Peer review of the West Angelas Deposit C and D Groundwater Dependent Vegetation Assessment (Rio Tinto 2017)

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This peer review of the GDE assessment report prepared by Rio Tinto addresses whether the approach utilised in the West Angelas Deposit C and D Groundwater Dependent Vegetation Assessment (Rio Tinto 2017) is appropriate to:

1. Determine the presence of any potential groundwater dependent species and groundwater dependent vegetation likely to represent a potential groundwater dependent ecosystem (GDE),
2. Attribute significance to any potential GDE identified, and
3. Understand the degree of sensitivity that any identified potential GDE may have to potential surface water (hydrological) and groundwater (hydrogeological) changes?"

Review of the Document and Underlying Assumptions

The Rio Tinto 2017 (RT2017) report outlines the results of an assessment of the presence, significance and sensitivity of any potential GDEs (as indicated by the presence of groundwater-dependent vegetation, or GDV), in the vicinity of the proposed dewatering, particularly local riparian systems occurring in Karijini National Park. The report also aimed to expand upon traditional methods to enable a more accurate and measured risk assessment of the potential for impact on GDE's. The author aimed to achieve this by a) conducting a riparian vegetation mapping exercise and detailed assessment of plant species present within the study area, and b) Systematic sampling of riparian basal area, as a proxy for water demands of potentially GDV.

The fundamental approach taken is underpinned by an established understanding of the relationship between water availability and productivity. However, there are several misinterpretations of some fundamental concepts surrounding groundwater-dependent ecosystems, obligate vs facultative phreatophytes and sensitivity to change, that detract from the overall findings of the report. I do acknowledge however, that the approach represented in the RT2017 report was driven by a paucity of comprehensive datasets on measured water availability, a limitation common to many Pilbara assessments of this type.

Species Habitat Associations and Groundwater Dependency

Whilst there are many studies drawn from to substantiate a link between common riparian species and shallow, accessible groundwater in the Pilbara, very few of these studies actually demonstrate the spatial and temporal variability in plant use of groundwater and the relative importance of this water source in maintaining plant assemblages over the long-term. Most of what is known about 'groundwater dependent vegetation' in the Pilbara is through many assessments of species habitat associations and development of indicator species of likely plant-water source 'dependency'. The RT2017 study does give some of the background to these assumed plant-water source relationships but there is a level of certainty expressed that I believe is not justified. There should be a clear and concise summary of the specific information known and not known about the groundwater use of the key species in the study. There is a predilection in GDE studies to assume that plant species observed to be associated with shallow groundwater in a subset of the species habitat range, are good indicators of groundwater-dependent ecosystems. The limitations of this approach, although somewhat justified given the limited data available, should be transparent and uncertainties clearly presented.

Uncertainty in Hydrological Modelling?

There is reference to modelling of the proposed drawdown footprint as well as current groundwater levels, aquifers and direction of subsurface flow, however there are no hydrological modelling methods and assumptions presented. I assume there is also an expert review of the groundwater modelling used to determine the footprint of groundwater drawdown and projected scenarios. The uncertainty surrounding the hydrological modelling is not mentioned but should be integral to discussion on likelihood of environmental impact.

Is Vegetation Alone a valid Measure of Ecosystem Value and Function?

Whilst I acknowledge that the RT2017 report has as its focus the groundwater dependency of vegetation, there are other components of the valued ecosystem that may be groundwater dependent (possibly more so). I assume this has already been considered and that the focus of the report was deliberately confined to identifying groundwater-dependent vegetation only.

Facultative and Obligate Phreatophytes

Most so-called GDE's are labelled as such just on the basis of having a plant species or two present that have a known association with shallow water tables/groundwater. Their degree of dependency is often not determined or, at best, inferred from intensive work done in other systems or bioregions. In most cases these chosen 'indicator' species turn out to be facultative phreatophytes, i.e. plant species that may use groundwater if available but otherwise are not restricted to these habitats. Therefore the presence of a known facultative phreatophyte, does not alone define an ecosystem as groundwater dependent. Other corroborating evidence, such as groundwater proximity, variability, quality, is required.

There should be caution in associating obligate phreatophytes with surface expressions of groundwater only, as this has led to confusion between wetland-plants and true phreatophytes. The author of the RT2017 report lists (Table 2.2) many short-lived wetland plant species as perennial moisture indicators of relevance to Pilbara GDE's. These species can be associated with surface expressions of water that have little to do with groundwater discharge or indicating GDE's. Exceptions are the larger woody riparian species that must tolerate long dry periods of no surface flow, and do so by exploiting deeper soil water stores and saturated layers for extended periods of time.

I believe the author's definition of facultative phreatophytes is not clearly defined. If an individual facultative plant grows to maturity under very mesic conditions with consistent groundwater access, they will undergo significant water deficit stress and possible mortality in the event of rapid drawdown and separation from groundwater sources. That is, plants of a facultative species can be just as susceptible to hydrological change as obligates, due to the past conditions under which they have developed (the species is facultative, not individual plants). As a species, they may persist in a drier habitat via seedling establishment and development according to the new state of water availability. An obligate phreatophyte on the other hand will not. The flip-side to this is that there can be stands of a known facultative phreatophytic species that are not dependent on groundwater.

Table 2.1 classifies a number of key Pilbara riparian species as low-high groundwater dependency and whether they are obligate or facultative in their use of groundwater. Such a table should also cite the evidence used to define species dependence (e.g. refer to publications that demonstrate the nature of their groundwater use, or highlight inferences and uncertainty), as this table is likely to be used in isolation from statements on the underlying limitations. There are also issues with the stated groundwater dependence (high to low), as the scale of dependence is not explained and gives the reader the impression that facultative phreatophytes cannot be highly dependent on groundwater as a source (see above). Furthermore, the water use strategy column mixes terminology used to describe sources of water used and tolerance of water deficit stress. A vadophyte sources all water from the unsaturated soil profile (vadose zone) and therefore doesn't use any groundwater, whereas a phreatophyte uses water from both the vadose zone and phreatic (groundwater and capillary fringe) zone, hence the name. Therefore, vadophytes cannot be classed as having low-moderate GW dependency. The term xerophyte however, refers to plants with significant adaptations to tolerate water-deficit stress, and does not exclude phreatophytes.

The proposed labels, obligate phreatophytic vegetation (OPV) and facultative phreatophytic vegetation (FPV), extend the incorrect use of definitions in the RT2017 report. Vegetation includes all plant species in an area/ecosystem/habitat, and whilst some species may be phreatophytic, many are not. Furthermore, the terms obligate and facultative phreatophytes applies to species and not assemblages of plants that vary in the way they source water. Therefore, it is incorrect to refer to vegetation (particularly mapping units) as obligate/facultative phreatophytes.

Water Availability, Basal Area and Groundwater Dependency

Whilst there is an established understanding that increased productivity and standing biomass is a response to greater water availability, one needs to be cautious regarding the relative role of groundwater in maintaining this relationship. Water availability (quantity and consistency) is defined as all sources of water available to the species/vegetation in question. The data required to differentiate groundwater as the key hydrological driver of biomass patterns, includes: groundwater proximity to surface, seasonal/inter-annual variability in water source availability relative to plant life history, soil water retention characteristics over the rooting depth of species considered, surface flow spatial and temporal patterns. The RT2017 study provides limited data (some hydrographs from a limited number of bores, and modelled drawdown) and therefore there is uncertainty in the relative importance of groundwater in driving vegetation structure and composition as measured in the RT2017 report. This uncertainty needs to be evident in the risk assessment used. Without evidence to the contrary, density and structure of the vegetation is a response to the antecedent hydrological conditions (not groundwater alone), and this response changes in equilibrium with hydrological conditions.

As an extension to this relationship between biomass and water availability, it is well documented that the structure and composition of plant biomass also reflects water availability. Plant species vary in their growth form, modes of reproduction and physiology, and environmental filters such as water availability, contribute towards determining the composition and structure of vegetation in a given habitat at a point in time. Since plants are sessile, and many species are long-lived (particularly large woody riparian species) and slow to reach reproductive age, measurable change in structure and composition develops over the long-term (months to decades). The rate and nature of change is modified by disturbance events like prolonged flooding, high-energy flows or fire. Plant composition, structure and standing biomass (like basal area) are therefore a manifestation of plant responses to antecedent conditions extending over decades or more, prior to the time of measurement. If short-term indications of plant response to changes in water availability are required, then physiological measures of water-deficit stress and recovery are required. Furthermore, if determination of whether a GDE exists or not is required (i.e. not potential GDE), then spatial and temporal data are needed on the actual water sources that define the habitat/s in question.

The Stromberg 1993 study used to determine GDV 'thresholds' on the basis of standing biomass (basal area per hectare), is based on a riparian facultative phreatophyte in Arizona USA with different growth metrics (often multi-stemmed below DBH height of 1.3m, RT2017 only measured tree basal area of single stemmed trees) to the Pilbara eucalypts species that dominate the study area. This may result in critical differences in the range of basal areas associated with groundwater use and therefore lead to inaccurate classes of dependence. Furthermore, Stromberg related structural characteristics (basal area included but also leaf area) of *Prosopis* to water table depth via a measure of plant water status, i.e. plant water potential. The plant water potential measures are an important step to validate water availability to the plant, which in turn can be related to water availability (measured in the Stromberg study) and depth to water table (although the Stromberg 1993 study did not validate assumptions of groundwater dependence via natural abundance water isotope studies). The RT2017 study does not measure depth to water table nor the plant water potential, and this relationship is known to be variable between species. Hence, using the Stromberg linear models to predict the groundwater-dependent 'threshold' in a different species is problematic. I would recommend caution in the use of this approach to define groundwater dependence without a baseline Pilbara study to validate the method, and quantify variation in plant basal area relative to actual measures of plant water status, water source use and relative importance of groundwater. The RT2017 report makes assumptions about 'significant' groundwater use based on the Stromberg data on biomass – water availability gradient. This qualitative approach, without site specific assessment, can't make accurate determinations of the relative importance of groundwater as a plant water source, nor the sensitivity to hydrological change. It can, however, define vegetation characteristics (structure and composition) and their relationship with inferred water availability.

Vegetation Sensitivity to Groundwater Drawdown

Maximum rooting depth of a species is not the same as the maximum depth threshold at which groundwater is no longer considered a significant contribution to plant water requirements. The later refers to the max depth at which groundwater is a relatively significant plant water source. Lowering of shallow vs deep having more or less impact is debateable.

The magnitudes of tolerable change referred to on page 12 of the RT2017 report are very general. Determination of the magnitude of tolerable (current cohort of plants) change should consider the antecedent hydrological conditions, rate of change, species in questions and soil type. A rapid drawdown of less than 2 metres during periods of extreme evaporative demand can easily result in vegetation mortality under particular conditions. The Weeli Wolli studies are quoted as evidence of no perceptible impacts after a 3 cm per day drawdown. To accurately determine the vegetation response to drawdown in terms of density and compositional (rather than short-term physiological studies) change, longer timeframes are required.

The 4 step process outlined on page 35, should start with defining the hydrological and geological features that will inform the characterisation of the habitat likely to support GDV. This provides a spatial prioritisation for assessing vegetation attributes. It is implied in the RT2017 report but not explicit as the first step in the suggested method. The current process essentially uses riparian/mesic vegetation as the indicator for habitats with higher water availability, and then determines various habitat characteristics to modify the risk rating (?). I believe this approach is confusing and contrary to accepted techniques in assessing environment-vegetation linkages. Surely landscape position, geomorphology and water courses are the first indication in the Pilbara, of mesic environments? There is much ambiguity in the 4 step method that would make it difficult to repeat accurately by a third party. Table 4.1 essentially rates a spectrum of vegetation structural classes (based on dominant overstorey species density) and their basal area values, on the risk of significant-impact from groundwater changes. Given that this risk scale is based on the extrapolation of the Stromberg work, this can only give a broad indication of the relationship between structural classes and general water availability but not the impact of change in groundwater availability. I don't believe the report gives an adequate definition of 'significant impact' as a consequence of change in groundwater access. Time-scales and the dynamics of all water sources (relative to groundwater) need to be represented. The attribution of obligate and facultative phreatophytes to each structural class in Table 4.1 is speculative. Figure 6.2 represents the same misconceptions as Table 2.1.

The RT2017 refers to the Weeli Wolli studies as examples of riparian groundwater dependent vegetation not being impacted by drawdown. However, questions remain about comparison with pre-drawdown condition surveys, and change over the longer-term such as recruitment rates, rate of canopy condition changes before vs now, gradual compositional changes towards relatively drought resistant species. The full spectrum of impact on the Weeli Wolli vegetation is not represented over the time-frame of the cited assessments, particularly when studying long-lived species with decades between successful recruitment events.

Section 4.6 on limitations does cover two of the common issues facing one-off vegetation surveys (i.e. fire history and non-perennial species) but does not cover any aspect of what I have discussed above. What is missing from the discussion on limitations is more significant to the study than what is presented.

Conclusions:

Given the above comments on the RT2017 report, I have summarised my response to the review questions as follows:

Is the Rio Tinto 2017 Approach Appropriate to Determine the Presence of potential GW-Dependent Species, Vegetation and Ecosystem?

The approach is appropriate to determine composition and structure (albeit just one measure) of riparian vegetation. Using established understanding of species habitat associations, the approach can be used to identify species and vegetation associated with habitats of higher water availability. With respect to determining groundwater dependency, the approach can only infer the potential for groundwater to be a significant plant water source, <u>if corroborating hydrological evidence is presented</u>. The use of basal area to define plant response to water availability does have merit (as demonstrated by the 1993 study of Stromberg and many others since). However, its use in defining dependency on groundwater and sensitivity to drawdown, is problematic, particularly given the approach has not been validated in the RT2017 report. Given the focus on vegetation, it is debateable whether this approach is applicable to identifying an ecosystem's dependence on groundwater, as the role of groundwater in the interaction between components and processes is not addressed.

Is the Rio Tinto 2017 Approach Appropriate to Attribute Significance to any Potential GDE Identified?

Through the process of identifying species composition, vegetation structure and inferring groundwater association, the approach can attribute significance. The report does discuss some aspects of the relative significance of the potential GDEs identified. The approach does give an adequate determination of the extent, composition and structure of vegetation, that can be used to assign significance. The significance of groundwater as a water source important to the maintenance of vegetation values, can be implied using this approach but with a low degree of certainty.

Is the Rio Tinto 2017 Approach Appropriate to Understand the Degree of Sensitivity that any Identified Potential GDE may have to potential surface water (hydrological) and groundwater (hydrogeological) changes?

This approach can be used to determine a gradient in vegetation composition and basal area relative to water availability. Vegetation groundwater dependence is implied using known species habitat preferences and extrapolations from the Stromberg study on a species of *Prosopis*. Without a validation of this method using the dominant Pilbara riparian species, one should be cautious when using this approach to define 'thresholds' of groundwater dependence and sensitivity to change.