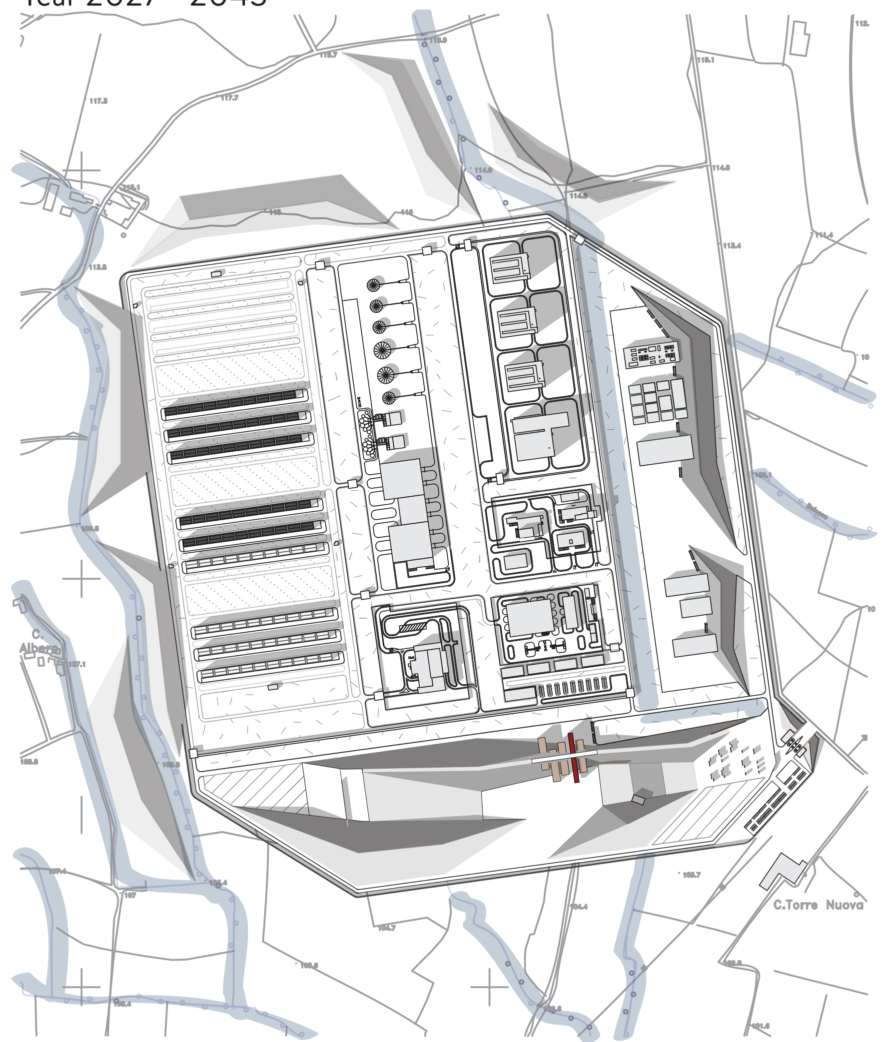
0 year

- The earth is dug for making place for the modules;
- The water drainage systems are built for protecting the site from any possible leaks;
- The earth from excavations is set aside forming the artificial hills of the Repository and the hills of the Archvie, thus a natural border is guarding the site;
- The National Repository and the Technological Park are constructed;
- The construction phase is finished and the staff is preparing to place the first modules in the site.

4 years

02 Operational Phase

Year 2027 - 2043



4 years

- At this point the first 50 modules are inserted in the site and cemented;
- The water drainage systems is working and functioning as a basin;

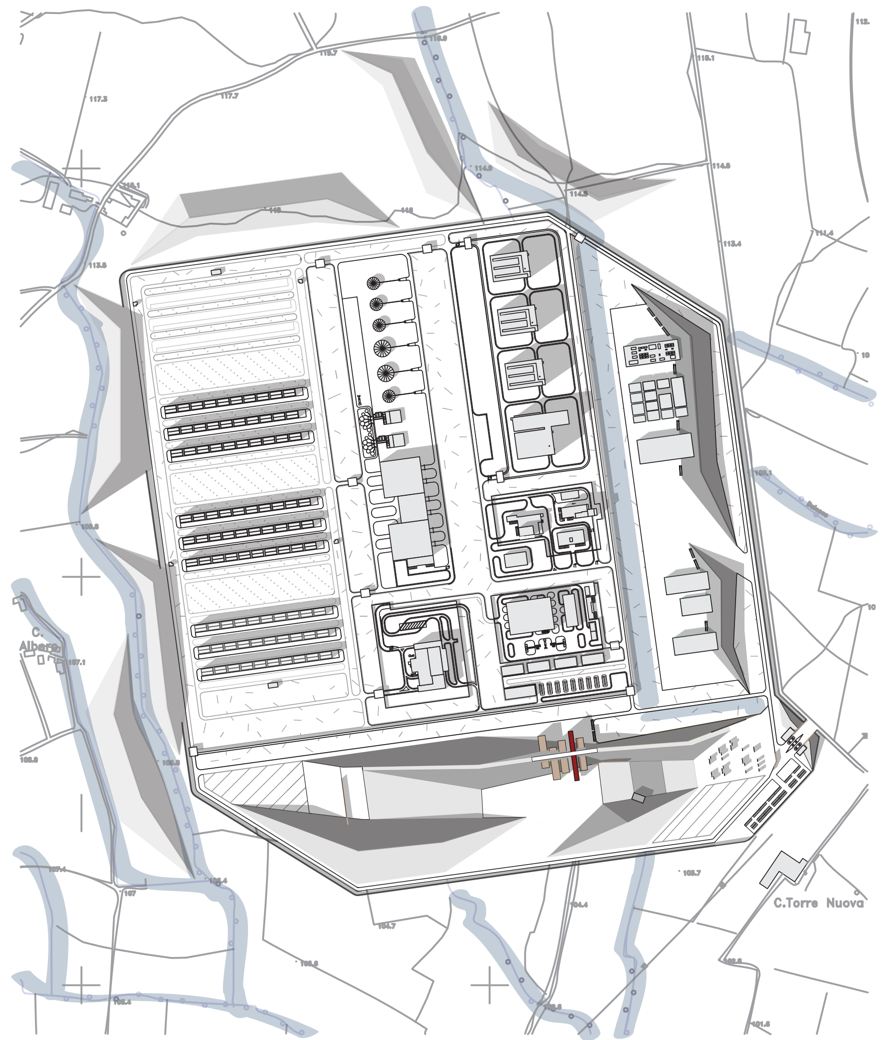
20 years

- When the site reaches the 20 years mark the rest of the modules prepared and inserted into the site reaching a total number of 90;

40 years

03 Operational Phase

Year 2043 - 2073



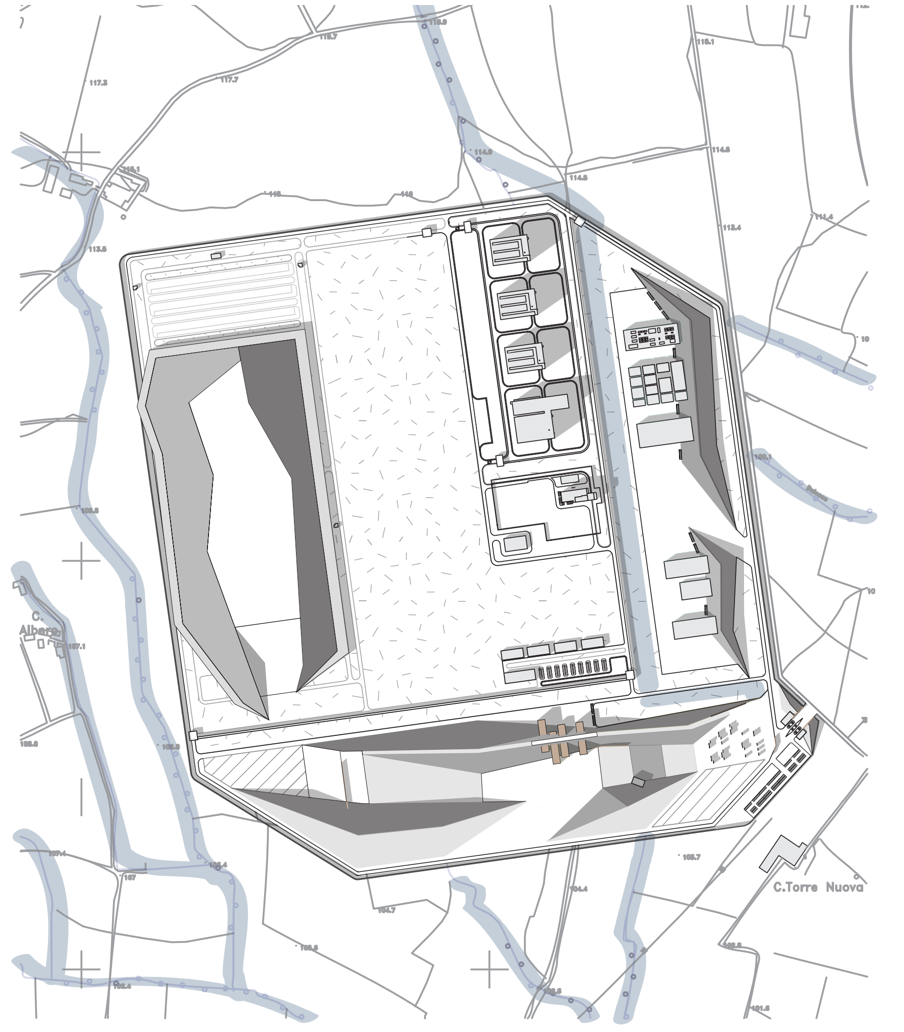
40 years

- The final cap of the modules is contructed;
- This ends the Operational Phase.

50 years

04 Entombing Phase

Year 2073 - 2123



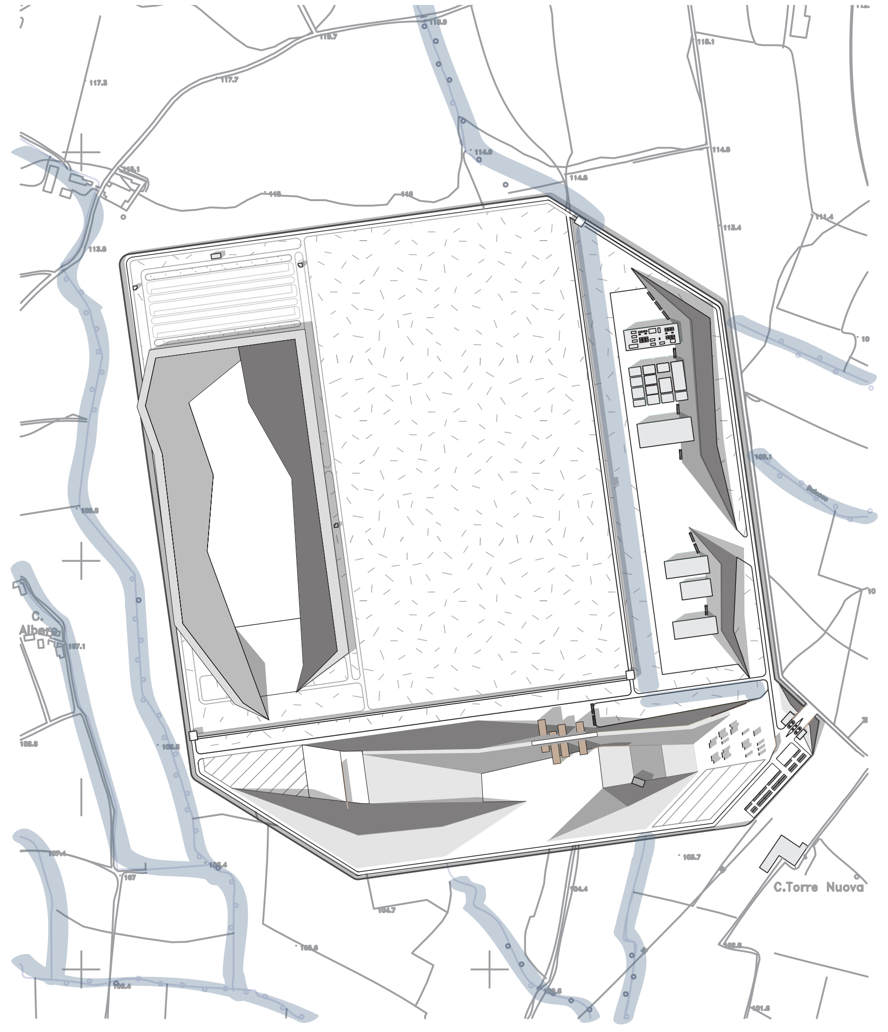
50 years

- The hills of the border are starting to be collected and used to bury the waste;
- All the engineering features and isolation processes are ready and put in place to guard the waste;
- The operational buildings and services have been decomis-sioned;
- The Office of the Archive are no longer functional;
- This completes the Entombing Phase.

100 years

05 Monitoring Phase

Year 2123 - 2373



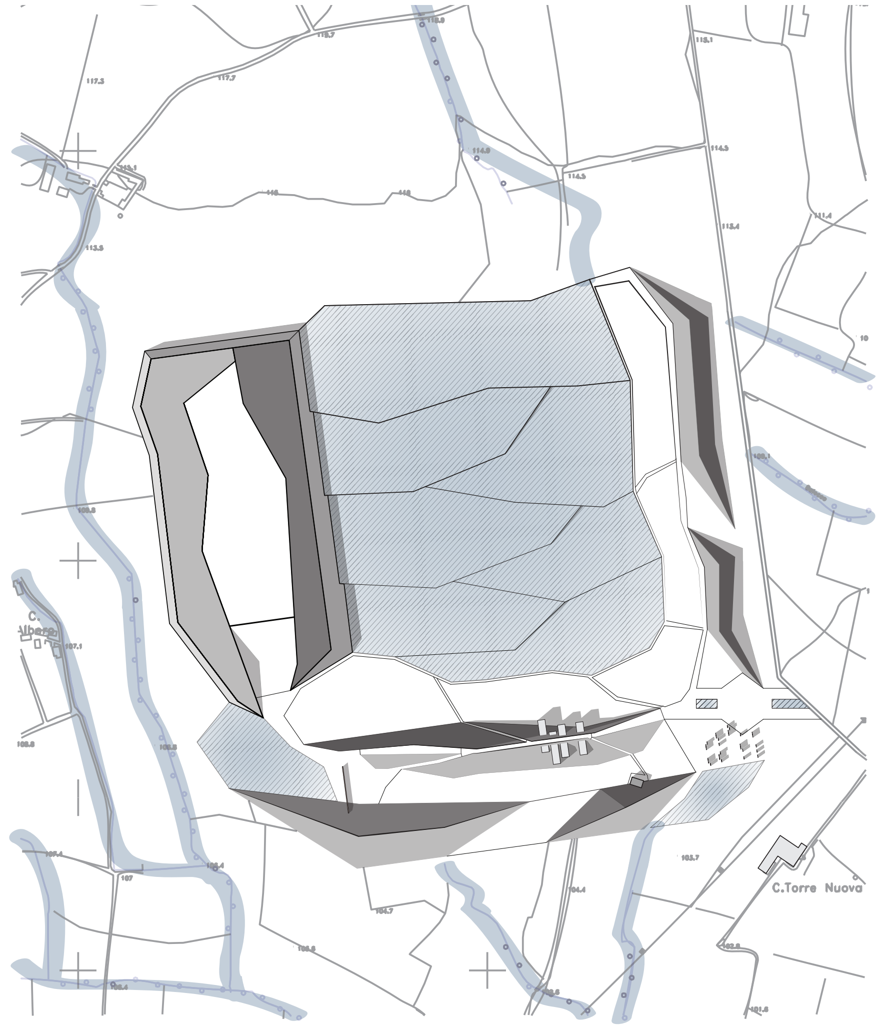
100 years

- The High Activity Level buildings are being decomissioned;
- The Technological Park is still active;
- The Archive's premises are still open for visitors. Only the sarcophagis of knowledge remain buried in the remained hills;
- The control points are still functioning.

350 years

06 Post-Operational Phase

Year 2373 - ...?

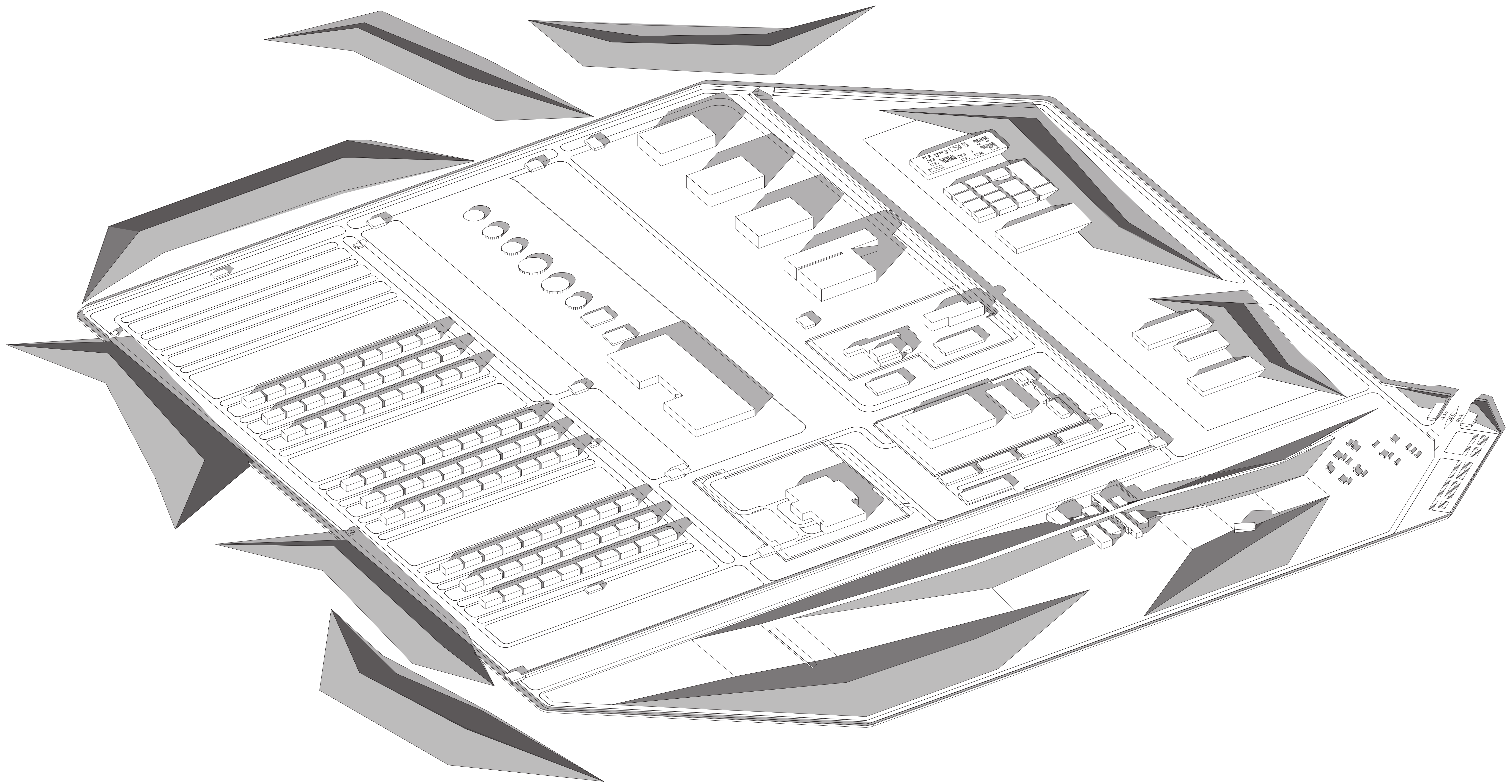


350 years

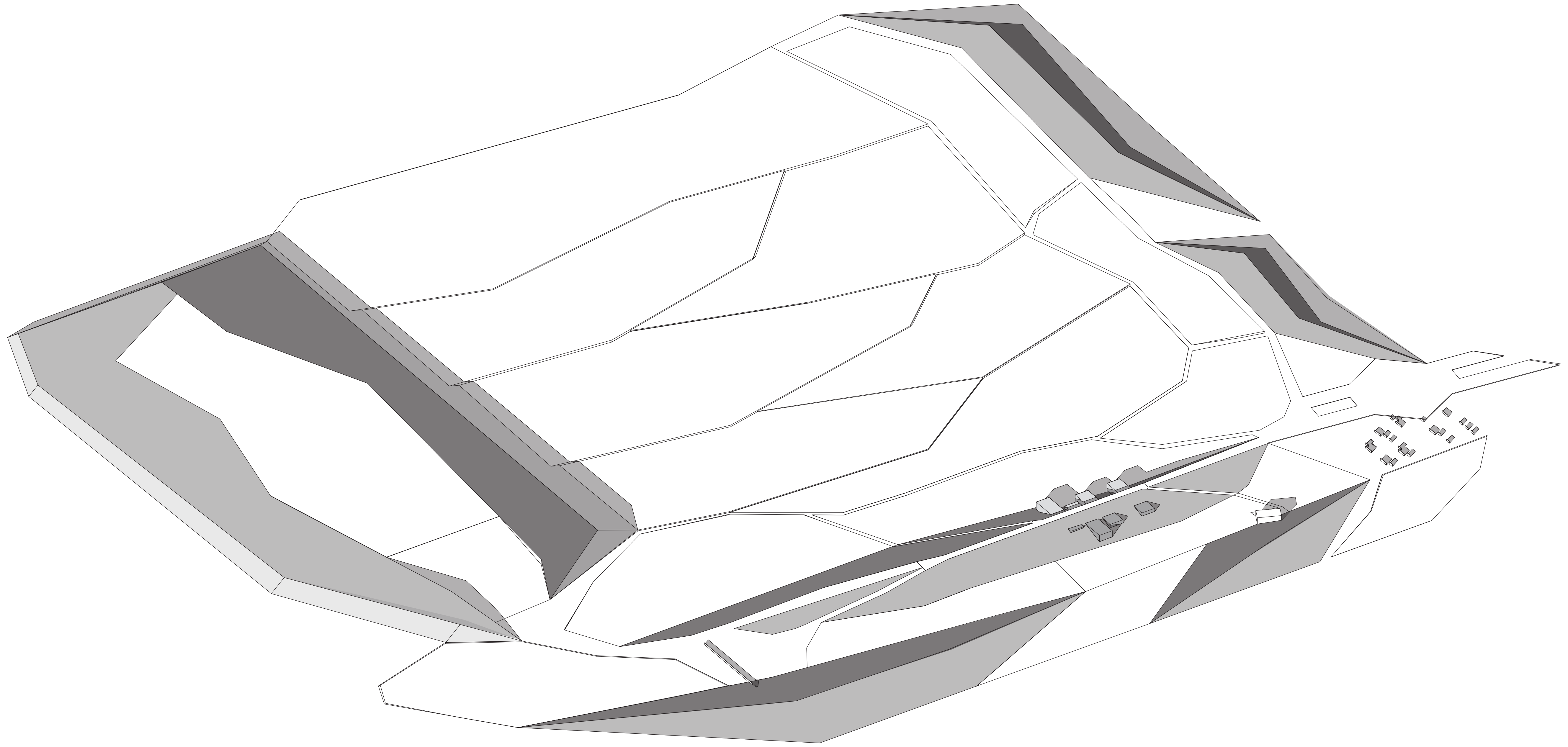
- The site transforms into a walkable park;
- All buildings of the site are removed, exeption making the sarcophagis of the Archive
- The waste blends with the landscape and becomes nature.

? years

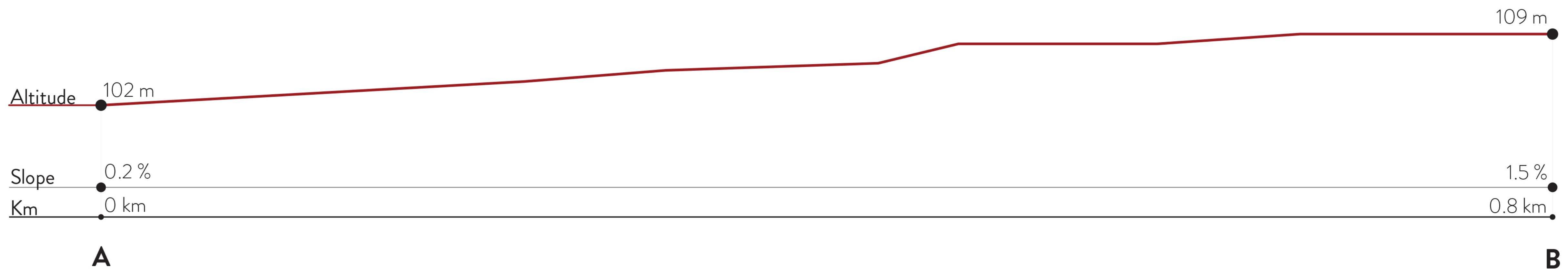
The earth collected during the Pre-Operational phase from excavations is now used to form artificial hills that will act as a visual barrier between the Nuclear Repository and it's neighbours. Those barriers will be placed along the site's fence and will constitute a natural barrier that protects the inside from outside and conversly.

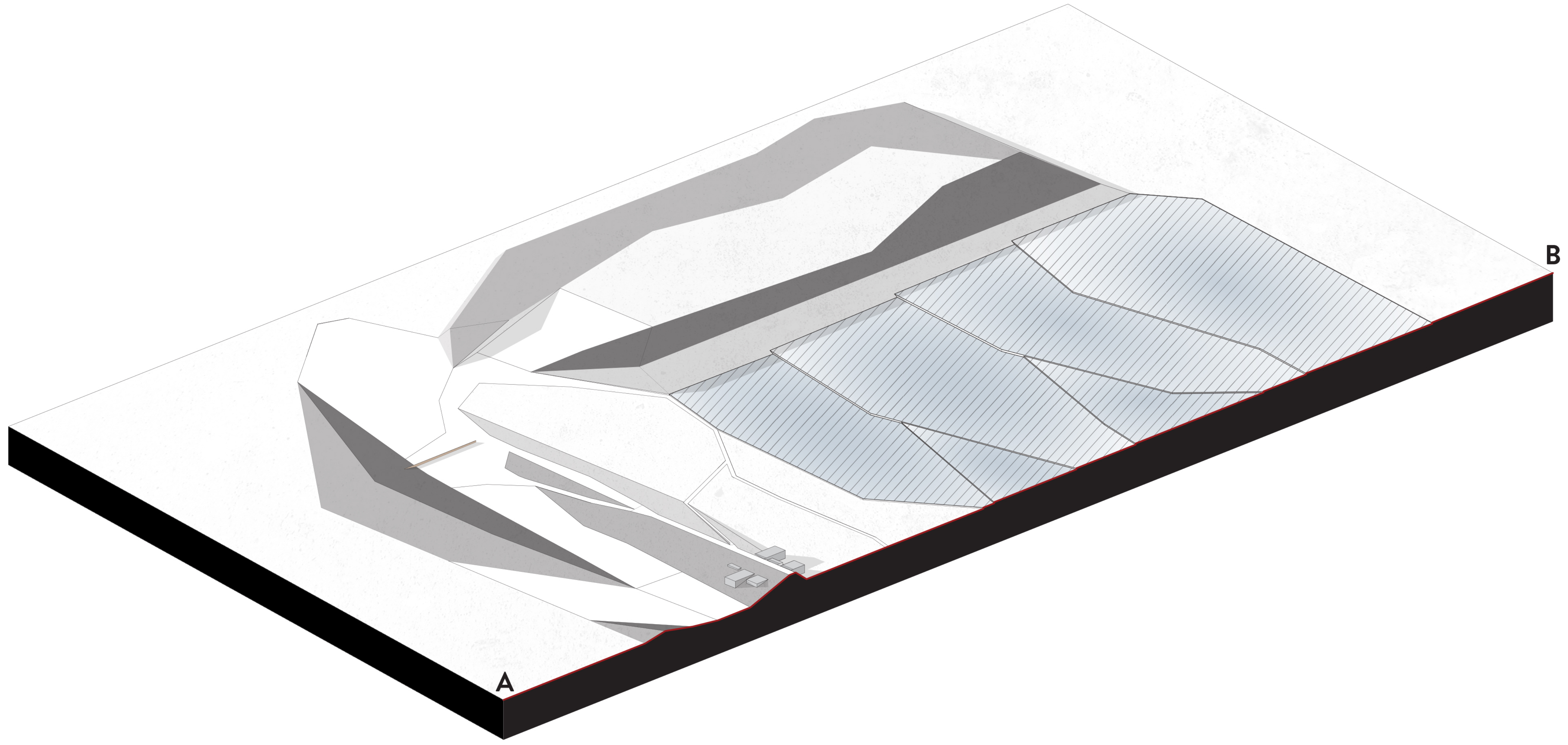


The site transforms from a repository into a walkable park while the waste blends with its landscape. The water pools enhance the site's experience by reflecting their surroundings and lead to a state of calmness and meditation as the visitors walk around the remnants of the old repository.



Elevation profile of the site





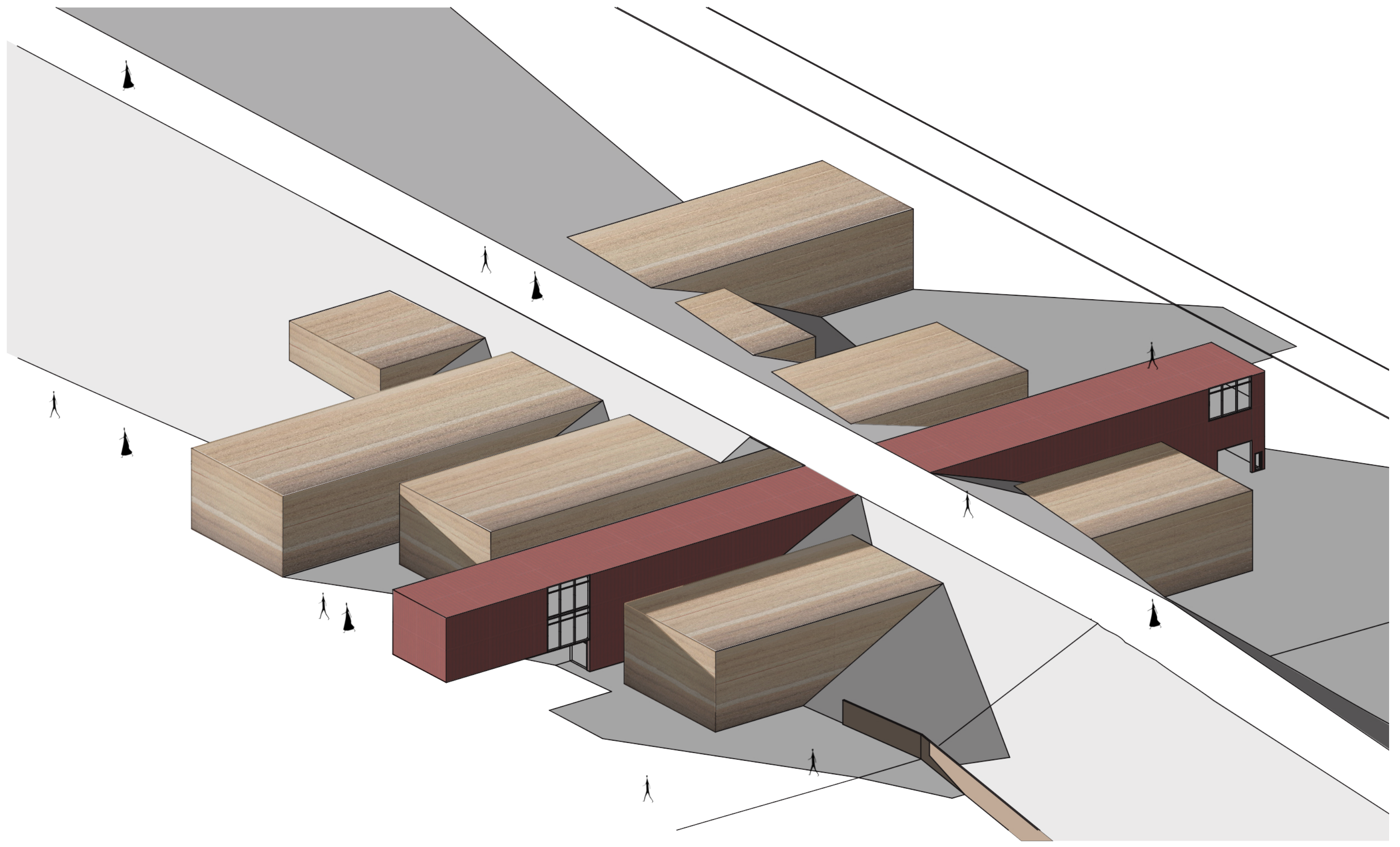
04

A Place of Memories

The archive of the repository was created as a space that will hold onto the memory of the area and will safely store all the documents that the repository will produce over the course of 50 years of production.

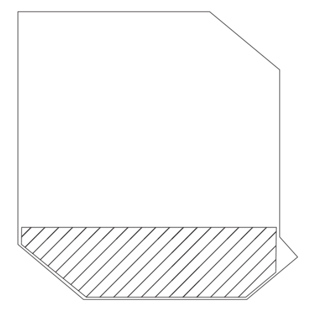
The design of the archive was created in strong relation with the site and its neighbouring areas of Alessandria so as to not disturb the space. It integrates with the surroundings through its form and barriers, taking care of the natural ones that circle the area. Thus, the rivers that were found have been used as natural barriers to which the artificial hills joined and gave form to the landscape of the archive. Once you enter the space of the archive, right at the entrance, you are encountered with informational walls that guide the visitors through the site and follow them on the path created by the landscape. Following this path, the people will then encounter a model of the cell in real scale and then they will arrive at the archive where they could take part in different educational activities related to the repository and the radioactive waste. Henceforth, exiting the archive and continuing to follow the info walls, the guests will be slowly taken on top of it from which point they can overlook the entire site and see every building of the repository.

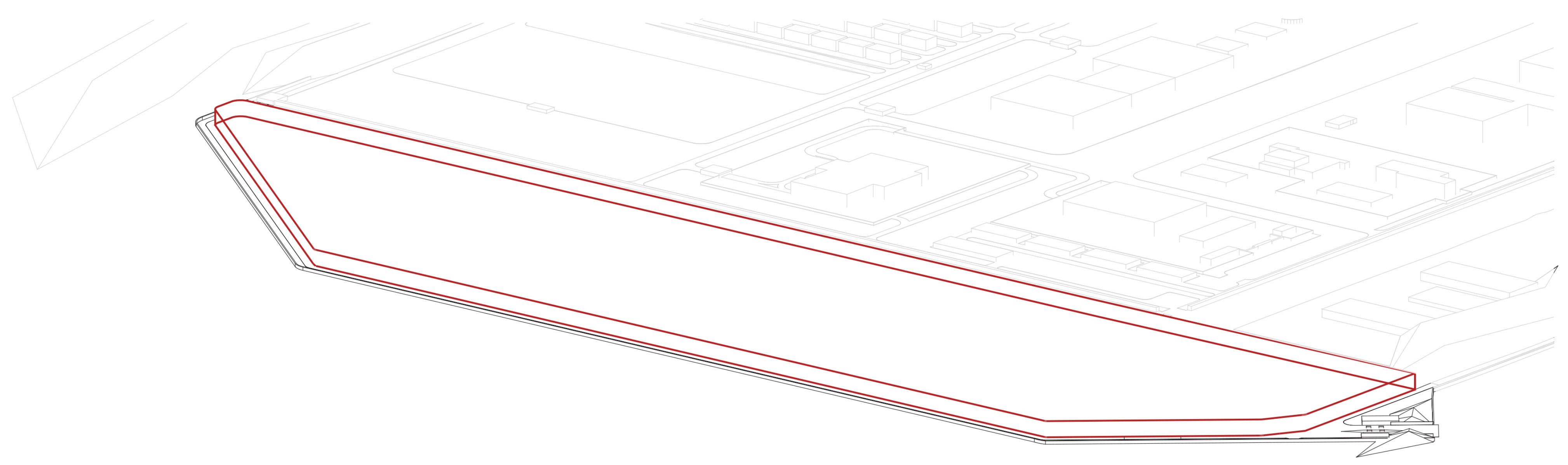
The concept of the archive follows a box in box approach that gives form to the blocks where the information is stored angains the meaning of buried sarcophagi. The first box is made by coloured concrete that is expected to decay while the inside box will be made of concrete and will emerge after the previous one will deteriorate due to the passing of time. Therefore, as the repository evolves as he passes from one phase to another,equivalently the archive follows.



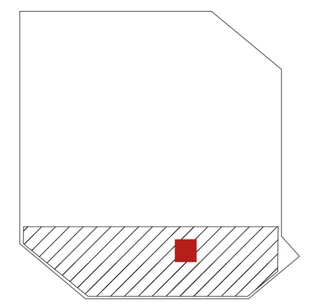
Concept

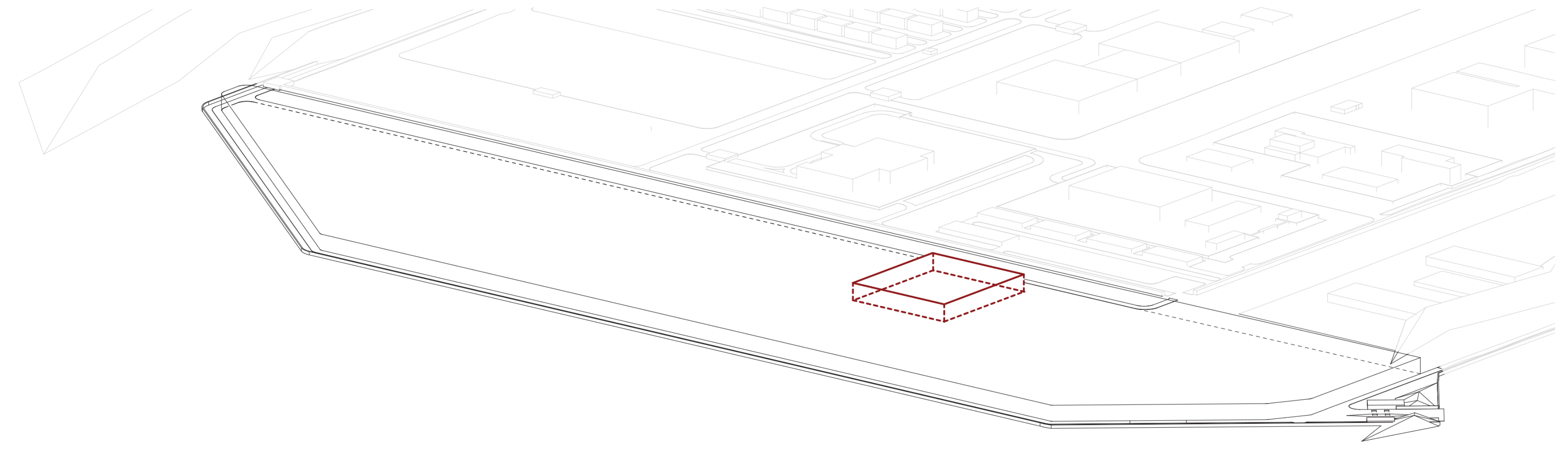
Phase 1
Preparing the space
-Raising the ground-



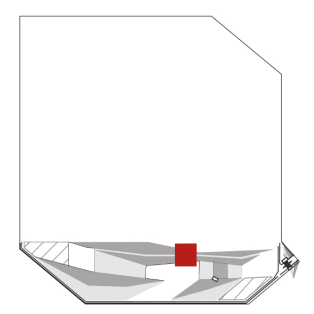


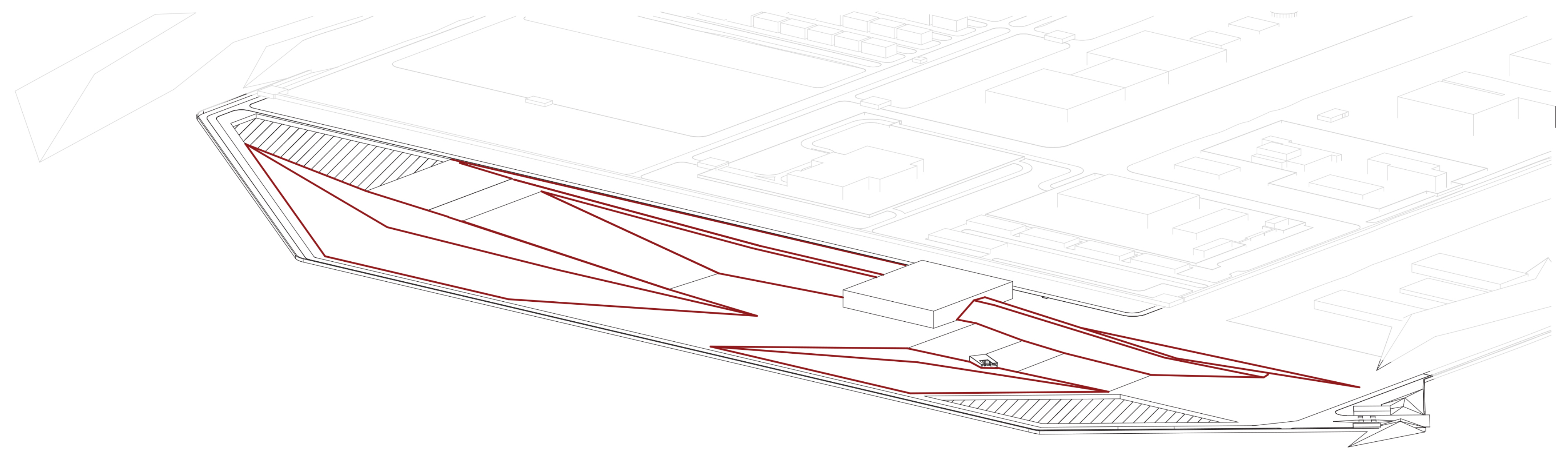
Phase 2
Defining the tomb



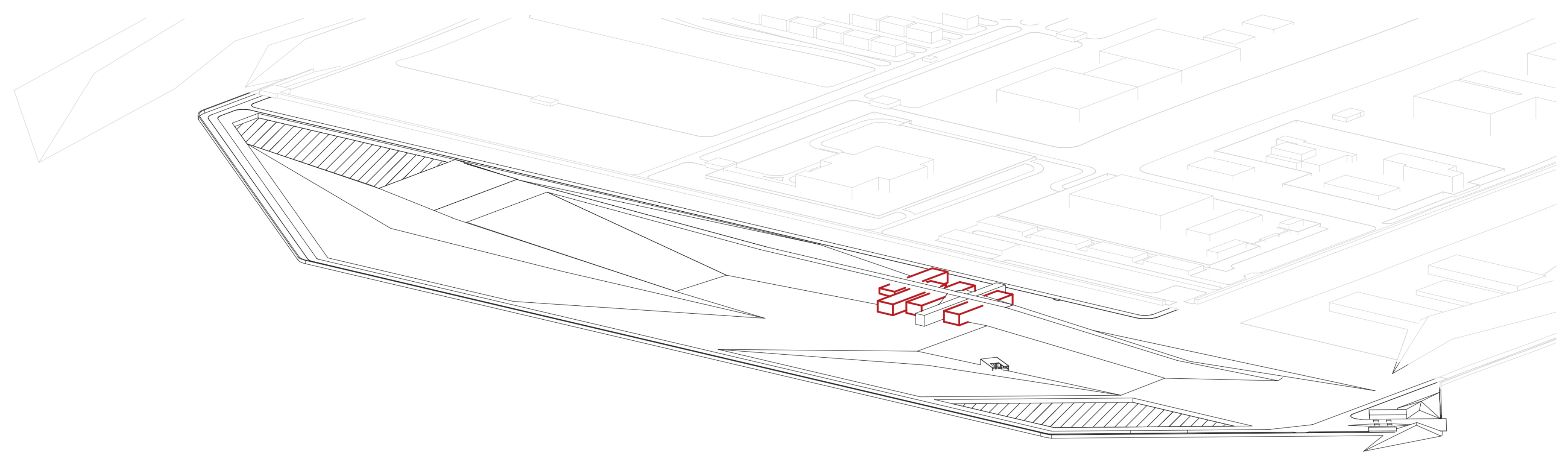


Phase 3
Shaping the path
-Hills and walls-

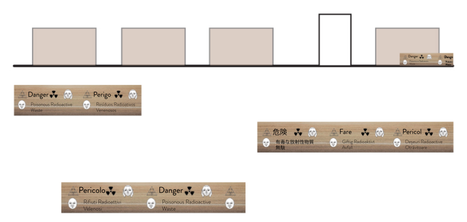


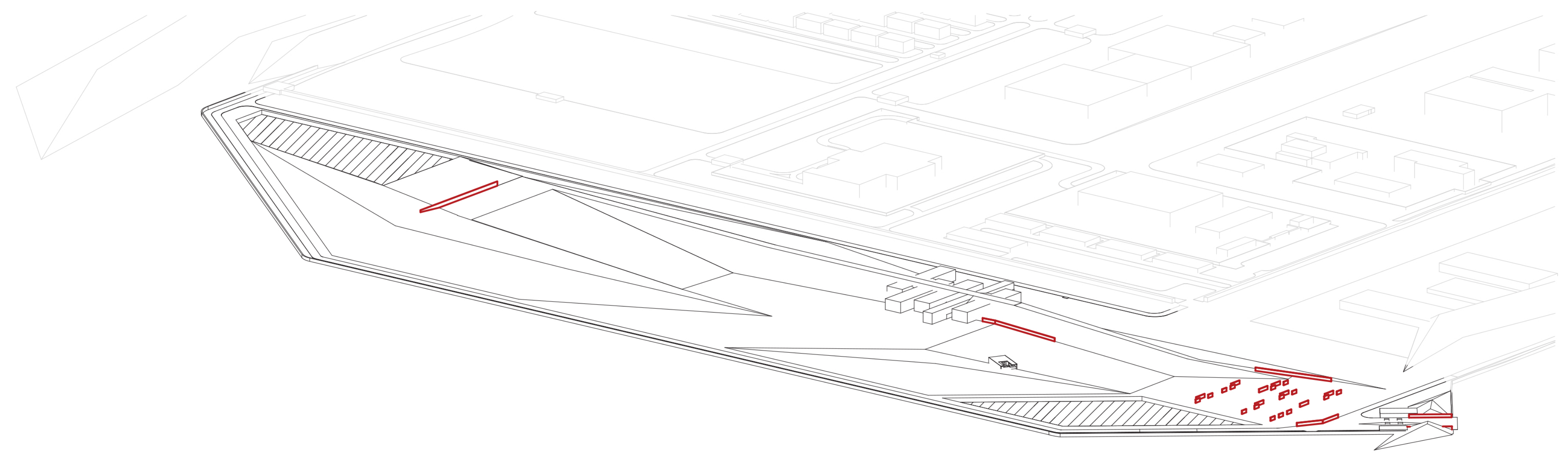


Phase 4
Sculpting sarcophagi

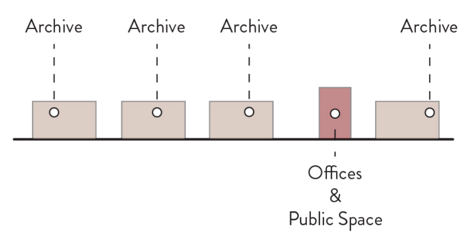


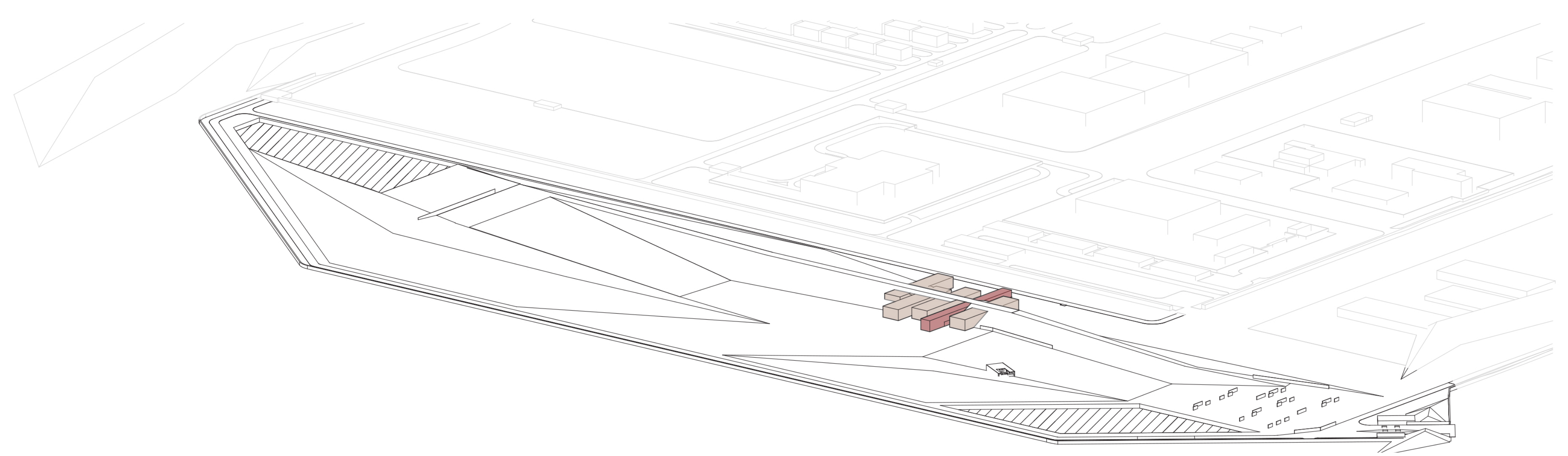
Phase 5
Offering guidance



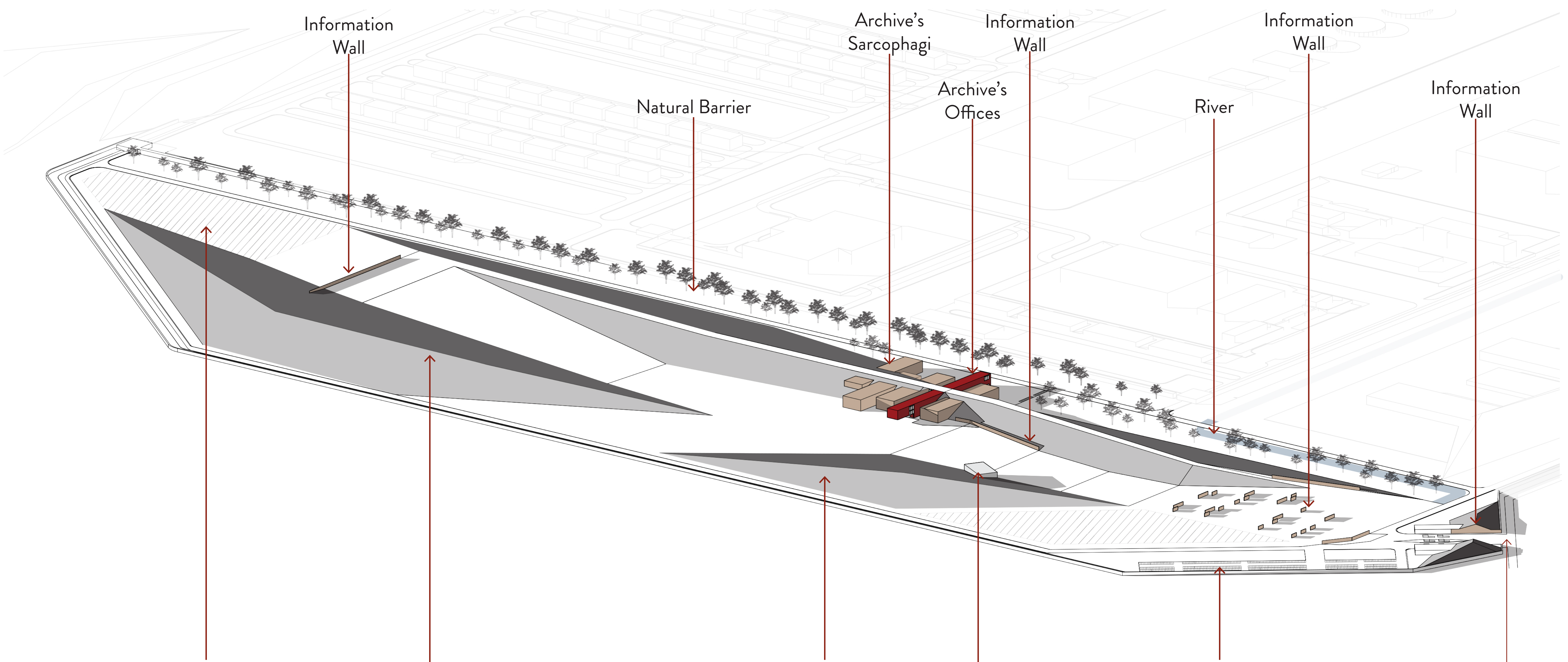


Phase 6
The Programme

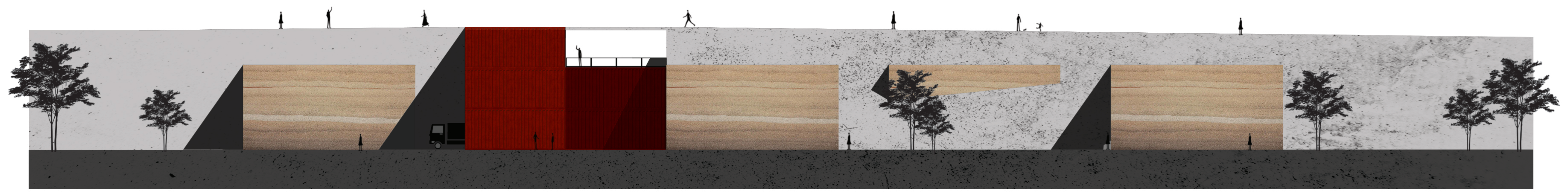




Close-up archive

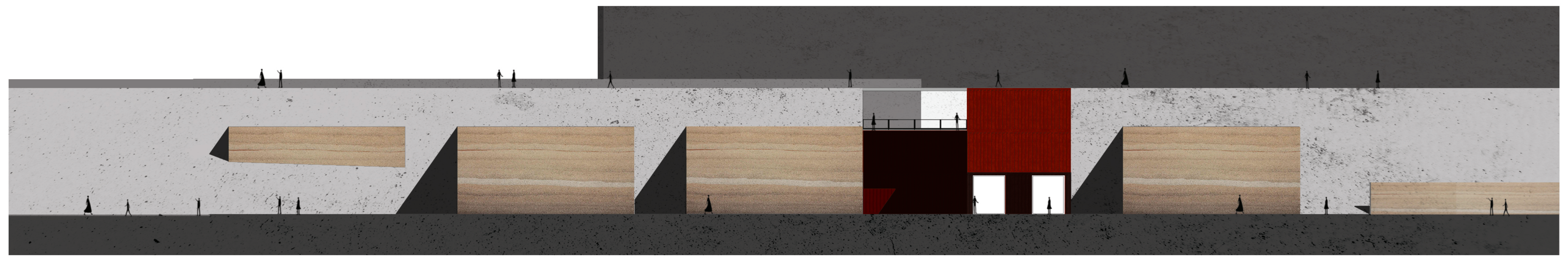


Elevations



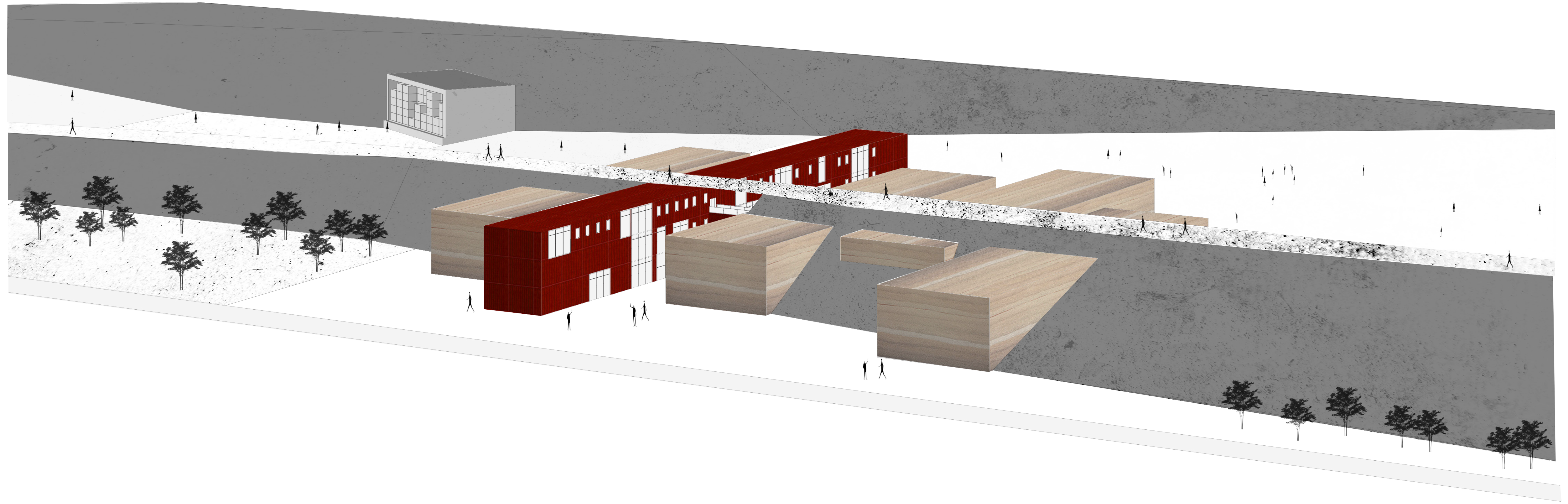
Elevation North

Scale 1 : 500

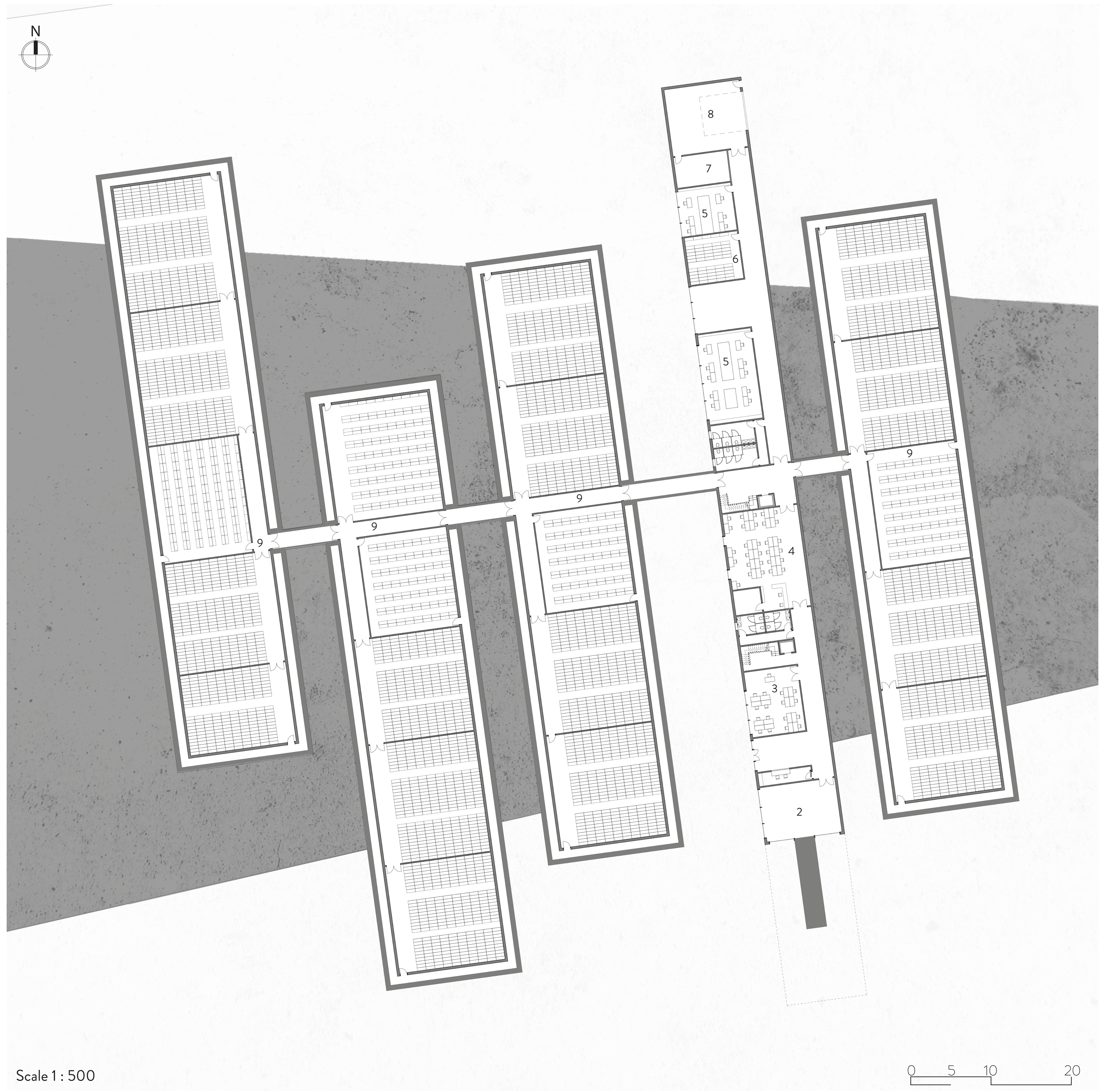


Elevation South

Scale 1 : 500

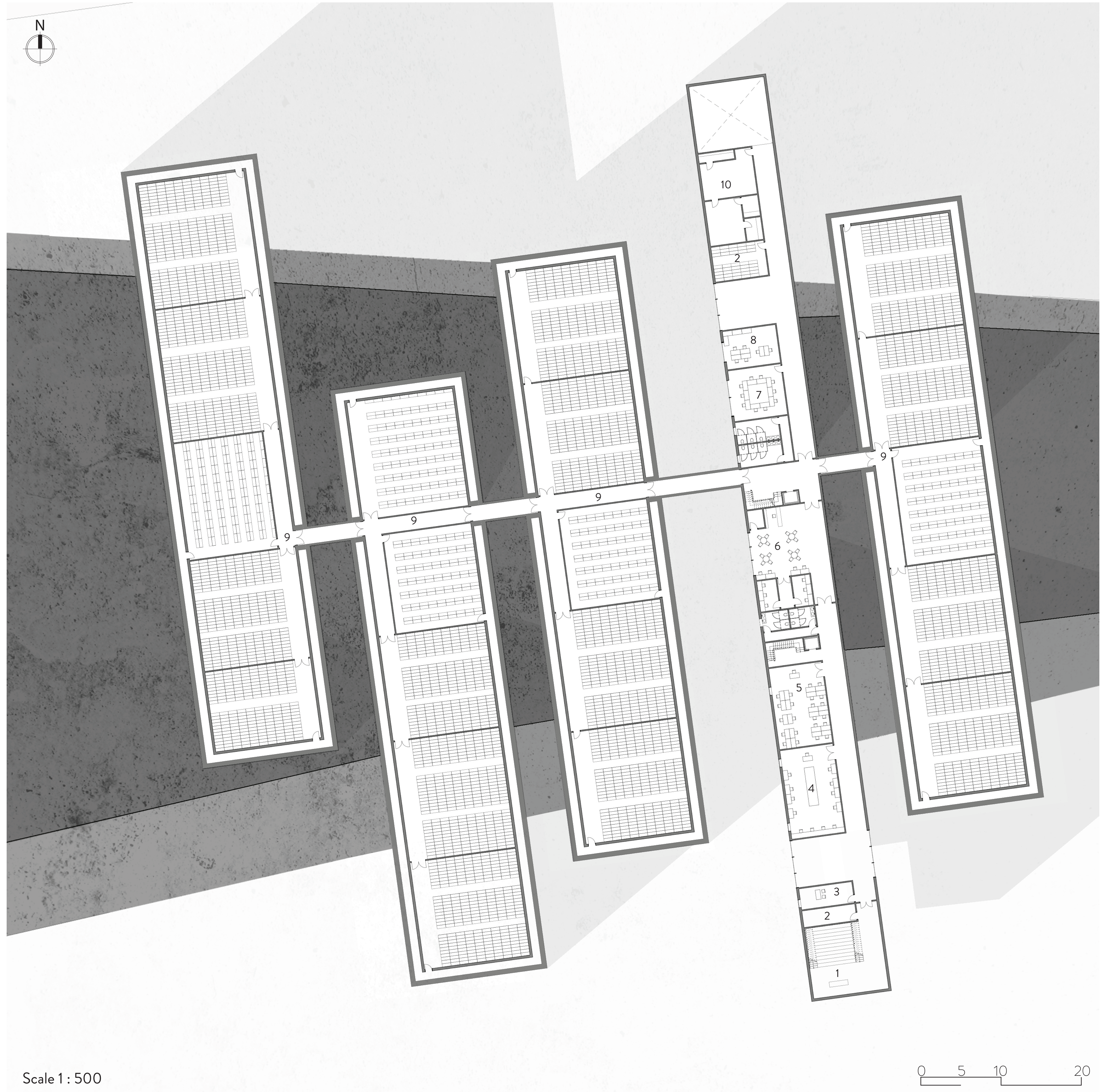


Plans



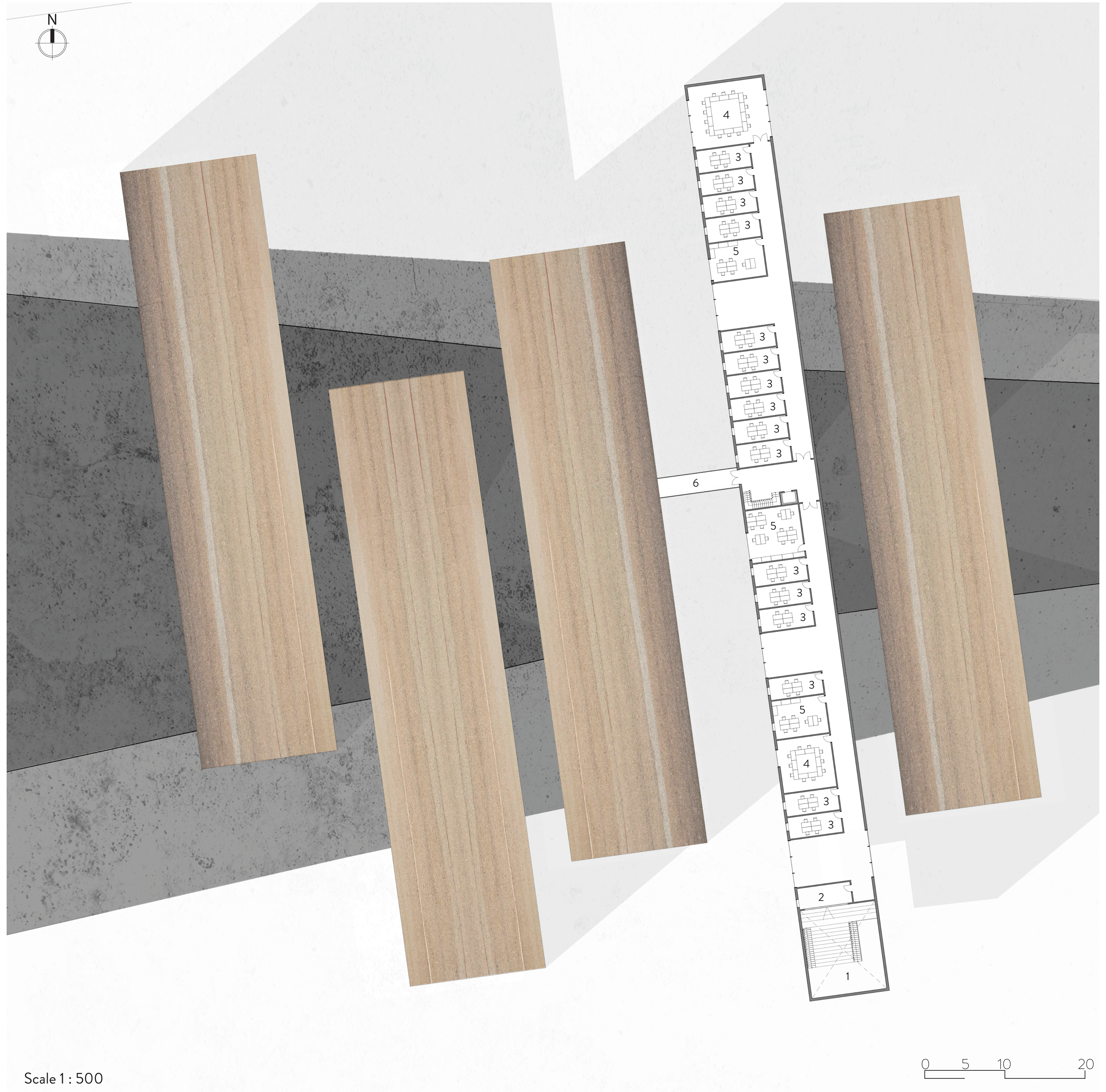
Ground Floor

1. Entrance Office
2. Exposition
3. Educational Room
4. Research and Consultation
5. Workshop - Sorting
6. Storage
7. Quarantine Room
8. Unloading Hall
9. Archive



First Floor

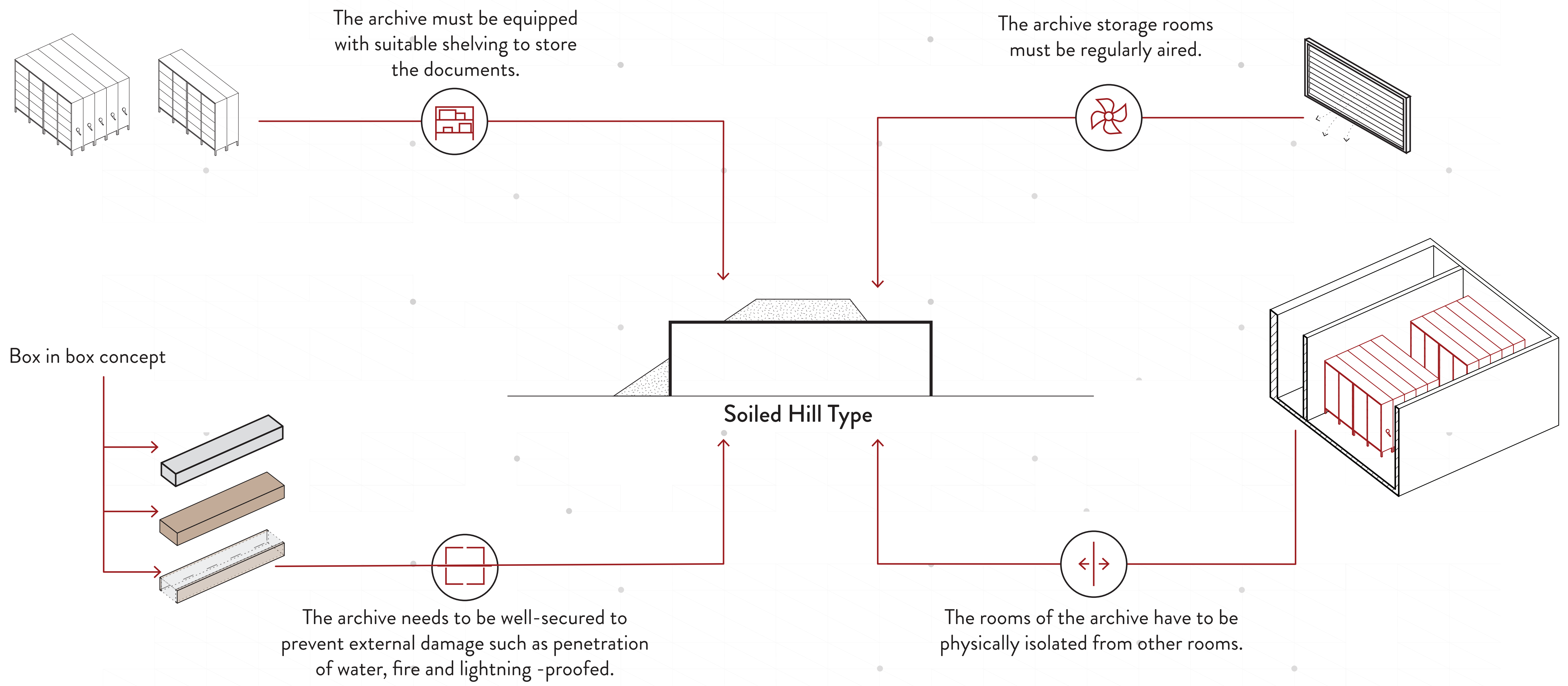
1. Conference Room
2. Storage
3. Office
4. Educational Workshop
5. Classroom
6. Research Room
7. Meeting Room
8. Conviviality Room
9. Archive
10. Workshop - Restoration

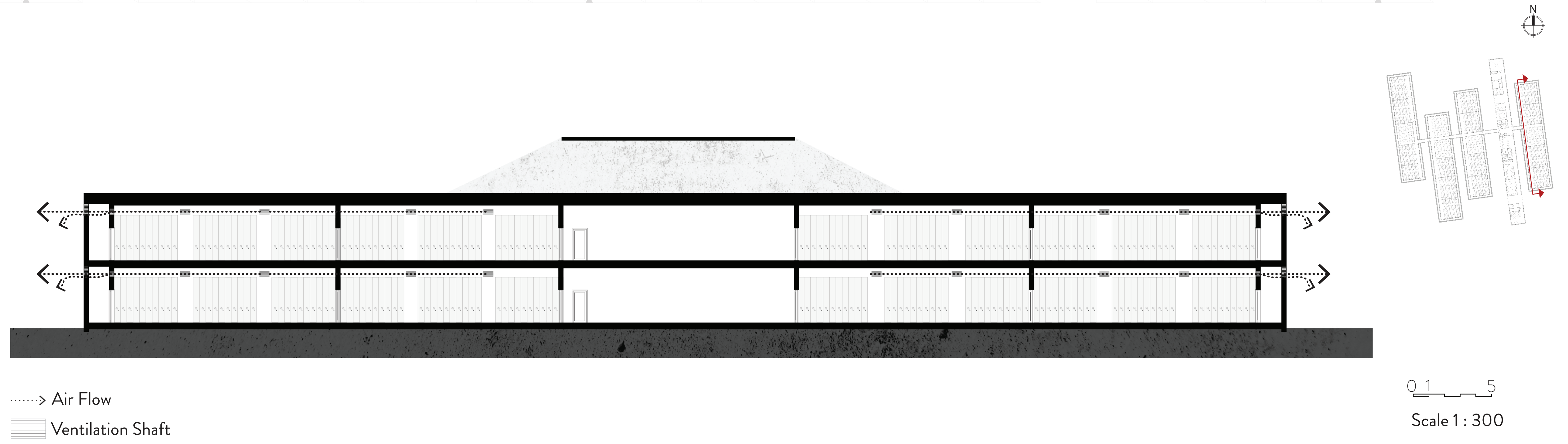


Third Floor

1. Conference Room
2. Projection Room
3. Office
4. Meeting Room
5. Conviviality Room
6. Balcony

Systems of the archive

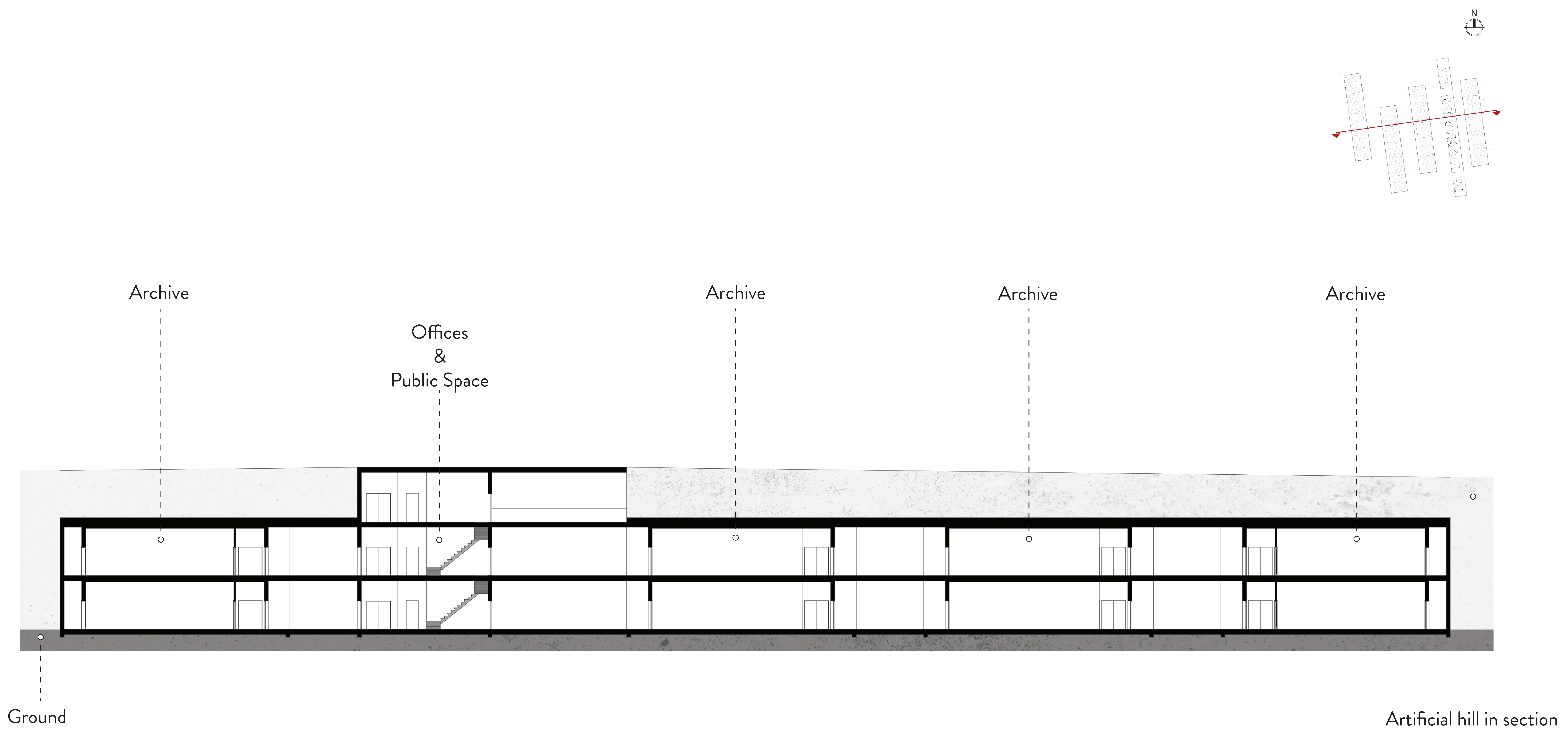




Section

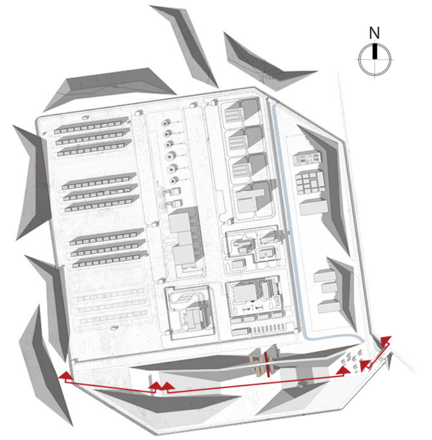
> Air Flow
Ventilation Shaft

Sections

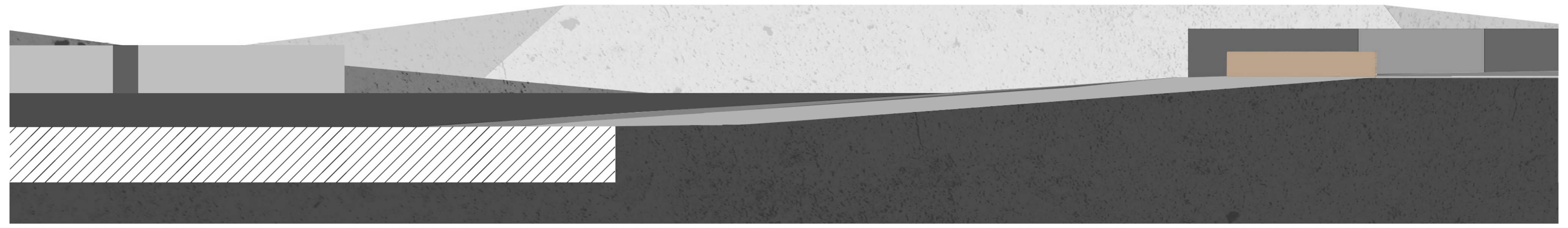


Section

0 1 5
Scale 1 : 300



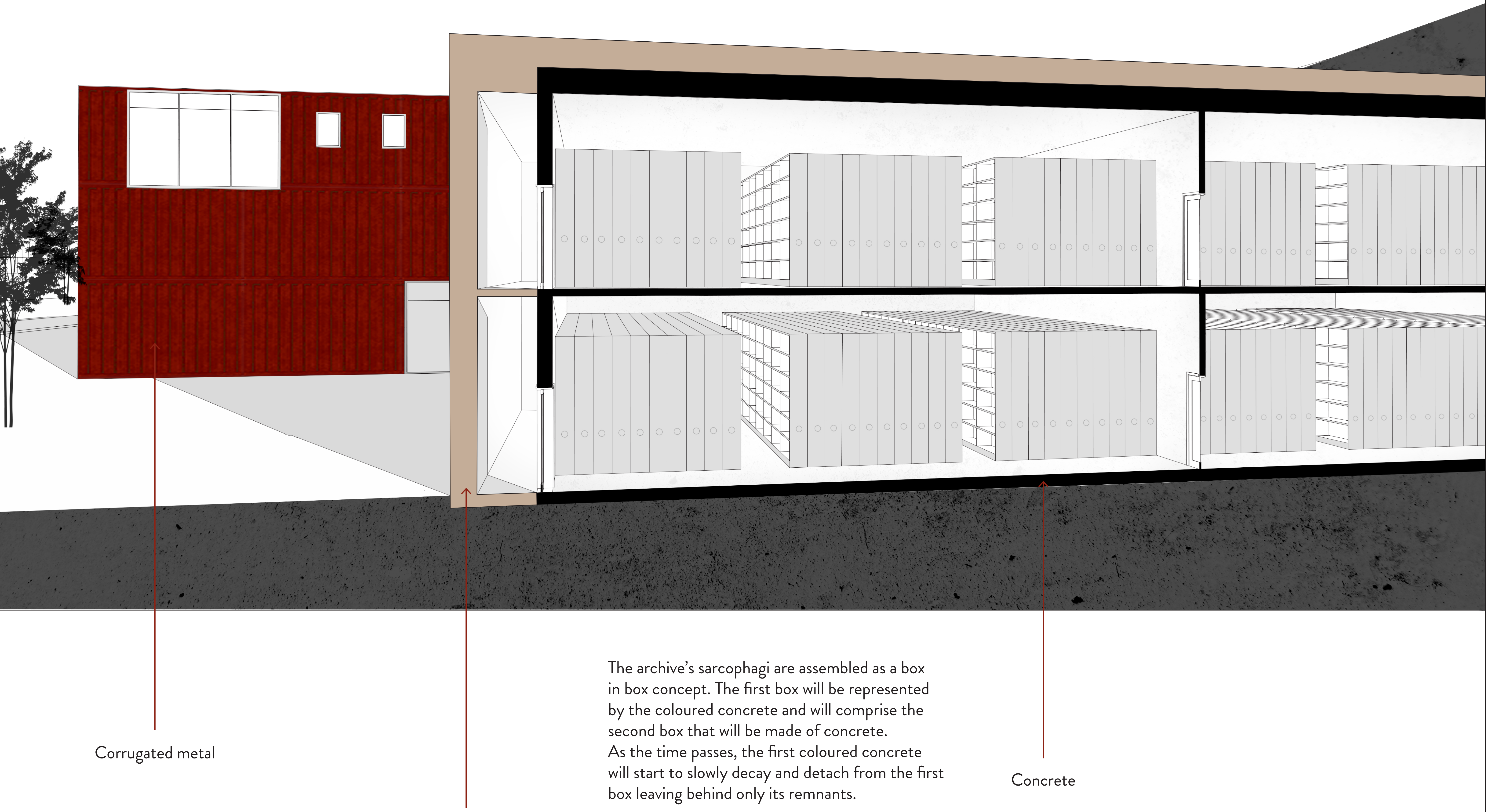
Section archive



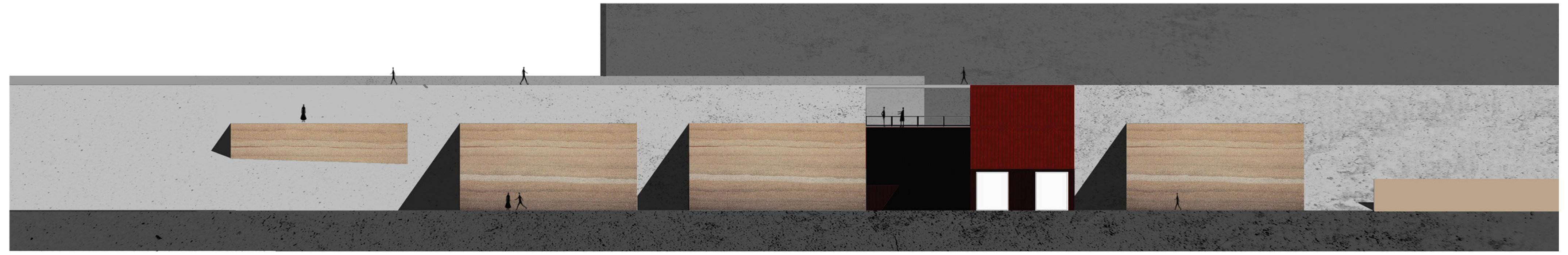
Section reservoir

Section entrance

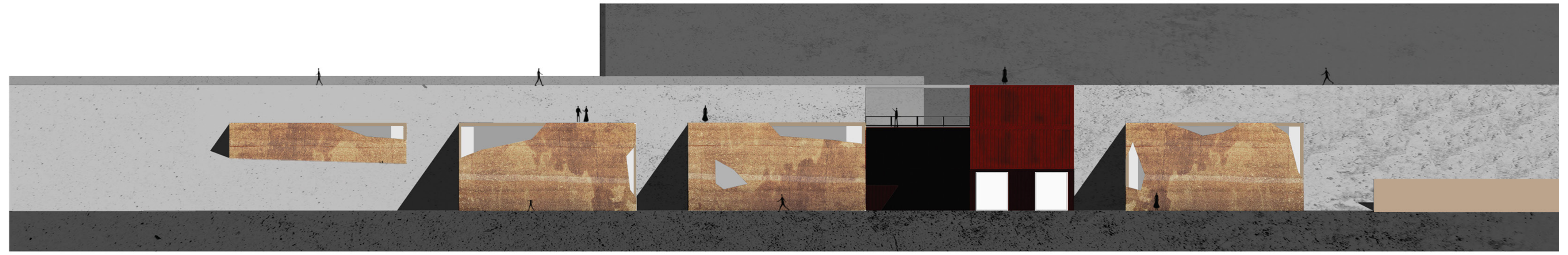
Time



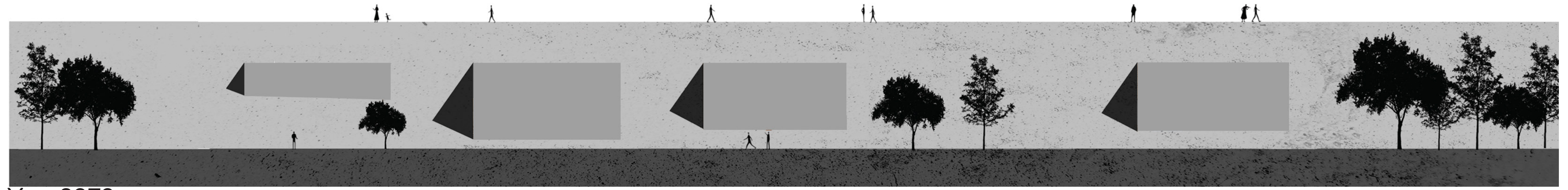
The archive's sarcophagi are assembled as a box in box concept. The first box will be represented by the coloured concrete and will comprise the second box that will be made of concrete.
As the time passes, the first coloured concrete will start to slowly decay and detach from the first box leaving behind only its remnants.



Year 2027

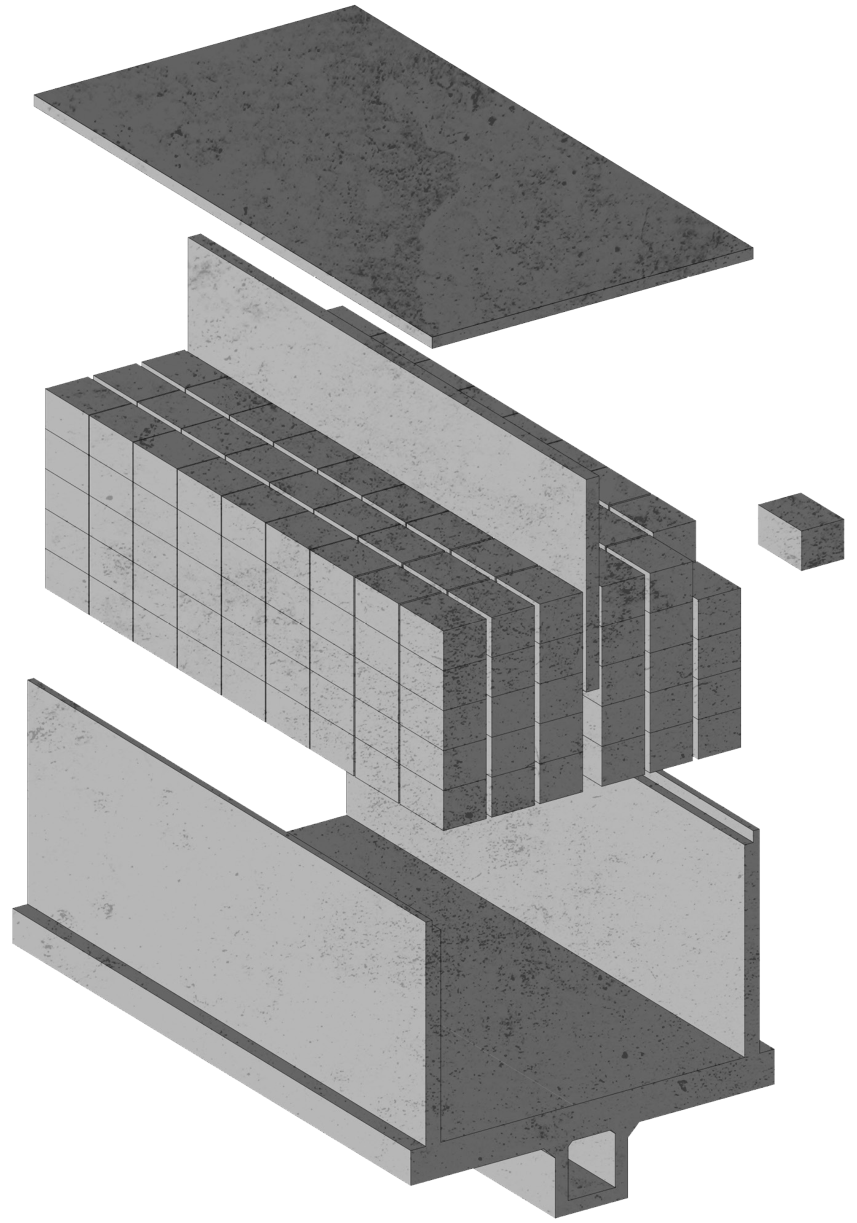


Year 2073

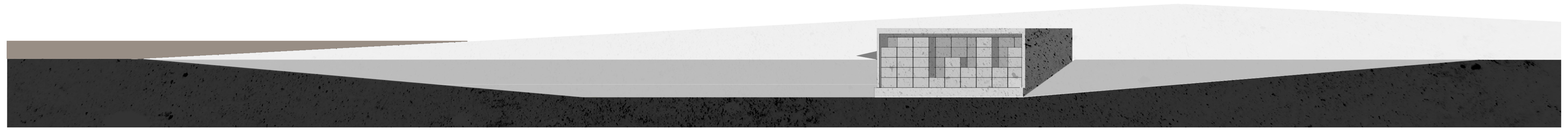


Year 2373

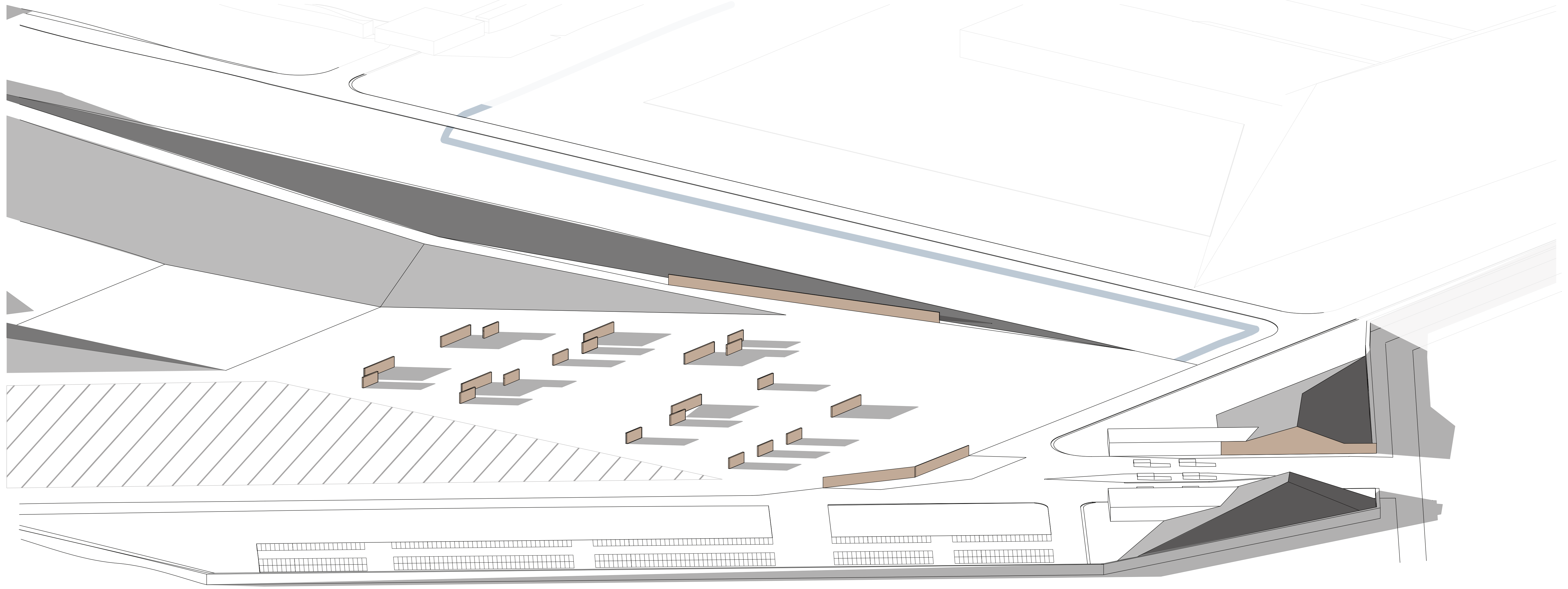
Replica of the module



The cell is formed from a special concrete designed to reisst for at leat 350 years. Each cell will be filled with modules that comprise the nuclear waste. There are 240 modules provided to saturate the cell and underneath it there are drainage system tunnels used to control any leakage that could take place



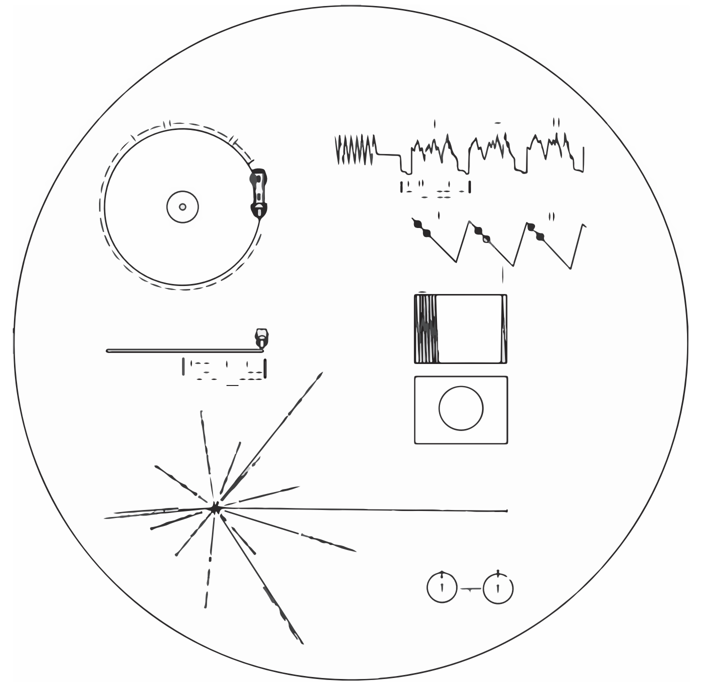
Information walls



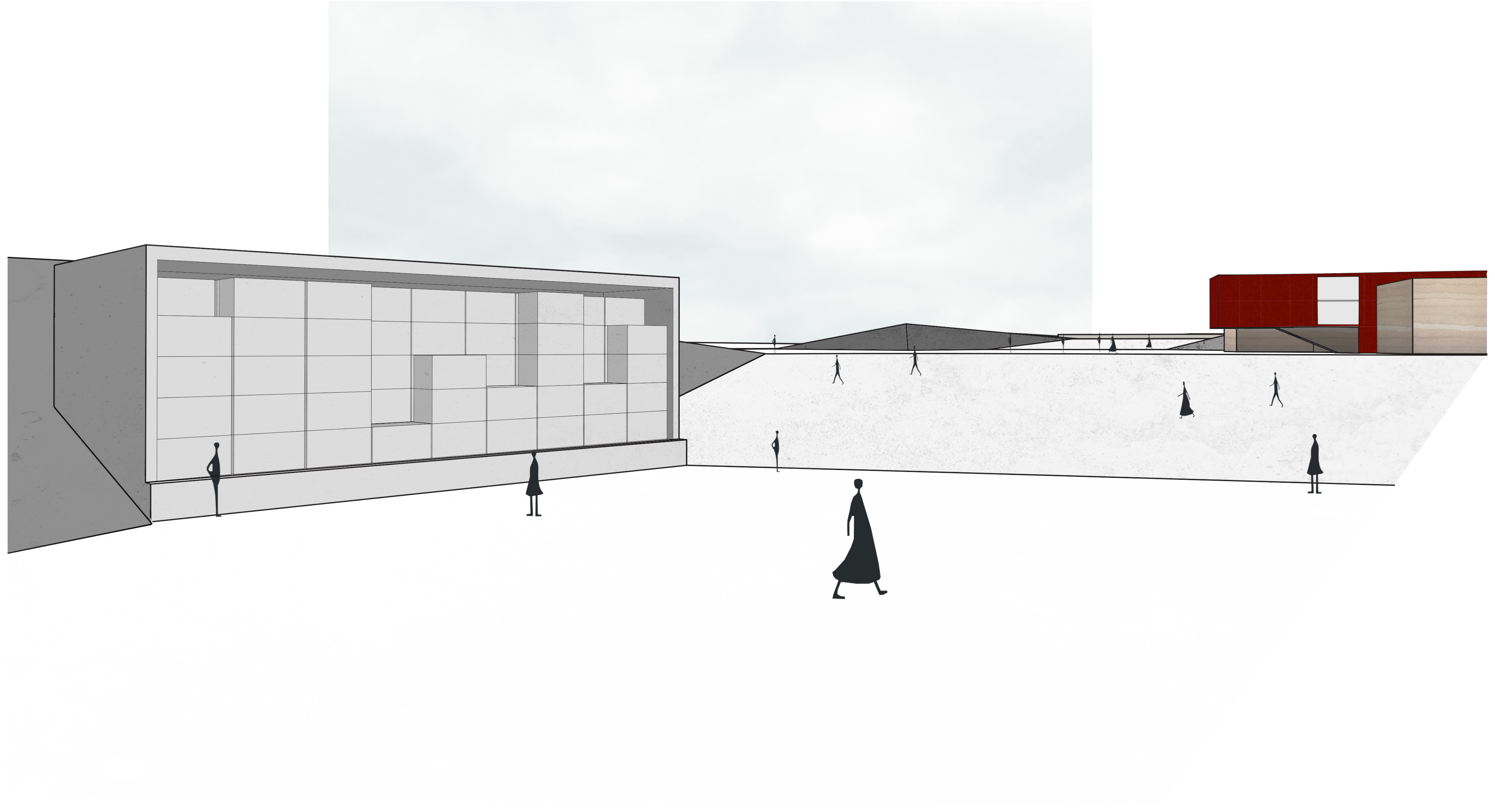
Carnac stones - France

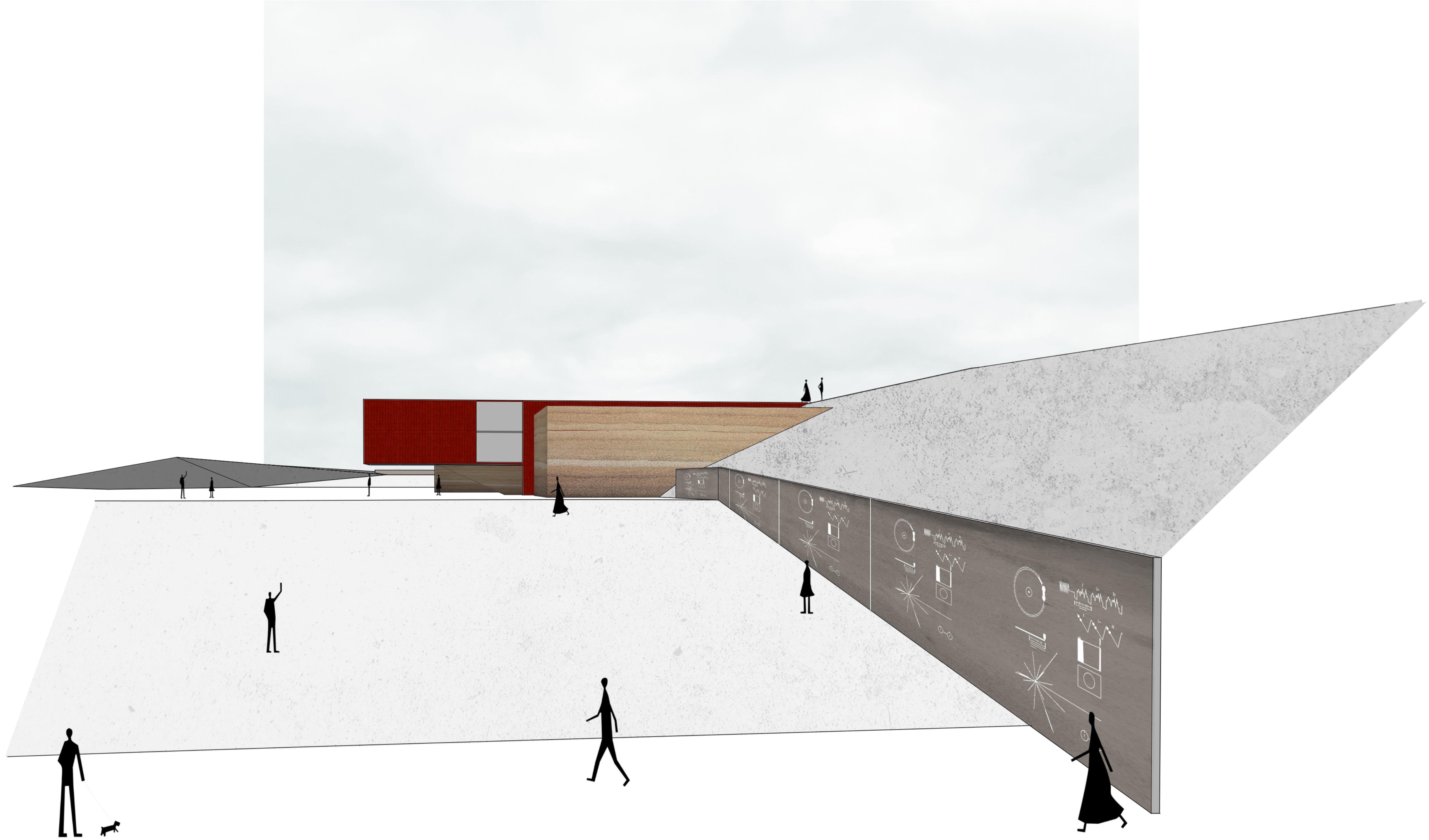
The information walls of the archive have the objective of informing people of the dangers which envelops the site of a nuclear repository. At the same time they also keep people safe by giving them guidance.

The idea of the walls was shaped after two refferences : the Carnac stones from France and the Voyager Golden Records. The Carnac stones represent a set of different stones with multiple functions (stone tombs, burial mounds, standing stones) each one arranged in many perfect rows.
The Golden Records are two identical phonograph records which were transported by the Voyager in 1977 and signify a time capsule that was cast in space in hopes that other forms of life will find it. Similarly, the information walls are cast in time in hopes of informing future visitors of the site about the dangers that lay in the ground.



Voyager Golden Records





Conclusion

This thesis was shaped by the existent problem of nuclear waste and its uncertainty regarding where it could be stored so as to not endanger the environment or the safety of future generations. Therefore, the Italian National Repository of Nuclear Waste and its Technological Park comes as a solution to this problem.

The primary issue in this thesis is time that attributes to the project this view of an atomic clock because radioactive elements are constantly irradiating the medium in which they have been immobilised, sometimes even at quantities that are perceptible. Changes can be seen, comprehended, and even managed in regards to short time periods, but this is not a real answer for extended time periods, which create a barrier for the following generation. They must be protected from potential radiation exposure, negative economic effects, and the requirement for ongoing maintenance or surveillance. In order to reduce the dread associated with the nuclear matter, the current generation must eliminate any issues that might arise in the future and advance knowledge of the radioactive field.

Time is viewed as a key element in many aspects of the project, from the repository's administration phases to the archive's shells, which deteriorate through time and leave only a ruin of what previously was there. The three main phases of the repository, which remain at the centre of the idea of time, are as follows: the first phase is the operational phase, during which the repository processes and stores the nuclear waste; the second is the dormancy phase, during which the waste will be buried and under close supervision; and the final phase is the afterlife phase, during which the repository can be put to normal uses, its memory being carried to new generations through what stays behind . The project focuses mainly on the archive and how the site evolves in time.

The archive represents a part of the Technological Park and is seen as a place of memory that will store current documents and carry them overtime to future generations in 4 sarcophagi semi buried into its landscape.

The offices of the archive will only last for the first 50 years following their removal, when the sarcophagi get completely sealed. The landscape of the archive will be an engaging component for its visitors as it carries them through a series of level changes that will give people the opportunity to view the entirety of the site from the top of the archive. The path of the archive, from its starting point until finish, accompanies the visitors through informational walls that guide them through the route by giving them information regarding the nuclear waste. Those walls will follow the sarcophagi into the future and will act as a reminder of the repository explaining to the future generations what lies underneath.

Concerning the development in time of the repository, the last phase of the site represents an afterlife that will transform the area into a walkable park which permits people to visit and understand what the site once represented. The information walls will once again guide the visitors and explain to them what the place represents.

Bibliography

Bagheri, Y. and Amir Mansouri, S. (2018) City entrance, as an element for creating an independent identity ... Available at: https://www.researchgate.net/publication/332413794_City_entrance_as_an_element_for_creating_an_independent_identity_for_the_city_landscape.

Classification of radioactive waste a safety guide ; a publication within the RADWASS programme (1994). Vienna: IAEA.

Classification of radioactive waste: General safety guide (2009). Vienna: International Atomic Energy Agency.

Considering timescales in the post-closure safety of geological disposal of radioactive waste (2009). Paris: OECD.

Corbellini, G. (2009) Bioreboot: The Architecture of R & Sien. New York: Princeton Architectural Press.

Disposal of radioactive waste: Specific safety requirements (2011). Vienna: International Atomic Energy Agency.

Hamilton, C. (2002) Refiguring the archive. Dordrecht: Kluwer Academic.

Issues and trends in Radioactive Waste Management: Proceedings of an international conference on issues and trends in Radioactive Waste Management (2003). Vienna: International Atomic Energy Agency.

Ketelaar, E. (2008) 'Archives as spaces of memory1', Journal of the Society of Archivists, 29(1), pp. 9–27. doi:10.1080/00379810802499678.

Koolhaas, R. (2002) 'Junkspace', October, 100, pp. 175–190. doi: 10.1162/016228702320218457.

Marini, S. and Corbellini, G. (2016) Recycled theory: Dizionario Illustrato. Macerata: Quodlibet.

Morton, T. (2021) Hyperobjects philosophy and ecology after the end of the world. Minneapolis: University of Minnesota Press.

Murray, R.L. (1981) Understanding radioactive waste: Prep. for Pacific Northwest Laboratory for U.S. dept. of Energy. NTIS.

Ojovan, M.I., Lee, W.E. and Kalmykov, S.N. (2019) An introduction to nuclear waste immobilisation. Amsterdam: Elsevier.

The principles of radioactive waste management (1995). Vienna: IAEA.

Radioactive waste in perspective (2010). Paris: OECD Publ.

Radioactive Waste Management 2000: Challenges, Solutions, and opportunities (2001). Bury St. Edmunds: Professional Engineering Publishing Limited for the Institution of Mechanical Engieers.

Rao, K.R. (2001) 'Radiactive waste : The problem and its management', Current Science, 81(12).

Rosenfeld, S.A. and Bautista, S.L. (2017) 'An archaeology of rituals', Rituals of the Past: Prehispanic and Colonial Case Studies in Andean Archaeology, pp. 3–20. doi:10.5876/9781607325963.c001.

Sandler, D. (2016) 'Counterpreservation as a concept', Counterpreservation [Preprint]. doi:10.7591/cornell/9781501703164.003.0002.

Vidler, A. (1999) The Architectural Uncanny: Essays in the modern unhomely. Cambridge: MIT Press.

Zografos, S. (2019) 'On Archives', in Architecture and fire. UCL Press, pp. 18–28.