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BOSA

TRANSMISSION PROJECT

BOSA TRANSACTION ADVISORY SERVICES

TRAINING: BOSA Transmission Line Corridor Route Selection Process

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1. INTRODUCTION

The scope of work for the Botswana – South Africa (BOSA) transmission interconnector project includes a training and development deliverable, referenced as Part 4: Formal Training. The objective of the training program is to enhance the capacity of SAPP CC, the Sponsors, and associated stakeholders, in all, or selected, components of this assignment, by means of formal training; thereby providing a sustainable BOSA project legacy.

The Transaction Advisor's (TA) approach to the delivery of training was developed in consultation with stakeholders; and was then approved by the relevant project governance institutions; namely the Project Meeting on 06 December 2016 and the MANCo on 17 February 2017. The TA approach is premised on the provision of a customised training service offering to deliver skills transfer, aligned to the specific studies and work streams that enable the delivery of the BOSA project. The TA uses a blended delivery approach to training delivery, focused on presenting the relevant theory, project work methods, results and outcomes in a classroom training environment, with hands on application of systems and tools utilised in the project, as appropriate to the specific training intervention.

The identification of the Transmission Line Corridor Selection training intervention as the first component for training delivery has been informed by the current project constraint associated with the proposed change in location of the Watershed B MTS site and the potential delivery schedule misalignment between the TA and Eskom's defined scope of work. Engagement with SAPP, DBSA, Eskom and BPC resulted in agreement to use the Watershed B transmission line corridors to Mookodi and Pluto substations, respectively, as the practical example in the delivery of the transmission line corridor selection training programme. The utilisation of this practical example to deliver a common understanding of the methodology, key concepts, results and outcomes of a route selection process, delivers benefit both in terms of enhancing stakeholders skills in the route selection process methodology, and achieves an outcome of a structured and verifiable improved understanding of the Watershed B line corridors, for application within the broader BOSA project context.

This report documents the route selection, MCDM and route optimisation processes for the selected line routes; thus serving as a significant secondary deliverable that has been achieved as an outcome of the training intervention. Preferred routes to link the revised general location for the Watershed B substation to Mookodi and Pluto respectively, have been selected as a consequence of following the methodology described in this report. These preferred routes can now be used as by Eskom as a refined input into the ESIA processes for the specified lines, as prescribed by legislation. The development of this deliverable in the training intervention has resulted in partial mitigation of the risk associated with the timing mismatch between the delivery of BOSA Part 3 and the comparable Eskom studies and processes associated with the Watershed B substation, and the transmission lines from this substation to Pluto and Mookodi substations, respectively. The TA's provision of the packaged preferred line route corridors to Eskom has the potential to have a material positive impact on the current forecast delays, provided that Eskom expedites the initiation of their internally driven ESIA processes for these two lines.

2. ROUTE SELECTION PROCESS

2.1. Workshop

The route identification is an integral component of the project scope for the TA. A training workshop was held between 3 and 6 April 2017 to showcase the principles of route selection in practice as part of the training exercise. The following roles players were part of the workshop (Table 1). Representatives of both the environmental (including social) and technical team members were present during relevant portions of the training in order to ensure that all relevant information, local knowledge and transmission line expertise were taken into consideration in the final decision; and that all interested parties agree on the way forward. The attendees at the workshop are indicated below (Table 1 and Attendance Registers in Appendix A).

Table 1: List of w orkshop attendees

INDIVIDUAL	ORGANISATION	FIELD OF INTEREST
Rowan Beukes	Eskom	Technical
Tobile Bokwe	Eskom	Technical
Christo Badenhorst	Eskom	Technical
Sebenzile Vilakazi	Eskom	Technical
Tshinanne Mutshatshi	Eskom	Technical
Tinny Makaringe	Eskom	Technical
Mpilo Masondo	Eskom	Technical
Phindile Dlamini	Eskom	Technical
Rosemary Paseko	Botswana Power Cooperation (BPC)	Technical
Jenamiso Moalosi	Botswana Power Cooperation (BPC)	Technical
Mokwaledi Keipeile	Botswana Power Cooperation (BPC)	Technical
Thulisile Nyalunga	Department of Environmental Affairs (DEA) SA	Competent Authority
Portia Makitlla	Department of Environmental Affairs (DEA) SA	Competent Authority
Makhosi Yeni	Department of Environmental Affairs (DEA) SA	Competent Authority
Galaletsang Ramokgwana	Department of Environmental Affairs (DEA) Botswana	Competent Authority
Senikiwe Faith Tsile	Department of Environmental Affairs (DEA) Botswana	Competent Authority
Chris van Rooyen	Chris van Rooyen Consulting	Avifaunal Specialist
****Elmie Weidema***	*Aurecon*	*Visual Specialist*
****Brian Collity***	*Scherman Colloty & Associates*	*Biodiversity Specialist*
Noeleen Greyling	Aurecon	Social Specialist
Andries can der Merwe	Aurecon	MCDM facilitator
Nigel Waters	Aurecon	Project Leader
Diane Erasmus	Aurecon	Environmental Team leader
Fayaaz Sattar	Aurecon	Technical
Jessica Allen	Aurecon	GIS Specialist
Angela White	Aurecon	GIS Specialist
Wendy Mlotshwa	Aurecon	Environmental Practitioner
** Specialist that were not able to attend workshop. Their assessments were completed remotely in consultation with the MCDM facilitator*		

2.2. Identification of potential routes

The optimum routing for an overhead electricity transmission line is ideally a straight line from one point to another, over a flat terrain with no obstacles, sensitive areas, or other constraints. As this is never possible, selection of the best route is an optimisation exercise, which aims to minimise the impacts on the environment and people, while accommodating technical challenges in the most cost-effective way.

A rigorous process was followed to identify a range of potential route alignment corridors. The best practice base information used to inform these potential route alignments included the following factors detailed in Figure 1. This also ensures that these considerations inform route selection from the earliest planning phase reduces the potential for associated problems to emerge during the later stages of the project.

Topography and slope

- Slope and topography affects ease of construction and access for construction and maintenance
- Areas with the flattest topography should be selected as far as possible, to allow the straightest line possible to reduce costs and minimise the need for angle poles
- Avoid areas with slope exceeding 1:10
- Slopes steeper than 1:18 are fatal flaws

Water bodies

- Large bodies of water should be avoided
- The maximum span between the tower structures determines the maximum allowable water crossing

Existing infrastructure and other land uses

- Line routes should run parallel to roads where possible
- Minimise distance that lines run parallel to pipelines and railways to reduce possibility of induced current effects
- Where unavoidable to cross, safe clearance distances should be ensured
- Ensure line crosses at the shortest route over railway or road and avoid small angles of intersection
- Line heights and clearance areas around airports as determined by air traffic regulations
- The possibility of cavity or land-falls must be considered in areas with mining activity
- Overhead lines are not permitted through protected areas of military installations

Other power lines

- If unavoidable, ensure crossing of new line over existing where multiple towers and spans can be installed between existing parallel lines
- This reduces the possibility of all power supplies being simultaneously compromised if lines collapse
- Consider positioning of wind energy converter and provide suitable clearance between rotors and overhead lines

Urban or residential areas

- Line corridors must avoid residential areas
- Challenging in rural areas, where residential areas are not well demarcated
- Relocation of people and their homes and assets may become necessary, which is time consuming and costly

Biodiversity

- Avoid protected areas, sensitive aquatic and terrestrial ecological areas and pristine natural vegetation
- Avoid bird flight paths, Important Bird areas and bird breeding and feeding areas

Heritage resources

- Avoid sites with known archaeological, historical, religious or cultural value
- Avoid tourist attractions

Figure 1: Factors considered in route selection process

Based on the above, 16 potential linkages between the proposed Watershed B and Mookodi substations in South Africa were identified (**Error! Reference source not found.**). A total of 15 potential linkages were identified for the route between Pluto and Watershed B substations (**Error! Reference source not found.**). It should be noted that these route alignment corridors include buffer areas to allow for the exact siting to be informed by detailed assessment of the study route.

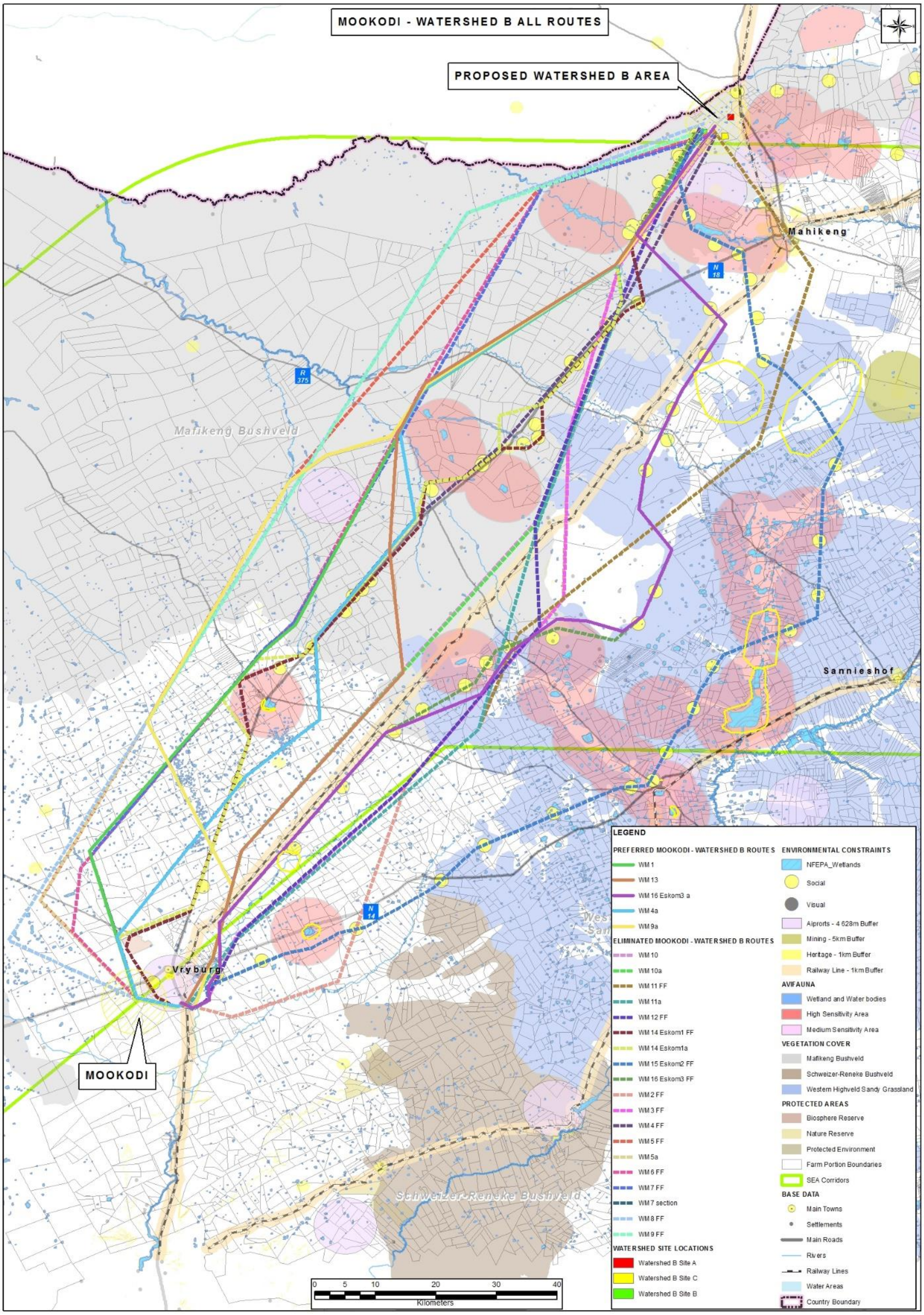


Figure 2. All route options between Mookodi and Watershed B substations, based on the outcomes of the route screening process

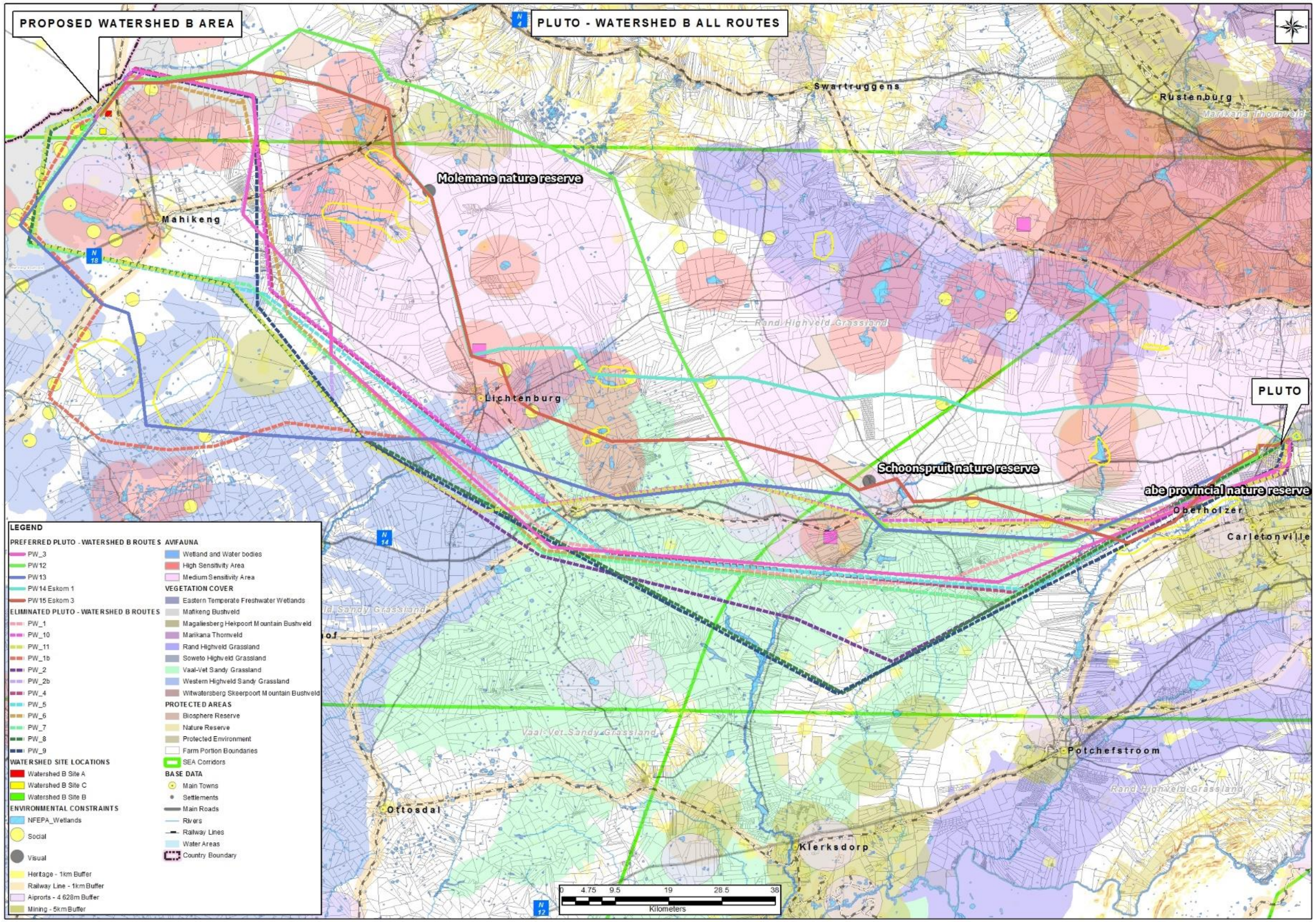


Figure 3. All route options between Pluto and Watershed B substation, based on the outcomes of the route screening process

2.3. Screening process

The screening for potential routes identified above was applied at a very coarse scale to identify any routes not fatally flawed by factors such as crossing towns and slopes too steep for construction or other considerations identified above. For both corridors the routes were further screened to identify a total of 5 corridors as potential routes for more detailed assessment, as reflected in Table 2 and Table 3 below. These tables summarise the outcomes of the screening of routes for Mookodi to Watershed B and Pluto to Watershed B corridors respectively.

Table 2: Summary of route options considered for the Mookodi to Watershed B corridor

Route Name	WM1	WM2	WM3	WM4	WM5	WM6	WM7	WM8	WM9	WM10	WM11	WM12	WM13	WM14	WM15	WM16
To be assessed further in MCDM																
Bird sensitive areas – especially problematic for transmission lines																
Known sites of heritage / cultural significance																
Large areas of subsistence and formal agriculture – high levels of compensation and possible resettlement																
Line route too close to settlements and urban areas – potential to constrain future development																

Table 3: Summary of route options considered for the Pluto to Watershed B corridor

Route Name	PW1	PW2	PW3	PW4	PW5	PW6	PW7	PW8	PW9	PW10	PW11	PW12	PW13	PW14	PW15
To be assessed further in MCDM															
Other infrastructure to be crossed – may result in difficulty crossing such infrastructure															
Steep slopes – costly/technically difficult to construct															
Line route too close to settlements and urban areas – potential to constrain future development															

Table 4: Potential routes used in the MCDM process

Watershed B-Mookodi	Pluto-Watershed B
WM1	PW3
WM4a	PW12
WM9a	PW13
WM13	PW 14 (Eskom 1)
WM16a (Eskom 3a)	PW 15 (Eskom 3)

The five potential corridors were identified for assessment during the MCDM workshop to allow for the identification of a preferred alternative to take forward to the feasibility study for more detailed assessment at a later stage in the project. The 5 alternatives selected for the Watershed B to Mookodi corridor are indicated in Figure 4 and for Watershed B to Pluto corridor are indicated in Figure 5.

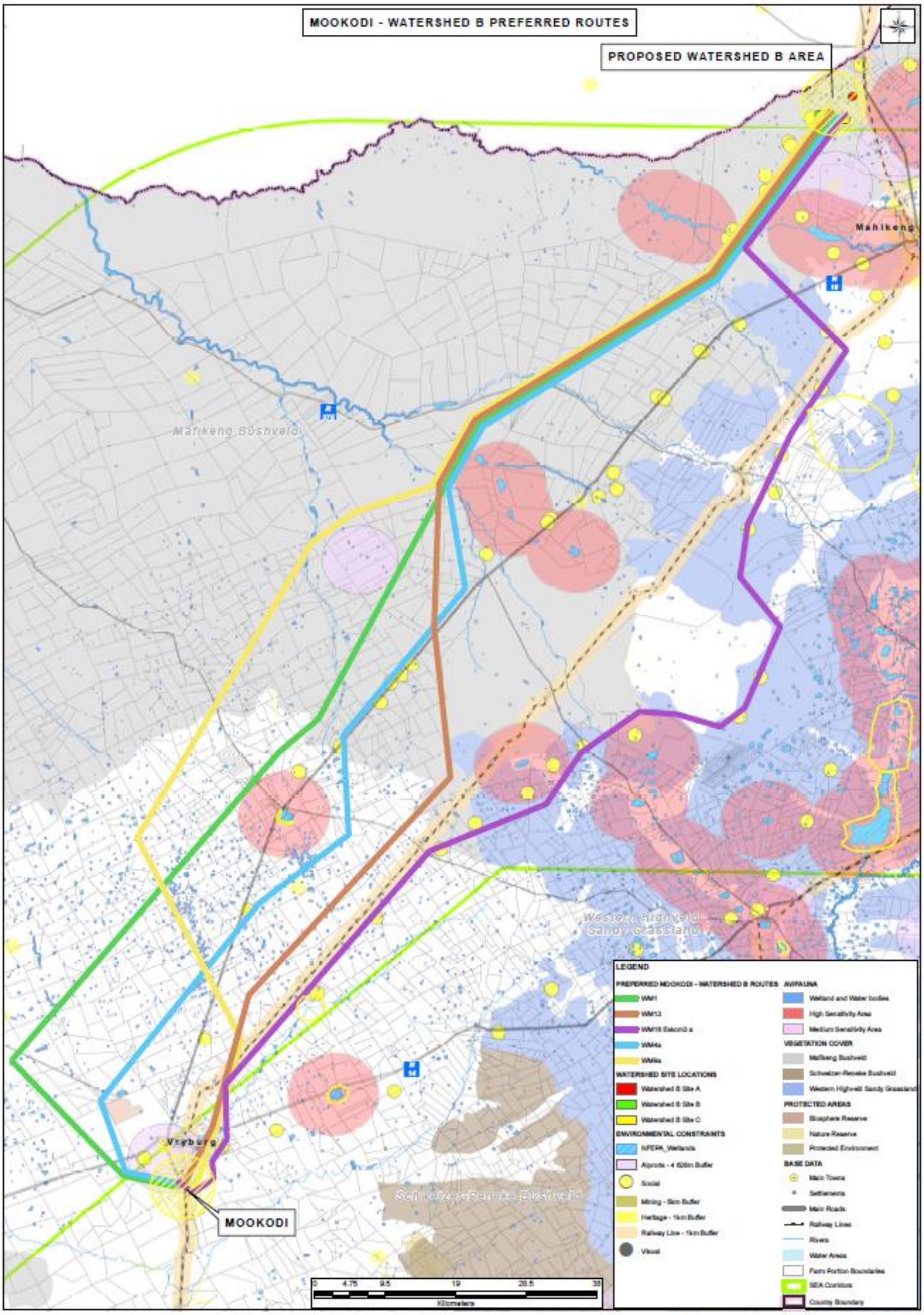


Figure 4. Preferred route options between Mookodi and Watershed B substation for MCDM process

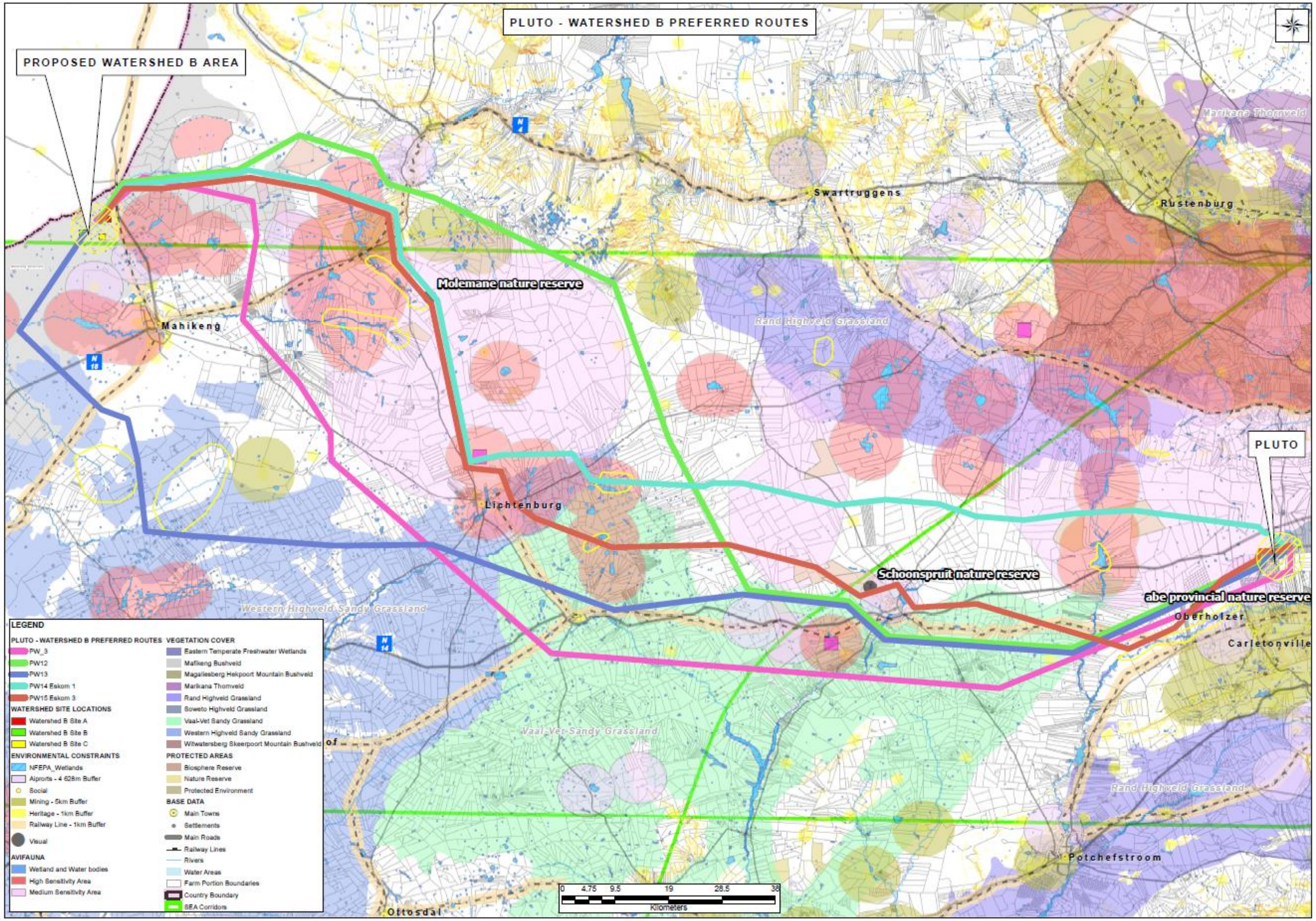


Figure 5. Preferred route options between Pluto and Watershed B substation for MCDM process

3. MCDM PROCESS MCDM BACKGROUND

The Multi-criteria Decision-Making Model (MCDM) process is a discipline aimed at supporting decision makers who are faced with making numerous and conflicting evaluations. It highlights conflicts and derives a way to reach a compromise in a transparent process. The process of MCDM prioritises options against a set of criteria. This process is well-suited to address complex technical, strategic and planning challenges. The MCDM approach thus allows for technical, financial, strategic, environmental and social constraints to inform decision making at the earliest possible stages of the Project. This enhances the sustainability of the Project for its lifecycle and assists in ensuring a smoother transition through the project phases by identifying constraints early and planning for these in the design phase.

This process provides the feasibility study with a documented approach to the options selection process that can later serve as motivation for the selected options (i.e. during an ESIA). The environmental assessment process requires the assessment of one preferred route alignment to be compared against two alternatives and as well as the no-go option. The outcomes of the MCDM process allows for these alternatives to be identified through a participatory and objective process.

3.1. MCDM Workshop

Within the MCDM workshop, participants representing particular fields of expertise or interests were asked to discuss and assess the suite of options against one another, on a one to one basis, and reach consensus on which option is preferred and by what margin. This process was repeated until all options and scenarios had been compared with all other options and scenarios using each of the pre-selected criteria. The MCDM Model then arithmetically collated preference scores and provided an overall ranking of the options. The MCDM model works on the premise that an experienced professional can readily determine which options are preferred when considered against certain criteria, e.g. environmental, without the need for detailed assessment.

3.2. Criteria used in the MCDM

The potential routes were assessed against the criteria identified below. Specialist input was obtained to draw up the criteria, which are deemed to have most relevance to the selection of route alignments. While there are a number of criteria that need to be considered in the ESIA phase when assessing the significance of impacts related to the proposed developments, the only criteria that are considered in route selection are those criteria that differentiate one site against another. Where the same criteria will apply to all routes equally, these have been disregarded as being relevant to this aspect of the study.

The criteria used to assess the route alignments fall into specific categories, described below and detail in Table 5.

Technical category. This relates to the impact of a specific route alignment with regard to achieving the technical goals of the project while reducing cost and increasing ease of both construction and maintenance activities.

Environmental category. This component refers to the need to select a route that minimises the risk to ecosystem functioning and environmental integrity. Therefore, the environmental criterion prioritises the anticipated impacts on the both terrestrial and aquatic fauna (especially avifauna who are negatively impacted by high voltage transmission lines) and flora.

Social category. This aspect considers the impact of route alignment on people. Specifically avoiding residential areas, areas where assets and livelihoods may be affected (e.g. the loss of agricultural land for tower structures, the impact on tourism activities in game farm areas) and the need for compensation. Visual impacts and the impacts on heritage resources is also an important consideration in routing power lines.

Strategic category. This aspect relates to proximity to growth areas.

The criteria that were used in the MCDM are detailed in Table 5.

Table 5: MCDM Criteria

Category	Criteria	Description
Technical (Inc. Financial)	Te1. Slope	Avoid steep slopes more than 1:10
	Te2. Access	Constructability and maintainability in terms of construction and access to site
	Te3. Length	Line length and associated cost
	Te4. Width	Width of corridor allows for more than one landowner to facilitate landowner negotiations
Environmental	En1. Biodiversity	Aquatic and terrestrial ecology; Ecological services
	En3. Avifauna	Flight paths; Nesting areas, Focal points
Social	So1. Heritage	Archaeological and cultural heritage resources
	So2. Compensation	Homes or other assets that will require resettlement or other compensation
	So3. Communities	Proximity to existing large villages or towns that will remain, distance to communities, agricultural resources
	So4. Visual	Visibility on ridges, potential tourism
Strategic	St1. Proximity	Proximity to potential growth areas

The criteria were weighted to ensure that criteria considered as more important in terms of site selection were given more significance in the site selection process. The weighting is detailed below and the results presented in the report are based on this weighting. However, it is important to note that the same order of route alignment preference was achieved with all criteria having the same weighting, although the degree of preference was minimally altered.

- Technical 25.0%
- Environmental 35.0%
- Social 35.0%
- Strategic 5.0%

Total 100.0%

3.3. Mookodi substation to Watershed B substation - Results

The results of the MCDM workshop for the alignment between Watershed B and Mookodi substations are discussed below based on each category and the individual criteria used to assess the route alignment, showing how each alignment scored without comparison against the other categories.

3.3.1. Technical

Technical criteria consider the cost and ease of both construction and operation, as well as other aspects such as landowner negotiations related to the physical properties of the line, which may increase costs and length of the process involved.

All routes scored equally for slope, indicating that there was no preference based on this criteria. No visible slope issues on any of the possible line routes. They all cross agricultural land which would pose no major issues to construction.

Most routes has access via farm roads. Preference was given to route WM4a due to its proximity to major roads. WM16a (197 km). is the longest route and least preferred on this criterion, while WM13 (175 km) is weakly preferred over WM1 (185 km), WM4a (186 km) and WM9a (184 km) and there is a strong preference over WM16a. Routes WM1, 4a, 9a and 13 all scored equally in first place for the criterion of width, allowing for more landowners to be accommodated within the corridor, weakly preferred over WM16a. All routes show no issues with servitude widths and potential to shift line routes during design. Route 16a however comes within close proximity to several settlements which might restrict the corridor width.

Consolidated technical outcome

Overall, Route M4a was considered the best route for the Watershed B-Mookodi corridor from an overall technical perspective (Figure 6), followed extremely closely by WM13. Technical considerations ensure the most cost-effective solution for the lifecycle of the project for the planning stages, through construction and operation to decommissioning.

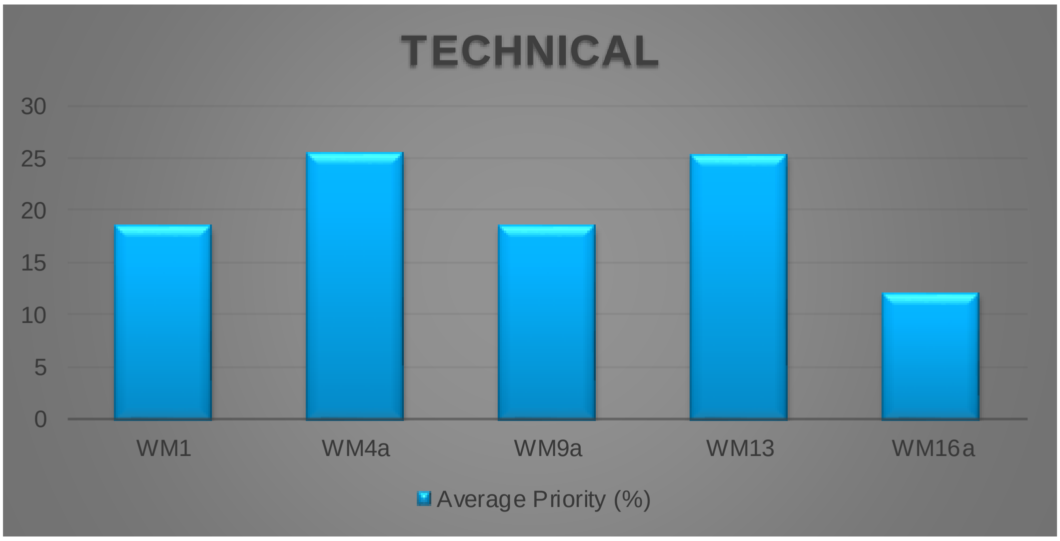


Figure 6. Mookodi to Watershed B Corridor - Preference of routes from a technical perspective

3.3.2. Environmental

Consideration of this aspect early on in the project planning ensures that constraints related to the biophysical environment are incorporated into the project at the earliest possible stage, contributing to environmentally responsible development and preventing project delays at a later stage in the project.

Ecology

Potential impacts on the biophysical environment include loss and alteration of terrestrial and aquatic habitat, loss of protected species and introduction of alien invasive plant species. The significance of the impact of a proposed transmission line is influenced by current level of disturbance along the route and the degree to which the proposed line will increase the levels of disturbance, as well as the uniqueness of the environmental resources that will be affected. Due to the nature of transmission lines, the construction phase is the most environmentally disruptive and many ecological systems can continue to function under the lines once operational. Limited area is lost through the construction of the towers and access roads. Animals will return to the site following construction. Environments with trees are most compromised by overhead lines as a corridor will need to be cleared and maintained as such to ensure sufficient clearance between the lines and trees. Most wetland areas within 2 km corridors can be avoided in the detailed design.

WM1 and WM4a both traverse similarly degraded areas of threatened ecosystem habitats wetland clusters, but WM4a avoids an additional future and a current protected area, which WM1 affects. WM9 is similar to WM1 but does not avoid a large wetland (pan) cluster. WM4a, when compared to WM9a, avoids a larger wetland (pan) cluster when compared to the wetland cluster it traverses and both traverse similarly degraded areas of threatened ecosystem habitats. WM16a as this avoids all wetland clusters and an additional proposed protected area, while traversing smaller and degraded portions of the Threatened Ecosystem habitats. However, there is a strong preference for WM13 as this avoids all wetland clusters, while traversing degraded portions of the Threatened Ecosystem habitats.

Avifauna

One of the main considerations for high voltage lines is possible bird collisions with the conductors. The collision potential is influenced by the flight behaviour of sensitive species and visibility of the conductors. Breeding areas, roosting and feeding areas and migration routes all influence where there will be high avifaunal activity and which areas will be most sensitive in terms of avifauna. The following aspects were considered when ranking the routes in order of preference:

- Proximity to vulture breeding areas
- Proximity to Important Bird Areas (IBA)
- Proximity to dams (avifaunal focal points)
- Proximity to vulture restaurants (avifaunal focal points)
- Proximity to protected areas

WM4a is preferred as it traverses degraded areas. WM13 is preferred next as it also passes over degraded habitats and avoids wetlands. All other routes are strongly preferred over WM16a due to bird sensitive areas.

Consolidated environmental outcome

The preference from both an ecological and an avifaunal impact perspective was for Route WM13 (Figure 7). Environmental considerations ensure a more environmentally sustainable solution for the lifecycle of the project for the planning stages, through construction and operation to decommissioning.

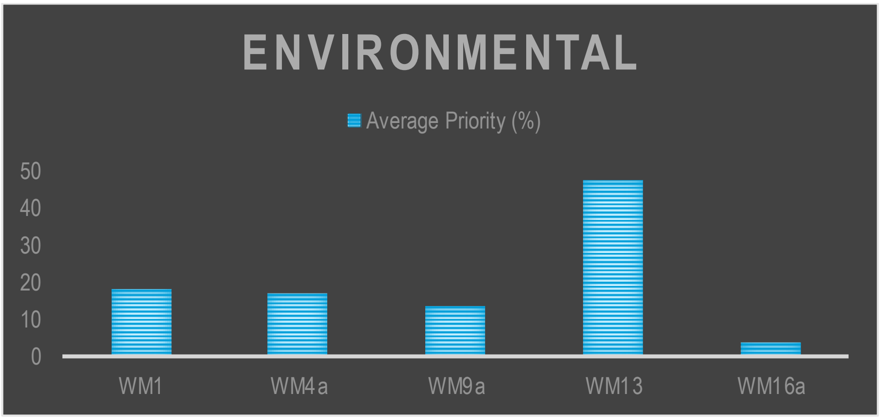


Figure 7. Watershed B-Mookodi Corridor - Preference of routes from an environmental perspective

3.3.3. Social

Consideration of this aspect early on in the project planning ensures that constraints related to the social environment incorporated into the project at the earliest possible stage, contributing to socially responsible development and preventing project delays at a later stage in the project.

Heritage

The rating of the alignments was focussed mainly on the occurrence of possible heritage sites. Due to the homogeneous natural and geographic landscape, it is difficult to attribute a geographic suitability factor to the environment that would dictate settlement patterns. The concentration of social nodes was also taken into consideration due to the possible occurrence of grave and burial sites associated with these communities which are considered heritage sites in themselves. The possible occurrence of Stone Age sites around the natural pans in the area was also considered during the evaluation phase, WM13 is the preferred route, followed by WM1 and then WS19a, while WS16a is the least preferred route.

Compensation and Communities

Both these criteria are influenced by the numbers and density of settlements and dwellings along the route, which must be avoided, as should places of interest along route. Resettlement is considered the most severe of social impacts and is to be avoided wherever possible and it is advisable to avoid physically dividing properties. The shorter the route the better.

Routes WM4a, 9a and 13 were considered to have the same preference and these were all weakly preferred over WM1 and absolutely preferred over WM116a, based on the number of towns, settlements and farm houses and placed of interest along the route, as well as cadastral boundaries, indicating density of settlement.

Visual

Transmission lines can affect the aesthetic quality of a landscape from a visual perspective. The visual impacts are influenced by the length of corridor, the topography (more visual on higher lying areas versus lower lying areas), as well as the proximity to national roads and tourism attractions. From a visual perspective, WM9a is weakly preferred over three of the routes and strongly preferred over WM9a, which is the least preferred route from a visual perspective.

Consolidated social outcome

The social considerations included the potential impacts on heritage resources, the landscape and community-related aspects. All these aspects combined to show Route WM13 **(**Figure 8Error! Reference source not found.**)** as the most preferred route for the Watershed B-Mookodi corridor**.** Social considerations ensure a more socially sustainable solution for the lifecycle of the project from the planning stages, through construction and operation to decommissioning.

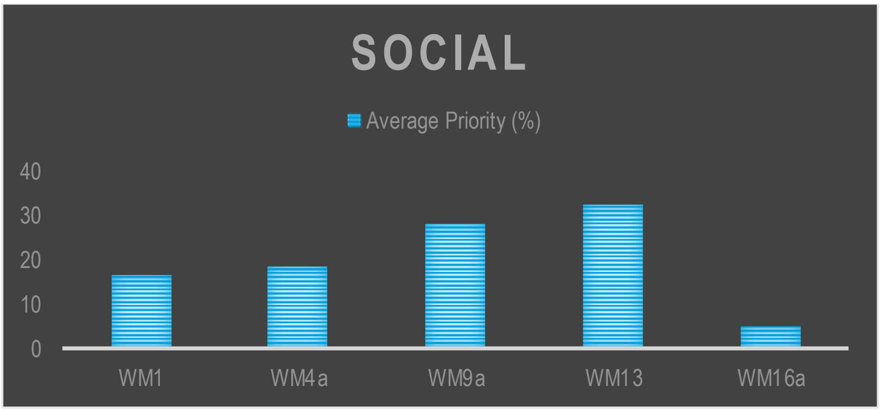


Figure 8. Watershed B-Mookodi Corridor - Preference of routes from a social perspective

3.3.4. Strategic

All line routes are equivalent as there is no major infrastructure to consider within the proximity of the lines.

This criterion considered the proximity of the line to potential growth areas in the future that would allow for potential to tap into the line in the future. All routes scored the same on this criterion (Figure 9) and this was therefore not a differentiating factor in the route selection process.

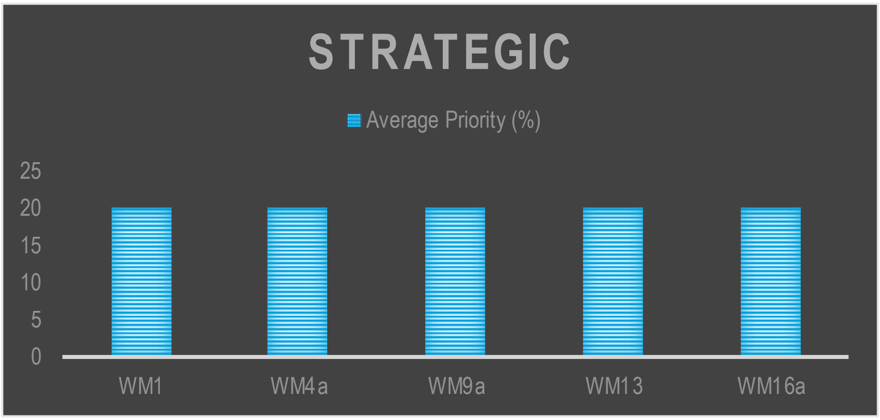


Figure 9. Watershed B-Mookodi Corridor - Preference of routes from a strategic perspective

3.3.5. Integrated outcome for route from Mookodi to Watershed B

All criteria were integrated to show the best routes overall. The integrated results of the MCDM process are shown below (Figure 10) based on the criteria used to assess the route alignment, showing how each alignment scored. The summary result finds an overall preference for Route WM13 for the Watershed-Mookodi linkage, with WM16a least preferred. The same order of route alignment preference was achieved with all criteria having the same weighting, although the degree of preference was minimally altered.

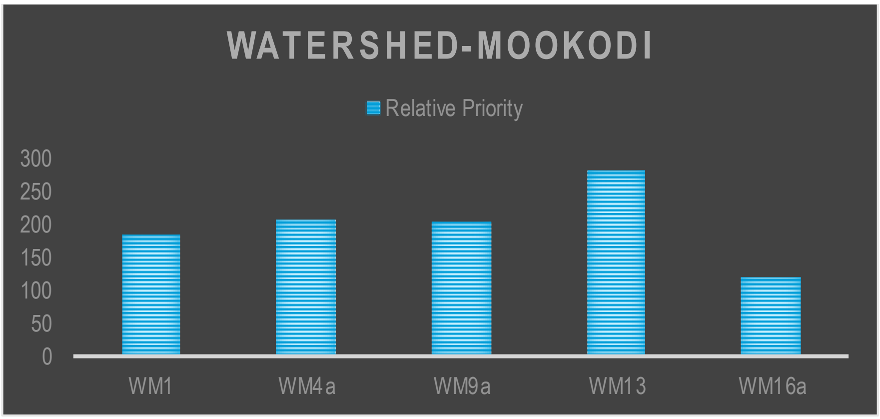


Figure 10: Watershed-Mookodi Corridor overall preference

3.4. Pluto substation to Watershed B substation - Results

The results of the MCDM workshop for each section of line are discussed below based on each category and the individual criteria used to assess the route alignment, showing how each alignment scored without comparison against the other categories. As the same factors influenced the consideration of alternatives for this corridor as for the Mookodi to Watershed B alignment, these are not discussed again in this section and only the order of preference is indicated below.

3.4.1. Technical

The entry / exit from the Pluto substation is constrained by infrastructure including pivots, while the entry / exit to Watershed B is similarly constrained, with options for alternatives in the middle section only. WP3, 13, 14 and 15 all score equally and have a marginal preference over WP12 in terms of slope. Because of proximity to a main road, WP14 is strongly preferred over WP12 and 13 and weakly preferred WP3 and WP15 in terms of access. WP14 is the shortest route and therefore preferred in terms of the criterion of length, while WP12 and 15 score second best and WP3 and 13 score worst. WP 14 is also preferred in terms of the criterion of width, weakly preferred to WP15 and 3, and strongly preferred to WP 13 and 12.

Route WP14 is the preferred route for the Pluto to Watershed B corridor (Figure 11) from a consolidated technical perspective.

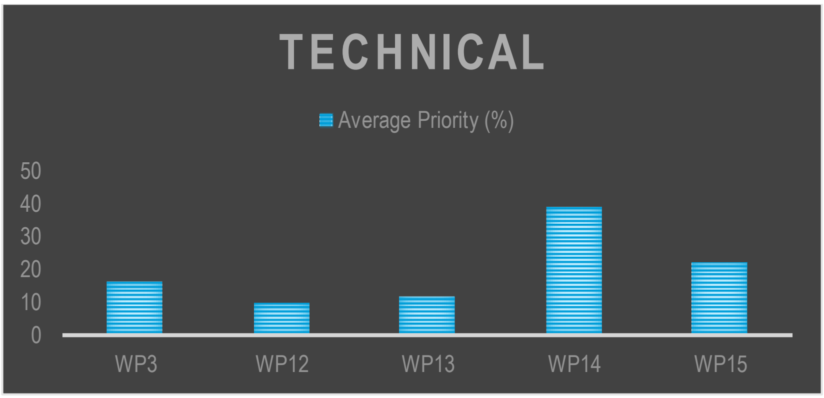


Figure 11. Watershed B-Pluto Corridor - Preference of routes from a technical perspective

3.4.2. Environmental

Route WP3 is weakly preferred over WP12 from an ecological perspective and strongly preferred over WP13, 14 and 15. WP3 traverses fewer pans / pan complexes and threatened ecosystem types, crossing degraded vegetation types and avoiding a higher number of formal and informal protected areas.

From an avifaunal perspective, WP3 is strongly preferred over WP12 and weakly preferred over WP12, 14 and 15. While WP12 traverses a protected area, it does run alongside an existing powerline. From an avifaunal perspective, it is better to place a new line along an existing line to consolidate one impact rather than create a new one elsewhere.

The preference from both a biodiversity and an avifaunal impact perspective was for Route WP3 (Figure 12.

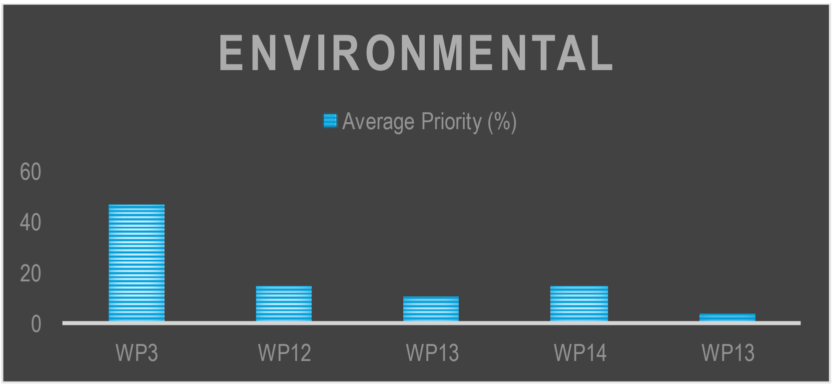


Figure 12. Watershed B-Pluto Corridor - Preference of routes from an environmental perspective

3.4.3. Social

Heritage

The choice of corridors in this situation is based on the analysis of likely heritage site occurrences, known occurrences and geographic suitability of areas for hosting heritage sites. The area to the north close to line PW12 shows the most variation in topography and hydrology. This creates a diverse landscape creating more opportunities for different settlement types. The elevated areas are also likely areas for rock art occurrences. The lines to the south are evaluated according to their traversing of natural pans, which in these areas are the major geographical feature to stimulate occupation and in the case of Stone Age sites, manufacturing. Line PW 3 seems to traverse the most homogeneous landscape and have the least impact on natural pans. This route seems to have the least impact on heritage resources. Routes PW14 and 15 have a very similar alignment and their impacts seems to be similar.

Compensation and proximity to communities

The line must be as short as possible and avoid settlements, places of interest, large commercial farmers and shared resources (dams etc.). The routes must preferably run with existing lines and roads. Routes WP14 is absolutely preferred over WP3 and 15 and strongly over WP13 and weakly over WP12.

Visual

WP12 is most preferred as it is the most remote and will possibly have the least amount of receptors. The ridges, located towards the north of the alignment form a backdrop which provides greater absorption capacity. Routes 13, 3 and 14 are then scored in that order of preference. WP15 is least preferred as it traverse close to the town of Lichtenburg and various nature reserves. It also runs parallel to the N14 for some distance.

Consolidated social outcome

Route WP14 was the most preferred route for the Pluto to Watershed B corridor (Figure 13).

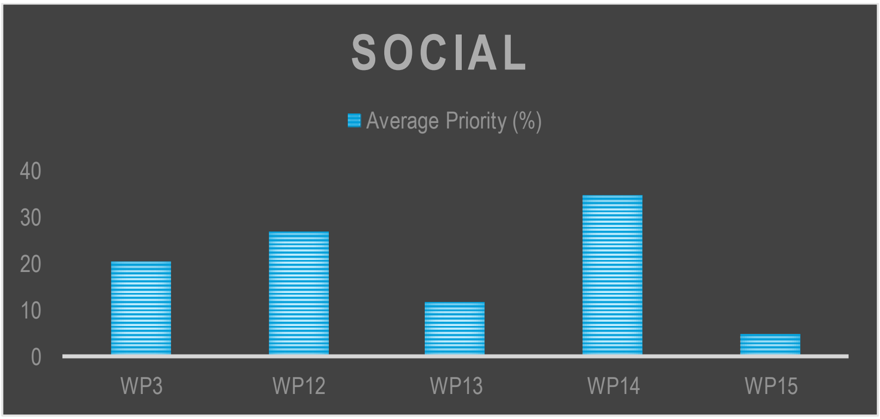


Figure 13. Watershed B-Pluto Corridor - Preference of routes from a social perspective

3.4.4. Strategic

Route WP3 and WP15 had equal preference for this criterion while WP13 was the least preferred route (Figure 14).

Figure 14. Watershed B-Pluto Corridor - Preference of routes from a strategic perspective

3.3.6. Integrated outcome for route from Pluto to Watershed B

The summary result finds an overall preference for Route PW14 for the route from Pluto to Watershed B, with WM13 least preferred (Figure 15). The same order of route alignment preference was achieved with all criteria having the same weighting, although the degree of preference was minimally altered.

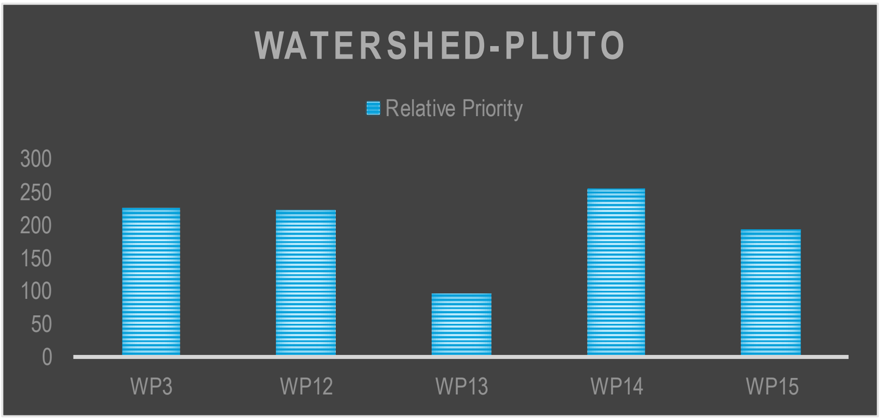
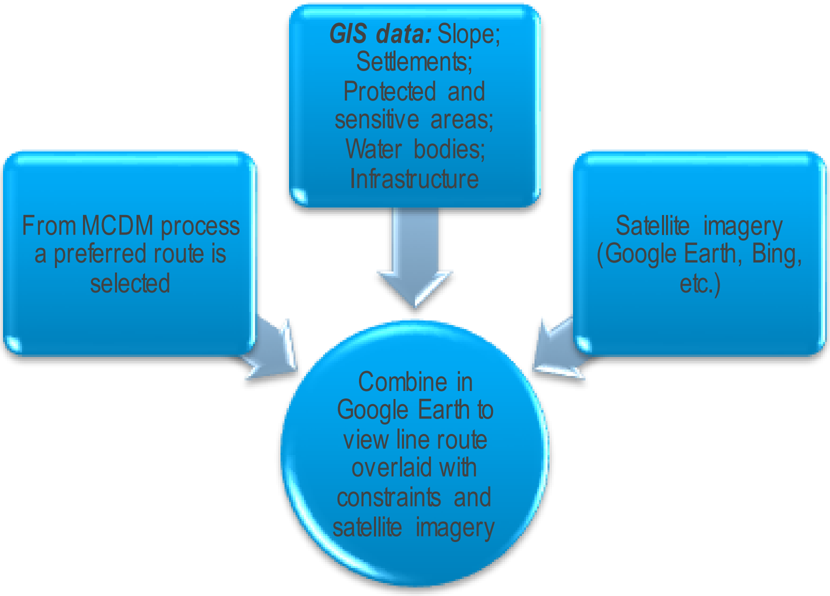


Figure 15. Watershed B-Pluto Corridor overall preference

4. ROUTE OPTIMISATION

Once the preferred route was selected, it was interrogated in more detail to mitigate the environmental, social and technical issues along the selected route as finer details of the terrain and constraints may have been overlooked in the previous route selection process. Any details that were missing in the GIS data were confirmed with an in-depth inspection of the satellite imagery. This allowed for minimisation of impacts on environment and people by moving the line route within the agreed buffer zone and also allowed for technical challenges to be accommodated cost-effectively. This informed the precise route for ESIA, land negotiations and preliminary design and allowed for a route to be approved for the LiDAR survey.

The process followed is indicated as follows:



A new line was thus created, based on the preferred line chosen in the MCDM process. A visual inspection of the line from end to end was done, using Google Earth and looking for points of concern. Where area of concerns were identified, the line was shifted to avoid them. However, each time a bend point was shifted or a new bend point created, the section before and after that point was again interrogated to ensure that there were no issues in the new line location. The width of the line corridor was also considered during optimisation, although actual tower positions were not considered.

Optimisation considered the following aspects:

- Places where the line crosses over settlements, homesteads or other buildings.
- Environmentally and socially sensitive areas.
- Road, river and rail crossings – these should be as close to perpendicular as possible, and bend points should be located away from the crossings.
- Farming infrastructure – farm fences, centre pivots, buildings, etc.
- Mining sites

The optimised route was then re-assessed to confirm that it was still the preferred route, in terms of line length and number of bend-points.

5. CONCLUSION AND WAY FORWARD

The early application of MCDM as part of engineering project development provides an effective tool for environmental planning at the project alternative level. It allows for assessment of alternatives required in terms of the ESIA process to commence at the earliest stages of the project, where it can add value and help to prevent challenges later in the process. It also addresses one of the key weaknesses of conventional alternatives assessment in ESIA, being the structured and defendable rating or scoring of alternatives to determine a preference ranking. The mathematically based, transparent and logical system of comparison is undertaken in a reproducible methodology which ensures that the project team can demonstrate the basis of their recommendation or decision. Applied in an interactive workshop environment and ensuring the appropriate participation of decision makers, engineers and environmental and social practitioners, it ensures that project outcomes are widely acceptable and supported.

The information contained herein will contribute to the “consideration of alternatives” aspects of such a study as well as providing background information to the public and authorities on the screening of options, in the future as required.

Based on the above outcome it is recommended that Route WM13 and PW14 be taken forward as the preferred alternative for more detailed assessment to link Mookodi to the proposed Watershed B substation and Pluto to the proposed Watershed B substation respectively. The preferred routes will need to be assessed in detail in an ESIA to allow for identification of potential mitigation measures to further reduce predicted impacts from the project.

6. APPENDIX 1

Attendance registers at workshops on 31 January and 24 April 2017.

AURECON	aurecon

ATTENDANCE REGISTER

Project No:	Project description: BOSA TRANSMISSION CORRIDOR		
Meeting No:	Venue: @PTA-Room-S12-GR1-Dining; @PTA-Room-S12-GR2-Dining	Date: 3 APRIL 2017	Time: 10H00 – 16H00

PRESENT

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17	Angela White	Aurecon	0127044180	angela.white@aurecongroup.com	
18	Jessica Allen	Aurecon	0828255202	jessica.allen@aurecongroup.com	
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AURECON aurecon

ATTENDANCE REGISTER

Project No:	**Project description:** BOSA TRANSMISSION CORRIDOR		
Meeting No:	**Venue:** @PTA-Room-S12-GR1-Dining; @PTA-Room-S12-GR2-Dining	**Date:** 4 APRIL 2017	**Time:** 08H00 – 16H00

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AURECON	aurecon

ATTENDANCE REGISTER

Project No:	Project description: BOSA TRANSMISSION CORRIDOR		
Meeting No:	Venue: @PTA-Room-S12-GR1-Dining; @PTA-Room-S12-GR2-Dining	Date: 5 APRIL 2017	Time: 08H00 – 16H00

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ATTENDANCE REGISTER				
Project No:	Project description: BOSA TRANSMISSION CORRIDOR			
Meeting No:	Venue: @PTA-Room-S12-GR1-Dining; @PTA-Room-S12-GR2-Dining		Date: 6 APRIL 2017	Time: 08H00 – 16H00

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	Mokwaledi Keipeile	BPC	+267 3603504	keipeilem@bpc.bw	
	Makhosi Yeni	DEA	0760704920	myeni@environment.gov.za	
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	Diane Erasmus	Aurecon	0833086750	diane.erasmus@aurecongroup.com	
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	SEBENZILE VILAKAZI	ESKOM	0828858114	VILAKAZS@ESKOM.CO.ZA	
	CHRISTO BADENHORST	Eskom	0823376587	BADENHC@ESKOM.CO.ZA	

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7. APPENDIX 2

MCDM Tables

MOOKODI to WATERSHED B

TECHNICAL

WATERSHED MOOKODI CORRIDOR

aurecon

SLOPE	WM1	WM4a	WM9a	WM13	WM16a
WM1		1	1	1	1
WM4a			1	1	1
WM9a				1	1
WM13					1
WM16a					

WATERSHED MOOKODI CORRIDOR

aurecon

Access	WM1	WM4a	WM9a	WM13	WM16a
WM1		1/3	1	1	1
WM4a			3	3	3
WM9a				1	1
WM13					1
WM16a					

WATERSHED MOOKODI CORRIDOR

aurecon

LENGTH	WM1	WM4a	WM9a	WM13	WM16a
WM1		1	1	1/3	3
WM4a			1	1/3	3
WM9a				1/3	3
WM13					5
WM16a					

WATERSHED MOOKODI CORRIDOR

aurecon

WIDTH	WM1	WM4a	WM9a	WM13	WM16a
WM1		1	1	1	3
WM4a			1	1	3
WM9a				1	3
WM13					3
WM16a					

WATERSHED MOOKODI CORRIDOR

Technical (including Financial)	WM1	WM4a	WM9a	WM13	WM16a
Te1. Slope	0.200	0.200	0.200	0.200	0.200
Te2. Access	0.143	0.429	0.143	0.143	0.143
Te3. Length	0.166	0.166	0.166	0.441	0.062
Te4. Width	0.231	0.231	0.231	0.231	0.077
Average Priority	18.48%	25.62%	18.48%	25.38%	12.05%

ENVIRONMENTAL

WATERSHED MOOKODI CORRIDOR

En1. Biodiversity	WM1	WM4a	WM9a	WM13	WM16a	PRIORITY
WM1	1	3	5	1/3	6	0.264
WM4a	1/3	1	3	1/6	5	0.129
WM9a	1/5	1/3	1	1/6	3	0.068
WM13	3	6	6	1	7	0.503
WM16a	1/6	1/5	1/3	1/7	1	0.037

Emax	5.35
CI	0.09
CR	7.90%

WATERSHED MOOKODI CORRIDOR

En2. Avifauna	WM1	WM4a	WM9a	WM13	WM16a	PRIORITY
WM1	1	1/3	1/3	1/5	5	0.097
WM4a	3	1	1	1/3	5	0.208
WM9a	3	1	1	1/3	5	0.208
WM13	5	3	3	1	5	0.445
WM16a	1/5	1/5	1/5	1/5	1	0.042

Emax	5.28
CI	0.07
CR	6.26%

WATERSHED MOOKODI CORRIDOR

Environmental	WM1	WM4a	WM9a	WM13	WM16a
En1. Biodiversity	0.264	0.129	0.068	0.503	0.037
En2. Avifauna	0.097	0.208	0.208	0.445	0.042
Average Priority	18.05%	16.84%	13.78%	47.41%	3.92%

SOCIAL

WATERSHED MOOKODI CORRIDOR

aurecon

So1. Heritage	WM1	WM4a	WM9a	WM13	WM16a	PRIORITY
WM1	1	5	3	1/3	7	0.264
WM4a	1/5	1	1/3	1/7	3	0.064
WM9a	1/3	3	1	1/5	5	0.130
WM13	3	7	5	1	9	0.510
WM16a	1/7	1/3	1/5	1/9	1	0.033

Emax	5.24
CI	0.06
CR	5.42%

WATERSHED MOOKODI CORRIDOR

aurecon

So2. Compensation	WM1	WM4a	WM9a	WM13	WM16a	PRIORITY
WM1	1	1/3	1/3	1/3	3	0.106
WM4a	3	1	1	1	5	0.281
WM9a	3	1	1	1	5	0.281
WM13	3	1	1	1	5	0.281
WM16a	1/3	1/5	1/5	1/5	1	0.050

Emax	5.03
CI	0.01
CR	0.56%

WATERSHED MOOKODI CORRIDOR

aurecon

So3. Communities	WM1	WM4a	WM9a	WM13	WM16a	PRIORITY
WM1	1	1/3	1/3	1/3	3	0.106
WM4a	3	1	1	1	5	0.281
WM9a	3	1	1	1	5	0.281
WM13	3	1	1	1	5	0.281
WM16a	1/3	1/5	1/5	1/5	1	0.050

Emax	5.03
CI	0.01
CR	0.56%

WATERSHED MOOKODI CORRIDOR

So4. Visual	WM1	WM4a	WM9a	WM13	WM16a	PRIORITY
WM1	1	3	1/3	1/2	4	0.186
WM4a	1/3	1	1/3	1/2	3	0.113
WM9a	3	3	1	3	5	0.431
WM13	2	2	1/3	1	3	0.213
WM16a	1/4	1/3	1/5	1/3	1	0.057

Emax	5.28
CI	0.07
CR	6.18%

WATERSHED MOOKODI CORRIDOR

Social	WM1	WM4a	WM9a	WM13	WM16a
So1. Heritage	0.264	0.064	0.130	0.510	0.033
So2. Compensation	0.106	0.281	0.281	0.281	0.050
So3. Communities	0.106	0.281	0.281	0.281	0.050
So4. Visual	0.186	0.113	0.431	0.213	0.057
Average Priority	16.51%	18.49%	28.09%	32.16%	4.76%

STRATEGIC

WATERSHED MOOKODI CORRIDOR

Strategic	WM1	WM4a	WM9a	WM13	WM16a
St1. Proximity	0.200	0.200	0.200	0.200	0.200
Average Priority	20.00%	20.00%	20.00%	20.00%	20.00%

WATERSHED MOOKODI CORRIDOR

St1. Proximity	WM1	WM4a	WM9a	WM13	WM16a	PRIORITY
WM1	1	1	1	1	1	0.200
WM4a	1	1	1	1	1	0.200
WM9a	1	1	1	1	1	0.200
WM13	1	1	1	1	1	0.200
WM16a	1	1	1	1	1	0.200

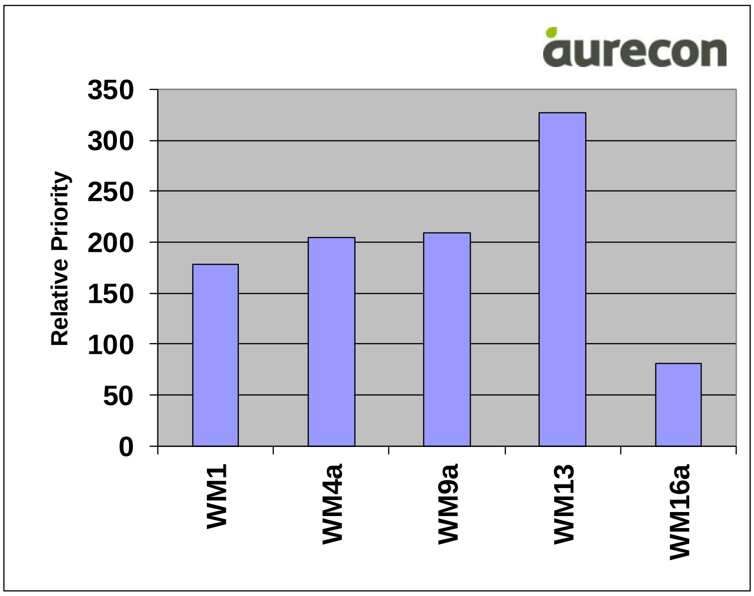
Emax	5.00
CI	0.00
CR	0.00%

INTEGRATED OUTCOME

WATERSHED MOOKODI CORRIDOR

RANKING RESULTS ORIGINAL AHP	Technical (including Financial)	Environmental	Social	Strategic	PRIORITY
RELATIVE WEIGHT	25.0%	35.0%	35.0%	5.0%	100.0%
WM1	0.185	0.180	0.165	0.200	0.177
WM4a	0.256	0.168	0.185	0.200	0.198
WM9a	0.185	0.138	0.281	0.200	0.203
WM13	0.254	0.474	0.322	0.200	0.352
WM16a	0.120	0.039	0.048	0.200	0.070

RANKING RESULTS IDEAL MODE AHP	Technical (including Financial)	Environmental	Social	Strategic	FINAL PRIORITY	NORMALISED
RELATIVE WEIGHT	25.0%	35.0%	35.0%	5.0%	100.0%	100.0%
WM1	0.72	0.38	0.51	1.00	0.543	178
WM4a	1.00	0.36	0.57	1.00	0.626	205
WM9a	0.72	0.29	0.87	1.00	0.638	209
WM13	0.99	1.00	1.00	1.00	0.998	327
WM16a	0.47	0.08	0.15	1.00	0.248	81
					3.052	1000



PLUTO to WATERSHED B

TECHNICAL

WATERSHED PLUTO CORRIDOR

Te1. Slope	WP3	WP12	WP13	WP14	WP15	PRIORITY
WP3	1	3	1	1	1	0.231
WP12	1/3	1	1/3	1/3	1/3	0.077
WP13	1	3	1	1	1	0.231
WP14	1	3	1	1	1	0.231
WP15	1	3	1	1	1	0.231

Emax	5.00
CI	0.00
CR	0.00%

WATERSHED PLUTO CORRIDOR

Te2. Access	WP3	WP12	WP13	WP14	WP15	PRIORITY
WP3	1	3	3	1/3	1	0.195
WP12	1/3	1	1	1/5	1/3	0.073
WP13	1/3	1	1	1/5	1/3	0.073
WP14	3	5	5	1	3	0.463
WP15	1	3	3	1/3	1	0.195

Emax	5.07
CI	0.02
CR	1.64%

WATERSHED PLUTO CORRIDOR

Te3. Length	WP3	WP12	WP13	WP14	WP15	PRIORITY
WP3	1	1/3	1	1/5	1/3	0.073
WP12	3	1	3	1/3	1	0.195
WP13	1	1/3	1	1/5	1/3	0.073
WP14	5	3	5	1	3	0.463
WP15	3	1	3	1/3	1	0.195

Emax	5.07
CI	0.02
CR	1.64%

WATERSHED PLUTO CORRIDOR

Te4. Width	WP3	WP12	WP13	WP14	WP15	PRIORITY
WP3	1	3	2	1/3	1/2	0.160
WP12	1/3	1	1/2	1/5	1/4	0.062
WP13	1/2	2	1	1/4	1/3	0.097
WP14	3	5	4	1	2	0.417
WP15	2	4	3	1/2	1	0.263

Emax	5.07
CI	0.02
CR	1.55%

WATERSHED PLUTO CORRIDOR

Technical (including Financial)	WP3	WP12	WP13	WP14	WP15
Te1. Slope	0.231	0.077	0.231	0.231	0.231
Te2. Access	0.195	0.073	0.073	0.463	0.195
Te3. Length	0.073	0.195	0.073	0.463	0.195
Te4. Width	0.160	0.062	0.097	0.417	0.263
Average Priority	16.49%	10.17%	11.87%	39.36%	22.12%

ENVIRONMENTAL

WATERSHED PLUTO CORRIDOR

aurecon

En1. Biodiversity	WP3	WP12	WP13	WP14	WP15	PRIORITY
WP3	1	3	5	5	5	0.498
WP12	1/3	1	3	3	3	0.236
WP13	1/5	1/3	1	1	1	0.089
WP14	1/5	1/3	1	1	1	0.089
WP15	1/5	1/3	1	1	1	0.089

Emax	5.07
CI	0.02
CR	1.49%

WATERSHED PLUTO CORRIDOR

aurecon

En2. Avifauna	WP3	WP12	WP13	WP14	WP15	PRIORITY
WP3	1	5	3	3	3	0.429
WP12	1/5	1	1/5	1/3	1/3	0.055
WP13	1/3	5	1	1/3	1/3	0.115
WP14	1/3	3	3	1	1	0.201
WP15	1/3	3	3	1	1	0.201

Emax	5.32
CI	0.08
CR	7.07%

WATERSHED PLUTO CORRIDOR

aurecon

Environmental	WP3	WP12	WP13	WP14	WP15
En1. Biodiversity	0.498	0.236	0.089	0.089	0.089
En2. Avifauna	0.429	0.055	0.115	0.201	0.201
Average Priority	46.38%	14.54%	10.17%	14.46%	14.46%

SOCIAL

WATERSHED PLUTO CORRIDOR

aurecon

So1. Heritage	WP3	WP12	WP13	WP14	WP15	PRIORITY
WP3	1	7	5	3	3	0.466
WP12	1/7	1	1/5	1/5	1/3	0.042
WP13	1/5	5	1	1/3	1/2	0.103
WP14	1/3	5	3	1	3	0.253
WP15	1/3	3	2	1/3	1	0.136

Emax	5.27
CI	0.07
CR	6.05%

WATERSHED PLUTO CORRIDOR

So2. Compensation	WP3	WP12	WP13	WP14	WP15	PRIORITY
WP3	1	1/5	3	1/7	3	0.101
WP12	5	1	3	1/3	5	0.253
WP13	1/3	1/3	1	1/5	5	0.086
WP14	7	3	5	1	9	0.524
WP15	1/3	1/5	1/5	1/9	1	0.036

Emax	5.40
CI	0.10
CR	8.85%

WATERSHED PLUTO CORRIDOR

So3. Communities	WP3	WP12	WP13	WP14	WP15	PRIORITY
WP3	1	1/5	3	1/7	3	0.101
WP12	5	1	3	1/3	5	0.253
WP13	1/3	1/3	1	1/5	5	0.086
WP14	7	3	5	1	9	0.524
WP15	1/3	1/5	1/5	1/9	1	0.036

Emax	5.40
CI	0.10
CR	8.85%

WATERSHED PLUTO CORRIDOR

So4. Visual	WP3	WP12	WP13	WP14	WP15	PRIORITY
WP3	1	1/5	1/2	3	5	0.149
WP12	5	1	5	5	7	0.534
WP13	2	1/5	1	3	5	0.197
WP14	1/3	1/5	1/3	1	3	0.080
WP15	1/5	1/7	1/5	1/3	1	0.039

Emax	5.41
CI	0.10
CR	9.09%

WATERSHED PLUTO CORRIDOR

Social	WP3	WP12	WP13	WP14	WP15
So1. Heritage	0.466	0.042	0.103	0.253	0.136
So2. Compensation	0.101	0.253	0.086	0.524	0.036
So3. Communities	0.101	0.253	0.086	0.524	0.036
So4. Visual	0.149	0.534	0.197	0.080	0.039
Average Priority	20.45%	27.06%	11.79%	34.51%	6.19%

STRATEGIC

WATERSHED PLUTO CORRIDOR

St1. Proximity	WP3	WP12	WP13	WP14	WP15	PRIORITY
WP3	1	1/3	3	1	1/3	0.129
WP12	3	1	5	3	1	0.344
WP13	1/3	1/5	1	1/3	1/5	0.054
WP14	1	1/3	3	1	1/3	0.129
WP15	3	1	5	3	1	0.344

Emax	5.04
CI	0.01
CR	1.00%

WATERSHED PLUTO CORRIDOR

Strategic	WP3	WP12	WP13	WP14	WP15
St1. Proximity	0.129	0.344	0.054	0.129	0.344
Average Priority	12.89%	34.39%	5.44%	12.89%	34.39%

INTEGRATED OUTCOME

WATERSHED PLUTO CORRIDOR

RANKING RESULTS ORIGINAL AHP	Technical (including Financial)	Environmental	Social	Strategic	PRIORITY
RELATIVE WEIGHT	25.0%	35.0%	35.0%	5.0%	100.0%
WP3	0.165	0.464	0.204	0.129	0.282
WP12	0.102	0.145	0.271	0.344	0.188
WP13	0.119	0.102	0.118	0.054	0.109
WP14	0.394	0.145	0.345	0.129	0.276
WP15	0.221	0.145	0.062	0.344	0.145

RANKING RESULTS IDEAL MODE AHP	Technical (including Financial)	Environmental	Social	Strategic	FINAL PRIORITY	NORMALISED
RELATIVE WEIGHT	25.0%	35.0%	35.0%	5.0%	100.0%	100.0%
WP3	0.42	1.00	0.59	0.37	0.681	267
WP12	0.26	0.31	0.78	1.00	0.499	196
WP13	0.30	0.22	0.34	0.16	0.280	110
WP14	1.00	0.31	1.00	0.37	0.728	286
WP15	0.56	0.31	0.18	1.00	0.362	142
					2.549	1000