Erosion Control and Reclamation For Nickel Projects

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Abstract

Nickel laterite mines are often located in tropical regions that are characterized by high rainfall, steep topography and endemic vegetation species. Due to the large surface area impact, erosion and sediment control during mining is one of the most significant environmental issues these operations face. An Erosion and Sediment Control Plan (ESCP) for a nickel laterite mining project is designed to protect the environment and downstream inhabitants from potential negative impacts due to mining in a cost effective manner. To be successful, the ESCP must be integrated within the mining plan. Certain design information is required when developing the ESCP, including an understanding of hydrology, topography, soils, vegetation and mine operations. Based on this information, ESCP measures can then be designed and constructed progressively during various phases of mining. Most ESCP's include shorter-term and longer-term components. Shorter-term components are developed for the active operations phase and longer-term components are maintained until vegetation on the final reclaimed surfaces is established and the land is returned to a pre-mining condition. A key aspect of a successful ESCP is development of adequate drainage measures for intense rainfalls. Generally an ESCP includes various components that are designed to work together to prevent erosion and collect sediment so as to clarify runoff from mining areas prior to discharge to the environment. In any ESCP, the establishment of vegetation is a key aspect for long-term protection of final surfaces such as waste stockpiles and tailings facilities. Investigations are required to determine suitable species. Implementation plans with suitable reclamation methods for maintaining final surfaces in a stable and environmentally acceptable manner are then developed. This may start with a review of existing reclamation activities at similar sites. A test plot program specific to the structures requiring reclamation is then initiated to test various vegetation species and soil amendment methods. An outline of ESCP methodologies and measures is presented herein along with some examples of ESCP design completed by Knight Piésold and implemented at nickel laterite mining projects, including examples of species selected for reclamation programs and results.

INTRODUCTION

Due to natural conditions, nickel laterite mining projects are often highly vulnerable to erosion. Typically the mining areas are characterized by steep topography or they are on plateaus above steep topography. Laterites develop in tropical climates with high annual rainfall and frequent high intensity rainfall events, particularly during wet seasons. Typical average annual rainfall may be in the order of 2000 mm with high intensity 24-hour events up to 500 to 600 mm. In addition, nickel laterite mining involves large surface areas because the horizontal ore bodies are typically 10 to 20 metres thick. Laterite soils in their natural state tend to be quite hard and cemented. Once disturbed however, laterite soils are highly prone to erosion.

The most significant environmental aspect of developing mining operations at nickel laterite projects is the provision of a suitable Erosion and Sedimentation Control Plan (ESCP) to minimize impacts to downstream environments. Properly implemented, the plan will protect downstream environments and reduce maintenance costs for mine infrastructure (i.e. prevention of sedimentation or washout of trafficking surfaces, drainage ditches, culverts, etc.). Ultimately, the ESCP must dovetail into the final reclamation plan by establishing fully stabilized and protected final reclaimed surfaces through successful re-vegetation that requires minimal or no maintenance in the long-term.

A practical and cost effective approach for implementing an ESCP is to fully integrate it with the mining operations. This helps to reduce earthworks and maintain production efficiency. In order to promote the integration, a phased approach to developing the ESCP can be taken. Initially a conceptual ESCP for the life of mine operations is developed that follows with the preferred mining arrangement. A typical mining arrangement and corresponding conceptual ESCP is shown on Figure 1.

Once an ESCP concept consistent with the mine plan is established, general design details and technical specifications are developed for construction of typical erosion and sediment control components. During each phase of mining (usually on an annual basis), more detailed design of significant erosion and sediment control measures is completed. This is followed by construction in conjunction with the mining development. Ongoing technical supervision and monitoring of erosion and sediment control works is conducted to ensure objectives are being met and to allow improvements to be made along the way.

ESCP DESIGN CRITERIA

In order to develop an effective ESCP, various data and design criteria must be reviewed and analysed. The ore reserve model and preferred mine development plan are reviewed to gain an understanding of the proposed stripping and mining sequences and schedules and to evaluate the changes to the various watersheds and their characteristics that can be expected to occur throughout the mining operations. This includes the topography prior to stripping, following stripping and following mining. Waste and ore characteristics are reviewed to predict erosion rates as well as to determine the maximum flow velocity. A review of historical monthly and extreme rainfall data is required to develop design flow criteria. Natural baseline environmental site conditions need to be reviewed to understand local sensitivities and establish short-term ESCP and long-term reclamation objectives.

For new mining operations waste overburden is generally placed in starter waste dumps for a short period at the start of mining. Subsequent overburden may then be placed into previously mined out areas for reclamation purposes. A 6 to 18 month period of exposure is normal for each area between the time stripping is initiated and the time when overburden waste is placed back into the mined out area. The final surface of the backfilled mining area needs to be designed to maintain historic watershed areas and contoured to promote drainage with minimal erosion until vegetation is established. Progressive reclamation of the final surface usually involves vegetating with a combination of grasses, shrubs and trees.

ESCP DESIGN APPROACH

A series of erosion and sediment control management measures are generally formulated using Best Management Practices developed worldwide (US EPA 1976, MNDM, 1995, Ontario MNR 1988, Ontario MNR 1989, Ontario MTO 1982, and IEAust 1996). The measures comprise methods for the management and control of surface water, prevention of soil erosion, and methods for removing sediments from surface water runoff prior to its discharge from the mining areas. This includes both longer-term measures for the reclaimed mining and waste/overburden stockpile areas and shorter-term measures for the active mining and stockpile areas. The conceptual ESCP contains a large degree of flexibility to permit adjustments to be made to account for any modifications in the mine plan or unforeseen site conditions. Measures and approaches presented in the conceptual ESCP can be readily implemented for all mining phases, although the specific layout and sizing of the individual erosion and sediment control structures will differ to suit each phase.

ESCP measures are designed to accommodate peak runoff flows generated by extreme rainfall events of reasonable return periods. The extreme rainfall events are selected from IDF curves developed during the review and analysis of the available historical rainfall data. Typically, the runoff is calculated using the Rational method by adopting representative runoff coefficients for the site conditions expected during the stripping, mining and reclamation stages. Erosion and sediment control methods for shorter-term measures are usually designed using a minimum 1-in-5 year extreme rainfall event. Such shorter-term measures generally include those associated with the overburden stripping and ore recovery operations, which are expected to occur over periods of 6 to 18 months in any particular mining area. Longer-term measures for sediment control are generally designed using a minimum 1-in-10 year 24-hour design event. Longer-term measures generally include final sedimentation ponds, mining area perimeter channels and ditches that will be in operation longer than 18 months and that are required to be functional until reclamation activities, including re-vegetation of reclaimed mining areas, is complete. This process could take as long as 5 to 10 years. Sedimentation pond spillways are normally designed to withstand as a minimum peak flows for the 1-in-50 year extreme rainfall event. Sedimentation basins are sized to settle out the smallest particle size that is practically possible, usually at least down to silt sized particles.

To facilitate the selection and design of appropriate erosion and sediment control measures, design tables and figures for sediment loads reporting from a variety of precipitation events, soil and vegetation conditions, slope gradients and slope lengths are prepared within the General Design Guidelines. Sediment loads are determined using the Revised Universal Soil Loss Equation (RUSLE), a method of predicting long-tem average annual soil erosion rates by runoff. The RUSLE is applicable for sheet and rill erosion at a variety of sites, including construction, mining spoils, landfill covers and agricultural land. It is not applicable for gully erosion. The sediment loads calculated by the RUSLE are used to compare the efficiency of various erosion control methods such as mulching, surface roughening and re-vegetation, and to determine the capacity requirements of sediment control structures such as sedimentation weirs, fences, basins and ponds.

ESCP COMPONENTS

Due to the intense rainfall events, the steep slopes and the lateritic soils that characterise nickel laterite mining areas, the ESCP focuses primarily on the management and control of surface water runoff. By putting in place measures that control the surface runoff, both the amount of sediment generated from erosion and the amount requiring collection can be minimized. General design and construction details that will allow positive implementation of erosion and sediment control management measures and techniques for various components are then developed. The components include structures for the prevention of soil erosion (erosion control) as well as methods for removing sediments from surface water runoff prior to the discharge (sediment control) from the mining areas. These components are implemented during mining operations, including overburden stripping, ore extraction, waste stockpile placement, reclamation and infrastructure construction. Some of the components that are typically included in an ESCP are illustrated on Figure 2.

The most significant components are the longer-term measures that must be in place prior to mining and throughout the mining operations and subsequent reclamation periods. These components usually include diversion and collection ditches around the disturbed area perimeter of each phase of mining, primary sedimentation basins to remove sediment from collected runoff from disturbed areas and reconstructed slopes for stockpiles and reclaimed areas. The upstream diversion channels and downstream sedimentation basins should be installed prior to development of a site as shown on Figure 3.

As the site is developed the downstream collection ditches should be installed to ensure all impacted runoff is sent to the sedimentation basins. In addition other shorter-term components should be implemented within the mining area to reduce erosion and sediment quantity reporting to the final sedimentation basins as the mine area is developed. A typical sequencing of the more significant components for Mining Areas is illustrated on Figure 3. The final frame (Step 3) shows the final reclaimed surface ready for re-vegetation with the primary sedimentation basins still in place.

The sedimentation basin arrangements for mining areas shown on Figure 3 are based on excavating the basins within the mining area. This requires that these areas be pre-stripped and mined in advance of the main orebody. This approach minimizes the earthwork that is required to construct the sedimentation basins. An alternative approach is to construct sedimentation basins downstream of the mining area. This adds more earthworks and increases costs but is simpler to manage, as it does not need to be fully integrated with mining. A photo of a typical sedimentation basin constructed within drainage a course downstream of a mining area is shown on Figure 3. In addition to mining areas, some stockpiles may also need to be constructed. For stockpiles, construction of the upstream diversion ditching and downstream sedimentation basins is of primary importance as well. In this case though, design of the basins is based on minimizing excavation and utilizing available waste overburden from mining operations for embankment construction. A typical stockpile sedimentation basin layout is shown on Figure 3 along with a photo of a completed sedimentation basin at the toe of a stockpile area.

RE-VEGETATION

Vegetation is one of the most cost-effective forms of long-term erosion control and reclamation. It is self-healing and attractive. Vegetation prevents erosion, unlike some control measures that collect sediment after soil has already eroded. Vegetation protects the soil surface from the erosive forces of wind and water and binds the soil with roots. Vegetation protects the soil from water erosion by absorbing the impact of raindrops, reducing the velocity of runoff and reducing runoff volumes through increasing water percolation into the soil. Vegetation will also greatly improve the aesthetics of any disturbed site.

Vegetation species considered for nickel laterite reclamation projects are based on observed characteristics of both local and widely distributed species. Species considered ideal for reclamation and erosion control use are generally robust, with low nutrient requirements, provide ground cover and are fast growing. The potential species discussed below are based on a review of existing reclamation work and opportunistic species found on existing re-vegetation sites in the Carribean. They are widely distributed species, however and are likely suitable for tropical sites worldwide (Species common names are given in Spanish).

Estrella (*Cynodon nlemfuensis*) is a large robust grass that spreads by rooted runners (stolons). It has a rapid growth rate and provides a quick ground cover, which is very effective at controlling erosion and sediment transportation. Also known as African Star Grass, Estrella appears to help hold moisture on the forest floor, facilitating greater water absorption by the soil due to the decrease in the water flow from the area and providing protection from drying by both sun and wind. It does require reasonable soil fertility and has been observed to perform best when soil amendments are added at the time of planting.

Hierba de Guinea (*Panicum sp.*) is a 0.6 to 2 m high tufted perennial, often with a shortly creeping rhizome. It is not highly drought tolerant and grows well on sloping land. It is suitable for grazing. Hierba de Jamaica is a low growing grass that has been observed to colonize laterite embankment slopes. Faragua (*Hyparrhenia rufa*) is a coarse grass used for hay and silage. It grows to a height of 0.6 to 2.4 m. Cortadera is a coarse clumping grass, with sharp edges, and is also referred to as cut grass. It is not palatable to cattle, except when the grass is young. It forms large clumps approximately 1 to 2 m high when it is mature.

Vetiver *(Vetiveria zizanoides)* is considered an excellent erosion control tool throughout the tropics. It is a big, course, very tough bunch grass that grows to about 1 m wide at the base with a clustered mass of dense stems. A line of vetiver across a slope acts similar to a solid barrier. Runoff water can ooze through the wall of grass, but any load of silt will be deposited on the upstream side. Vetiver combines several characteristics to make it an ideal erosion control species. It reduces erosion when in a hedge just one plant wide. Certain types appear to bear infertile seed and produce no spreading stolons or rhizomes and they remain where they are planted. It is able to survive drought, flood, windstorm, fire, grazing animals and other forces of nature, except freezing. It has a deep penetrating root system. It is easy to establish and maintain and can survive on many soil types with a range of fertility, acidity, alkalinity, and salinity.

The tree species Casuarina (*Casuarina equisetifolia*) has been extensively used in the re-vegetation of the some of the nickel laterite mining areas reviewed. Casuarina is native to Australia, but has been widely cultivated and naturalized in tropical and subtropical regions, becoming an invasive problem species in some jurisdictions such as Florida. It is tolerant of poor soil nutrients and a variety of weather conditions. Casuarinas commonly shed their needles as a natural survival mechanism to minimize its moisture loss and uptake requirements during the dry season. These needles provide a barrier against erosion and sediment transportation on the soil surface. The needle bed provides a cover that allows rainfall to flow over top of the bed while the needles impede the rate of water flow by creating an uneven surface. The needle bed is also very effective at retaining moisture, providing a sun and wind barrier and minimizing evaporation.

Test plots simulating potential re-vegetation species and soil amendment options are usually established to provide information on species performance for initial establishment, erosion control and longevity. Amendments are commonly added to soil at the time of planting to both provide nutrients and improve soil texture. Amendments include nutrients, typically nitrogen, phosphorous and potassium (although other nutrients could be added should testing reveal a serious deficiency) and organic matter. Locally available manure provides an ideal amendment since it would contain a variety of nutrients and would provide organic matter to improve soil texture. In addition, manure often contains a seed bank of locally adapted vegetation species that may prove suitable for re-vegetation purposes. Amendments add to the cost of a planting program and therefore the benefits of the amendments should be determined through the use of test plots prior to fully implementing any reclamation plan. Typically these amendments, in addition to a control plot without any amendment, are used in test plots with different vegetation species to determine the most cost effective means for establishing a suitable long-term erosion control cover.

CONCLUSIONS

Developing and implementing an effective ESCP is an important aspect of reducing the environmental impacts of nickel laterite mine operations. Integration within the mining plan development provides an opportunity to minimize costs of the ESCP and final reclamation plan implementation by minimizing earthworks required to construct sedimentation basins, final reclaim surfaces etc. The effectiveness of the ESCP components in preventing erosion and collecting sediment to clarify runoff from mining areas prior to discharge to the environment should be assessed through a monitoring program. Additional information collected at the early stages of development can then be used to update and improve the ESCP and finalize the reclamation plan. The implementation and results of a vegetation test plot program are crucial to selection of practical vegetation species and soil amendments for application in the reclamation plan.

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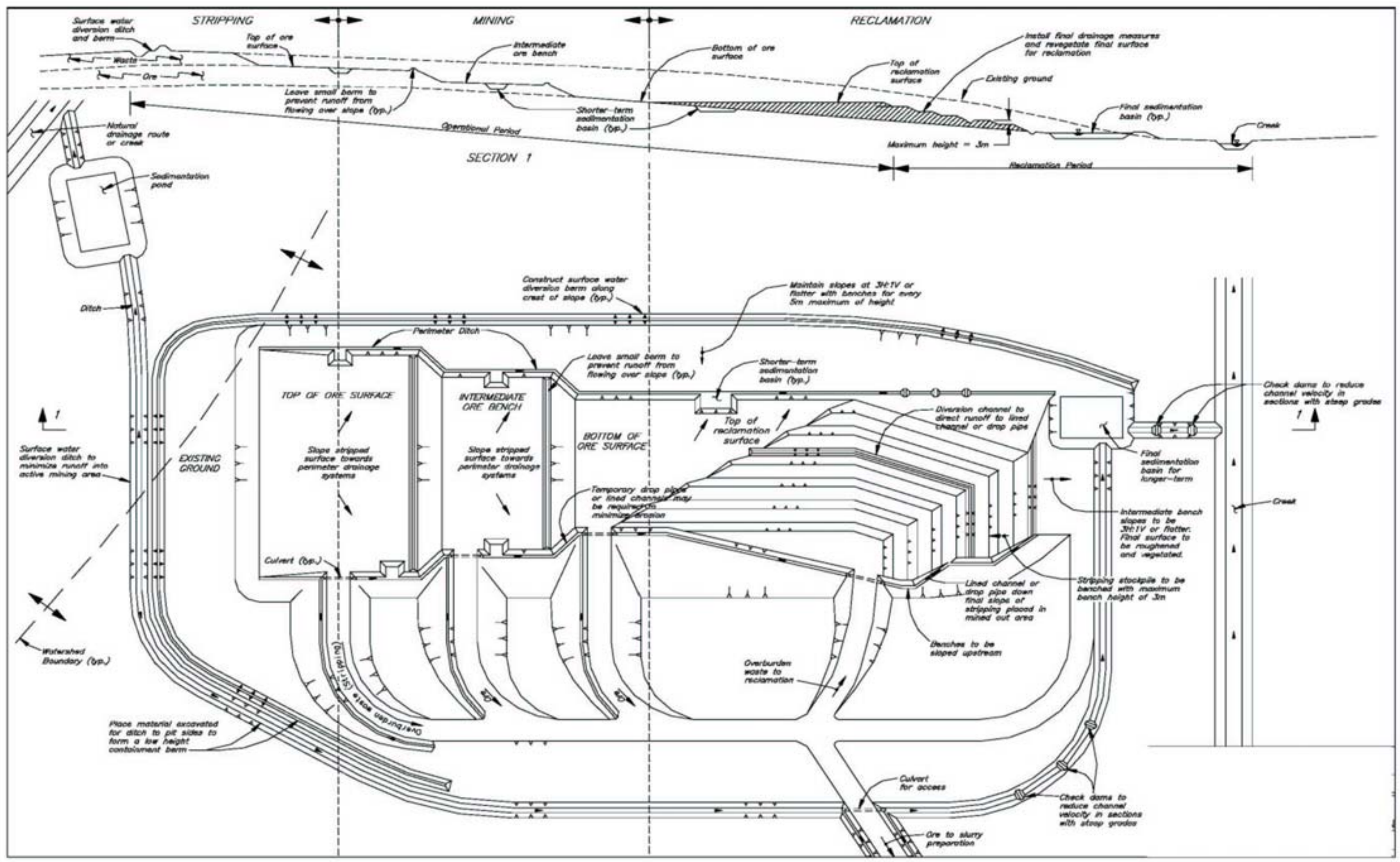

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Erosion Control and Reclamation for Nickel Laterite Projects

MINING DEVELOPMENT PHASES AND CONCEPTUAL ESCP

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NB908-00002/5	1	0

FIGURE 1

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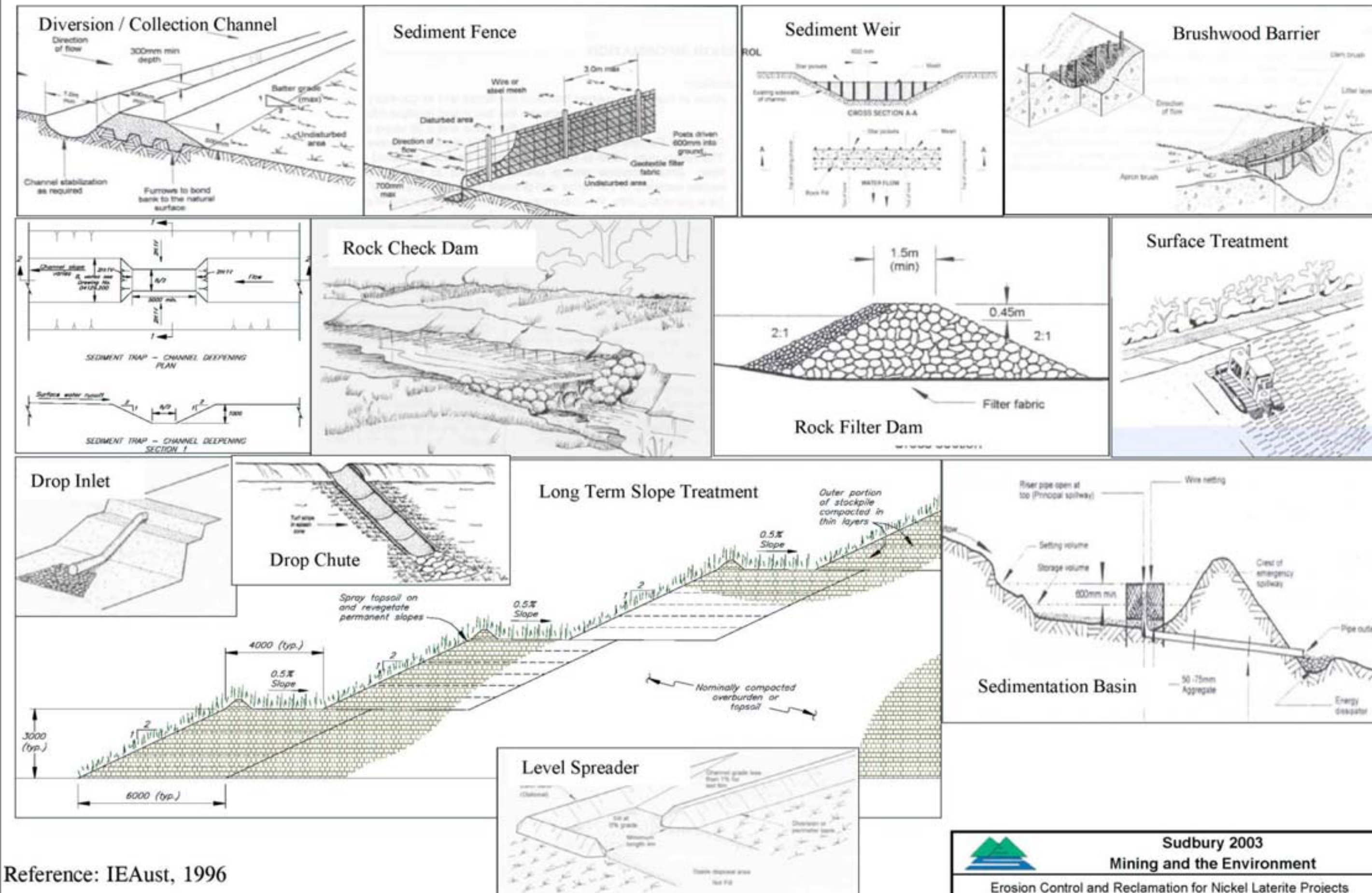

Reference: IEAust, 1996

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ESCP TYPICAL COMPONENTS		
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	FIGURE 2	

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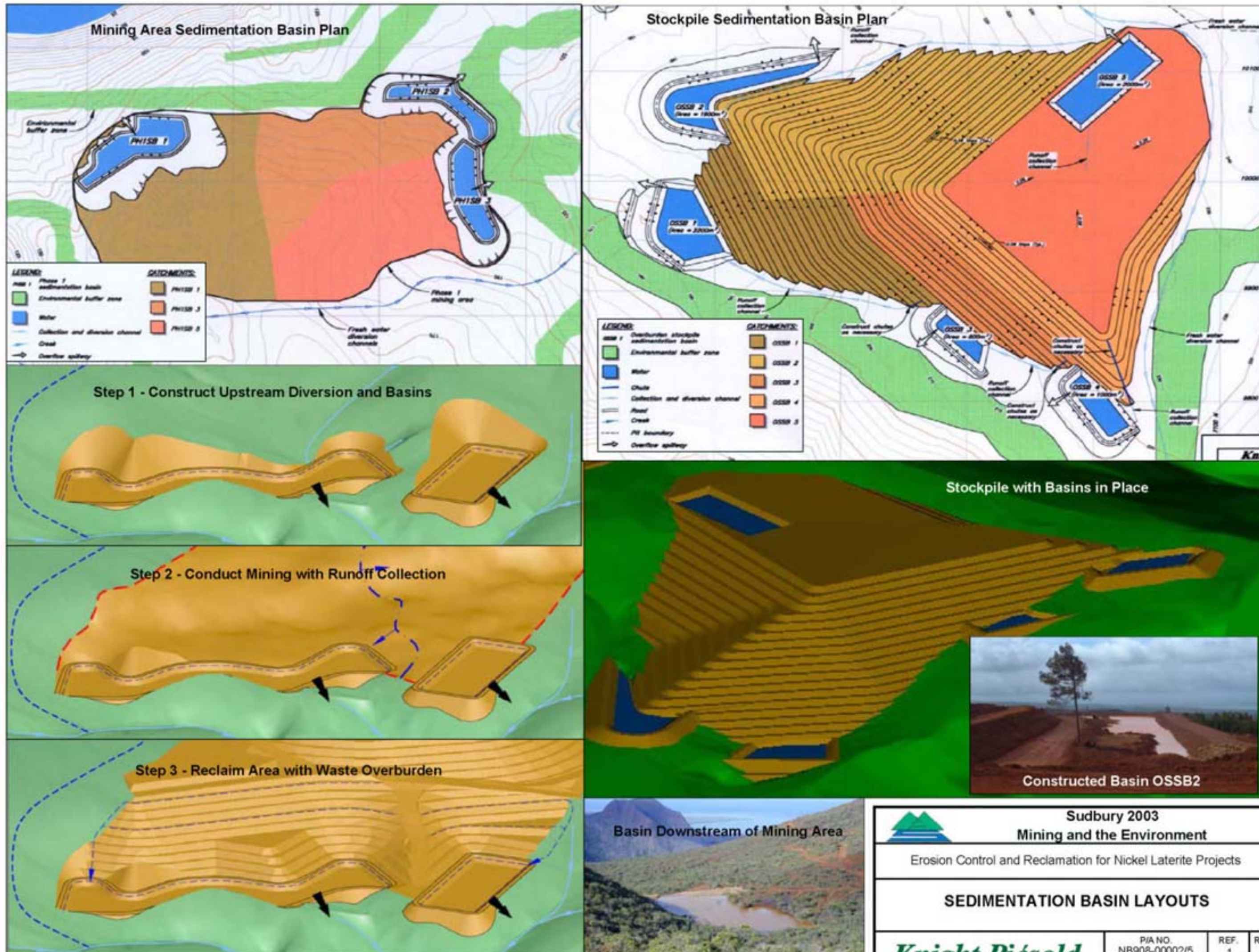

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SEDIMENTATION BASIN LAYOUTS

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FIGURE 3

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